Explorer

Actively Q-Switched, High-Repetition Laser Systems

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).

Spectra-Physics
A Newport Corporation Brand

3635 Peterson Way
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Part Number D-000-2140, Rev. B
March 2010

Preface

This manual contains information for safely installing, operating and servicing your *Explorer* actively Q-switched, high-repetition laser system. The system consists of an OEM *Explorer* laser head, *L-Series* power supply and customized operating software. This manual covers several *Explorer* models with output wavelengths at either 355 nm or 532 nm. These lasers use the same *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 IV laser that 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 the *Explorer* system components.

Chapter 5, "Installation," contains instructions for installing the system, including hook-up diagrams and lists of required components.

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 *Explorer* models along with some general considerations regarding laser output. A complete 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 compete 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 that can be returned via system queries.

Appendix D contains a short section on laser theory regarding the laser crystal and the harmonic generation used in the *Explorer,* as well as a brief description of some of the basic physics common to most 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. Please note that the *Explorer* lasers are OEM systems that are designed to be integrated into a master system that, itself, complies with regulatory requirements.

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

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

Explorer systems are designed for indoor use. The environmental conditions under which these laser systems will function are:

Operating specifications:

Altitude	0 to 2000 m
Temperature	18°C to 35°C
Max. Baseplate Temperature	40°C
Relative humidity	< 80%, non-condensing
Mains supply voltage	not to exceed ±10% of the nominal voltage
Insulation category	II
Pollution degree	2

Non-operating specifications:

Altitude	0 to 12000 m
Temperature	–20 to 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

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.

Danger! Laser Radiation	Laser radiation is present.
Danger!	Condition or action may present a hazard to personal safety.
Danger!	Condition or action may present an electrical hazard to personal safety.
Warning!	Condition or action may cause damage to equipment.
Warning! ESD	Action may cause electrostatic discharge and cause damage to equipment.
Caution!	Condition or action may cause poor performance or error.
Note	Text describes exceptional circumstances or makes a special reference.
Don't Touch!	Do not touch.
Eyewear Required	Appropriate laser safety eyewear should be worn during this operation.
	Refer to the manual before operating or using this device.

Standard Units

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	Ω
temperature	Celsius	C
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	milli	(10^{-3})	m	femto	(10^{-15})	f
kilo	(10^{3})	k	micro	(10^{-6})	μ	atto	(10^{-18})	a

Abbreviations

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

ac	alternating current
AOM	acousto-optic modulator
AR	anti-reflection
CDRH	Center of Devices and Radiological Health
CW	continuous wave
dc	direct current
FPS	first pulse suppression
fs	femtosecond or 10^{-15} second
HR	high reflector
IR	infrared
OEM	original equipment manufacturer
OC	output coupler
ps	picosecond or 10^{-12} second
RF	radio frequency
rpm	rotations per minute
SHG	second harmonic generation
TEC	thermoelectric cooler
TEM	transverse electromagnetic mode
THG	third harmonic generation
UV	ultraviolet
λ	wavelength

Unpacking and Inspection

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. **Equipment must be returned in the designated Spectra-Physics shipping container or the laser warranty is void.**

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 (2 lb). The laser head weighs approximately 1.2 kg (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-XX[1]-Head1)
- (1) laser head cable 2, 26-pin (PS-L08-XX[1]-Head2)
- (1) jumper plug for the ANALOG IN connector
- (2) keys for the *L-Series* power supply
- (1) heat-conducting foil for mounting the laser head on the heat sink

[1] *Where "XX" is: 05 = 0.5 mm, 10 = 1 m, 20 = 2 m and 50 = 5 m.*

Chapter 1 Introduction

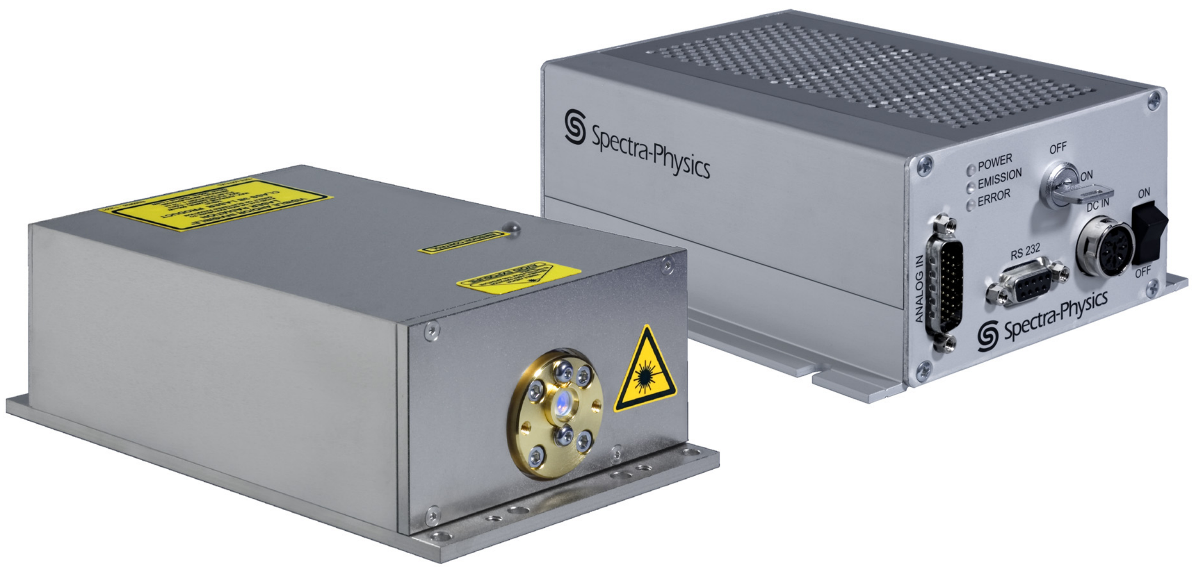


Figure 1-1: The *Explorer* Laser Head (on left) and *L-Series* Power Supply

Spectra-Physics *Explorer* systems are solid-state, Q-switched OEM lasers that produce superior quality ultraviolet or green output beams at adjustable repetition rates up to 150 kHz. The *Explorer* lasers described in this manual are available at wavelengths of 355 nm or 532 nm. These lasers are designed for applications where a high repetition rate, low cost-of-ownership and ease of integration are essential.

For each wavelength, there are models with different ranges of adjustable repetition rates: up to 60 kHz and up to 150 kHz. The models in the lower range have an internal single-pulse energy monitor, while the higher repetition rate models have an internal average power meter.

The *Explorer* laser provides stable pulse energy through the entire range of its repetition rate, as well as precise triggering or gating of pulsed output in response to user-provided signals. Changing the *Explorer* pulse energy or pulse repetition rate has 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). All versions of the *Explorer* offer a variety of methods for controlling laser output: internal or external triggering or gating capability, a unique trigger output that is highly coincident with the laser pulses (“OptoSync”), as well as Burst mode and First Pulse Suppression. A description of these capabilities is provided in Chapter 3.

Table 1-1: High Repetition Rate *Explorer* OEM Models

Explorer Part Number	Wavelength (nm)	Ave Power (mW)	Max PRF (kHz)
EXPL-355-300-E	355	300	60
EXPL-355-300-P	355	150	150
EXPL-532-1W-E	532	1000	60
EXPL-532-1W-P	532	1000	150
EXPL-532-2W-E	532	2000	60
EXPL-532-2W-P	532	1800	150
EXPL-532-200-E	532	2000	60

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, high-quality beam with an adjustable repetition rate, along with good mode quality in a cost-effective package. *Explorer* is a rugged, sealed unit designed for simple hands-free operation. Sufficient cooling for the laser head must be provided. The laser head can be air-cooled using the optional fan-cooled heat sink, or it can be cooled by conduction through a user-provided heat sink.

All optical components are contained in the laser head itself. These include the laser crystal, the diode laser pump source and the nonlinear crystals that convert the fundamental infrared light into the 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 diode laser pump source is typically operated at a derated power level in order to ensure extended lifetime.

Note In the context of this manual, the diode laser module is sometimes referred to simply as the “diode,” e.g., “the diode current.”

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. A parallel interface on the power supply connects to the laser head to provide monitor and control functions.

The power supply requires a single 24 Vdc, 4 A power source, has an integrated cooling fan and 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* system 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 for operating 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.

Chapter 2 Laser Safety

Danger! Laser Radiation

Eyewear Required

Spectra-Physics *Explorer* lasers are *Class IV—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 ultraviolet beam at 355 nm is invisible and is, therefore, especially dangerous.* Residual light at 1064 nm, 808 nm and 532 nm wavelengths might also be present.

Note

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

Precautions For The Safe Operation of Class IV 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 that 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).

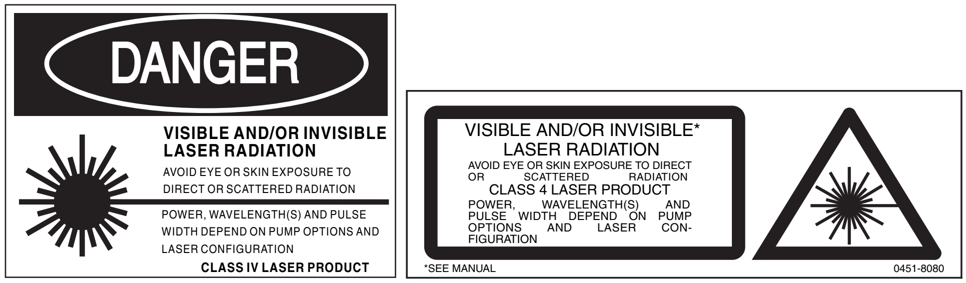


Figure 2-1: These standard safety warning labels are appropriate for use as entry warning signs (EN 60825-1: 2007, ANSI Z136.1, Section 4.7).

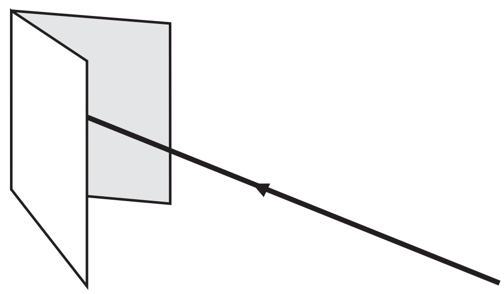


Figure 2-2: Folded Metal Beam Target

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 the laser, avoid unnecessary exposure to laser or collateral radiation[1] 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 the laser.

[1] *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

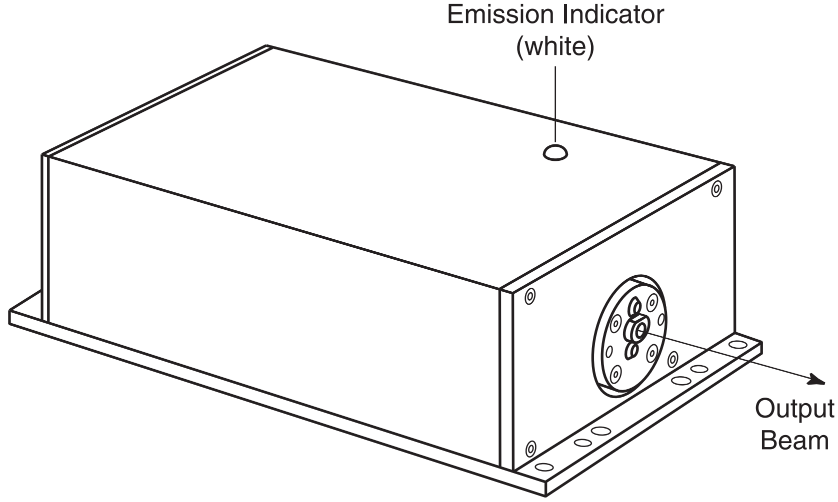


Figure 2-3: Laser Head Emission Indicator

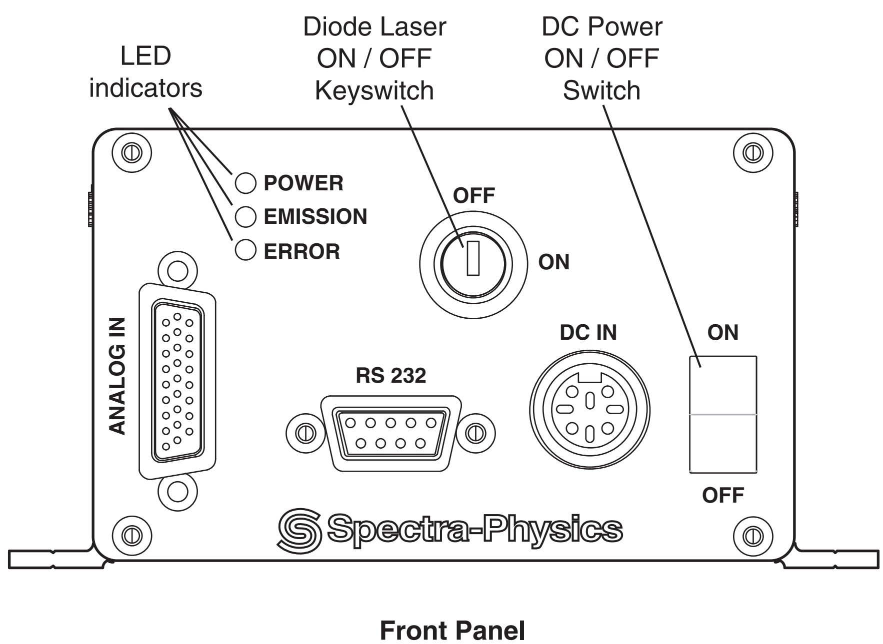


Figure 2-4: Power Supply Safety Devices

Emission and Power Indicators

The system provides the following emission and power indicators:

- A white EMISSION indicator on top of the laser head (Figure 2-3) turns on about 3 seconds before actual emission occurs.
- A blue EMISSION indicator on the power supply front panel (Figure 2-4) turns on about 3 seconds before actual emission occurs.
- A yellow POWER indicator on the power supply front panel (Figure 2-4) turns on when the power switch is turned on.
- If the *Explorer* is operated using the *L-Win* software, an indicator on the *L-Win* Main display turns green when the power switch is turned on, the diode laser keyswitch is set to ON, and the proper ON command has been issued by the software. This *L-Win* indicator turns on about 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. Refer to “Front Panel Connections” on page 4-4 for more information.

Shutter

The *Explorer* lasers are OEM systems that are designed to be integrated into a master system that, itself, complies with regulatory requirements. 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 it 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 power switch on the front panel of the power supply (Figure 2-4) provides electrical power to the laser system when turned on.

Safety Interlocks

External Interlock

Pins 7 and 8 of the ANALOG IN connector must be shorted together for normal system operation. They can be used in an interlock circuit to terminate laser emission when a normally closed safety switch wired to these pins is opened. Such a switch can be attached to an access point, such as an entry panel, that might be opened unexpectedly. See Chapter 7 for the circuit requirements.

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, nor is the *Explorer* laser to be operated with the cover removed.

Maximum Emission Levels

Table 2-1 lists the maximum emission levels possible for the *Explorer* lasers. Use this information for selecting appropriate laser safety eyewear and to implement appropriate safety procedures. These values do not imply actual system power or specifications.

Laser light at longer wavelengths is generated in the production of the green and ultraviolet emission, and the diode pump laser used in all *Explorer* models produces infrared light. These wavelengths are 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	Leakage Wavelengths
Laser Output: 355 nm	1 W, 0.1 mJ, 5 ns	Doubled Fundamental: 532 nm < 10 mW
		Diode Laser Emission: 808 nm < 10 mW
		Fundamental Beam: 1064 nm < 10 mW
Laser Output: 532 nm	4 W, 1 mJ, 5 ns	Diode Laser Emission: 808 nm < 10 mW
		Fundamental Beam: 1064 nm < 10 mW

System Operation Using a User-Provided Control Device

When the *Explorer* 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 any 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 as 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.

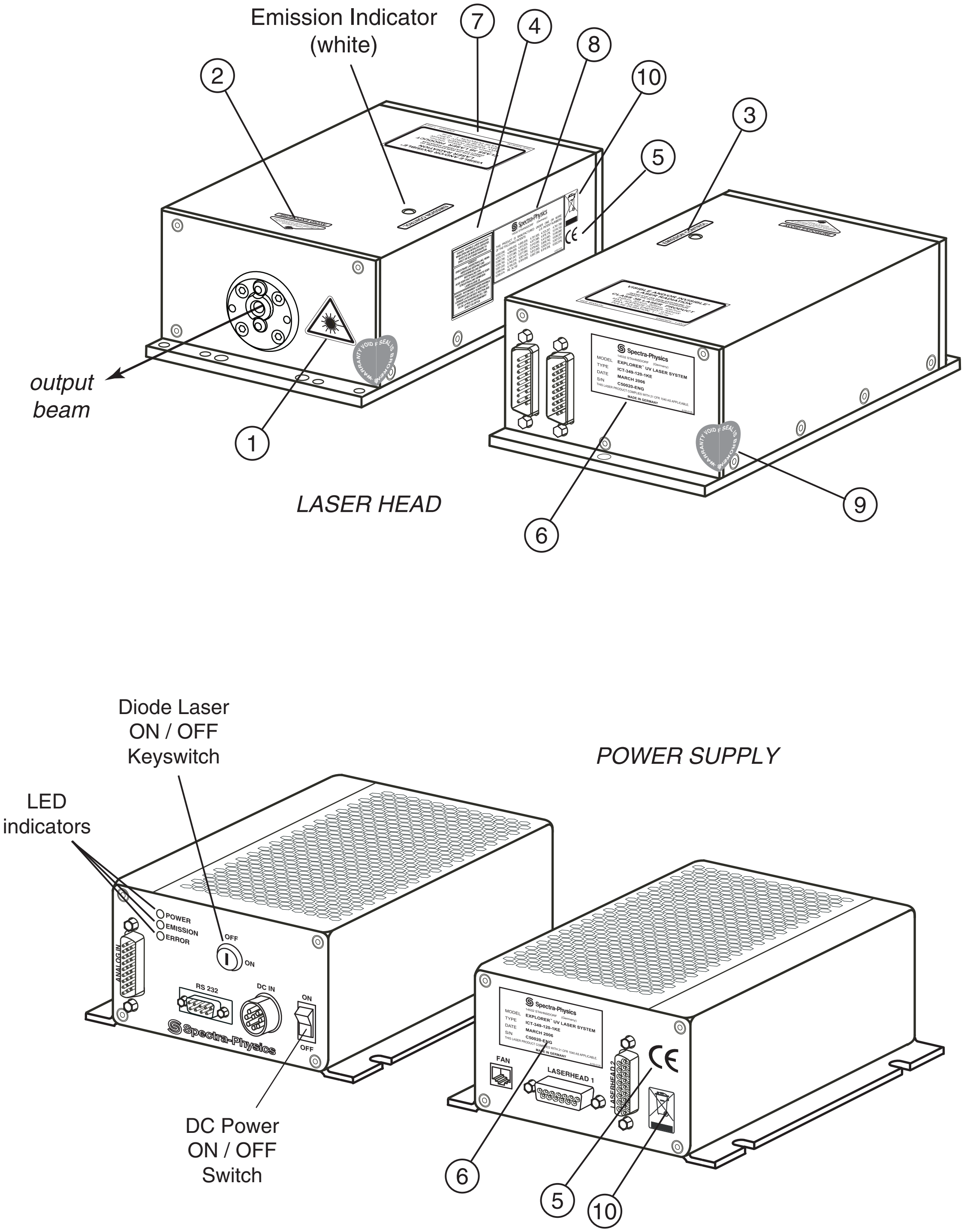
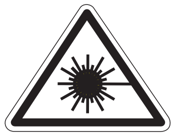


Figure 2-5: ***Explorer*** **Radiation Control Drawing**

CE Warning Labels



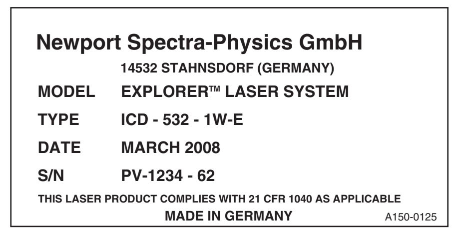
Aperture Symbol
Label (1)

Aperture Warning
Label (2)

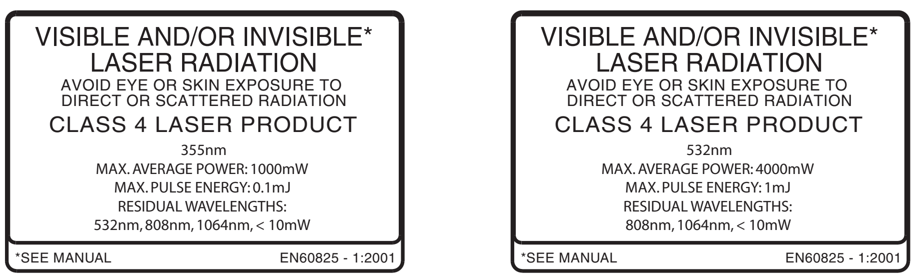
Emission Indicator
Label (3)

Invisible Radiation
Danger Label (4)

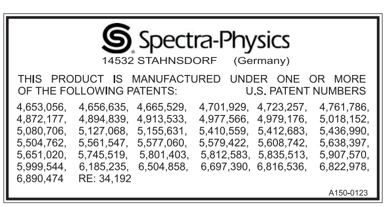
CE Approval
Label (5)



Serial Label, Laser Head
and Power Supply (6)

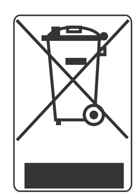


Class 4
CE Warning Label (7)



Patent
Label (8)

Warranty
Seal (9)



WEEE
Label (10)

Figure 2-6: ***Explorer*** **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 geemitteerd! Vermijd blootstelling!
Emission Indicator Label (3)	Indicateur d'émission	Emissionskontrolle	Control de la emisión	Controle van emissie
Class 4 CE Warning Label (7)	Rayonnement laser visible et/ou invisible. Exposition dangereuse de l'oeil ou de la peau au rayonnement direct ou diffus. Laser de classe 4. Puissance maximum moyenne de 1 W (355 nm), 4 W (532 nm) Energie maximum par impulsion 0.1 mJ (355 nm), 1 mJ (532 nm). Durée d'impulsion 5–20 ns	Sichtbare und/oder unsichtbare Laserstrahlung. Bestrahlung von Auge oder Haut durch direkte oder Streustrahlung vermeiden. Laser Klasse 4. Mittlere maximale Leistung1 W (355 nm), 4 W (532 nm) Maximale Pulsenergie 0,1 mJ (355 nm), 1 mJ (532 nm). Pulsdauer 5–20 ns	Radiación láser visible y/o invisible. Evitar la exposición directa ó dispersa sobre la piel o los ojos. Producto Láser Clase 4 Potencia máxima promedio 1 W (355 nm), 4 W (532 nm) Energía máxima del pulso 0,1 mJ (355 nm), 1 mJ (532 nm). Duración de pulso 5–20 ns	Zichtbare en/of onzichtbare* laser straling. Vermijd blootstelling aan ogen of huid door directe of gereflecteerd straling. Klasse 4 laser produkt Maximaal uittredend vermogen 1 W (355 nm), 4 W (532 nm) Maximaal pulsenergie 0,1 mJ (355 nm), 1 mJ (532 nm). Pulsduur 5–20 ns

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 that addresses 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 10 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
3635 Peterson Way
Santa Clara, CA 95054
United States of America

declare under sole responsibility that the:

Laser System Model: Explorer 355, Explorer 532

manufactured after September 18, 2008

meets the intent of EMC Directive 2004/108/EC for electromagnetic compatibility and LVD Directive 2006/95/EC for low-voltage directives. Compliance was demonstrated to the following specifications as listed in the official *Journal of the European Communities*:

EMC Directive 2004/108/EC

EN 55011: 1998+A1 + A2: industrial, scientific and medical (ISM) radio-frequency equipment radio disturbance characteristics (conducted and radiated emissions).
EN 61000-4-2: 1995 + A1 + A2: Electrostatic discharge immunity test.
EN 61000-4-3: 2002 + A1: Testing and measurement techniques—radiated, radio-frequency, electromagnetic field.
EN 61000-4-4: 1995 + A1 + A2: Testing and measurement techniques—electrical fast transient/burst immunity test.
EN 61000-4-5: 1995 + A1: Testing and measurement techniques—surge immunity test.
EN 61000-4-6: 1996 + A1: Testing and measurement techniques—immunity to conducted disturbances induced by radio-frequency fields.

Low Voltage Directive 2006/95/EC

EN60825-1: 2007: Equipment classification, requirements, and users guide
EN60950-1: 2006: Safety of Information Technology Equipment.
EN61010-1: 2001 + Corr 1 + Corr 2: General Requirements, Safety requirements for electrical equipment for measurement.

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

Dave Allen
Vice President and General Manager
Lasers Division of Newport Corporation
September 18, 2008

Sources for Additional Information

Laser Safety Standards

Safe Use of Lasers (Z136.1)
American National Standards Institute (ANSI)
25 West 43rd Street, 4th Floor
New York, NY 10036
Tel: (212) 642-4900

Occupational Safety and Health Administration (Osha Standard, 01-05-001-pub8-1.7
U. S. Department of Labor
200 Constitution Avenue N. W., Room N3647
Washington, DC 20210
Tel: (202) 693-1999
Web site: 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
Web site: http://www.acgih.org/home.htm

Laser Institute of America
13501 Ingenuity Drive, Suite 128
Orlando, FL 32826
Tel: (800) 345-2737
Web site: http://www.laserinstitute.org

International Electrotechnical Commission
Journal of the European Communities
IEC 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
Web site: http://www.iec.ch

Cenelec
35, Rue de Stassartstraat
B-1050 Brussels, Belgium
Tel: +32 2 519 68 71
Web site: http://www.cenelec.eu

Document Center, Inc.
111 Industrial Road, Suite 9
Belmont, CA 94002
Tel: (650) 591-7600
Web site: 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
Web site: 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
Web site: http//:pennwell.365media.com/laser focus world/search.html

Photonics Spectra Buyer's Guide
Photonics Spectra
Laurin Publications
Berkshire Common
PO Box 4949
Pittsfield, MA 01202-4949
Tel: (413) 499-0514
Web site: http://www.photonics.com

Chapter 3 The Explorer Laser System

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

Note Appendix D provides an introduction to the physical principles that underlie the design of the *Explorer* laser.

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. Models include detection circuitry to either measure the energy of individual pulses or measure the average output power of the laser.

Optical Design

The 808 nm output of the single-emitter diode laser inside the laser head is coupled into the laser 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 focused into the laser crystal by a beam-shaping telescope. The laser crystal absorbs the 808 nm pump light and is energized to produce a high-quality laser beam at 1064 nm. The energy of this output is concentrated into a series of intense pulses using an acousto-optic Q-switch.

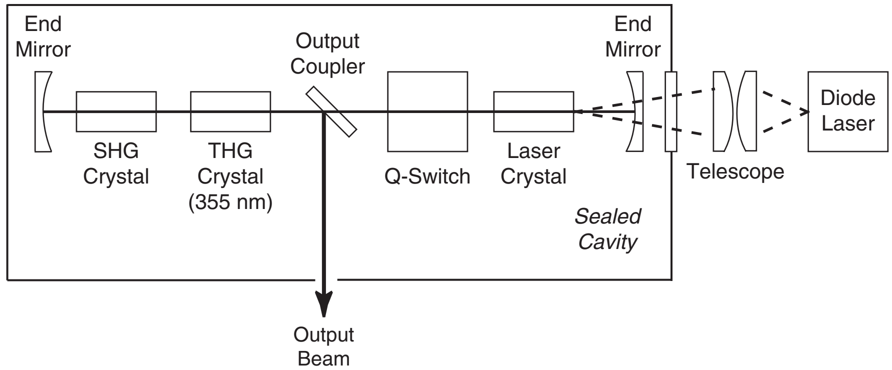


Figure 3-1: Optical Design of the *Explorer* Laser Head

The Q-switched output of the IR laser beam is converted to shorter wavelengths inside the laser head by means of nonlinear optical crystals.

Frequency Doubling and Tripling

Materials with certain crystalline properties will transform a fraction of intense incident laser light into coherent light output at shorter wavelengths. For efficient conversion, care must be taken to keep the incident beam and the converted beam in phase within the crystal. The intense pulses produced by Q-switching are much more efficient than a continuous laser beam at producing the shorter wavelengths obtained through this nonlinear harmonic generation, also referred to as frequency conversion.

Green output at 532 nm is generated by frequency doubling the fundamental IR laser output at 1064 nm in a crystal of lithium triborate (LBO), a process also referred to as second harmonic generation (SHG). The nonlinear wavelength conversion takes place entirely inside the laser head. A specially coated mirror directs the green light out of the laser cavity while confining the infrared wavelength inside.

Ultraviolet output at 355 nm is obtained by frequency-tripling the fundamental IR laser output at 1064 nm. This conversion is accomplished using two separate LBO crystals. A portion of the fundamental beam is first doubled to 532 nm in the SHG LBO crystal, then this frequency-doubled light is mixed again with the fundamental wavelength in the third harmonic generation (THG) crystal to produce the final ultraviolet output beam. Again, 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 confining the green and infrared wavelengths.

The LBO crystals must be heated and temperature-stabilized to maintain good conversion efficiency. The *Explorer* software and command structure provide the ability to adjust the temperatures of these crystals when necessary.

Pulse Energy and Average Power Monitors

A small fraction of the laser output is reflected into a detector (not shown in Figure 3-1). For models with a repetition rate up to 60 kHz, measurement is provided as an individual pulse energy value. For those with higher repetition rates, average power is measured.

For single-pulse measurement, the detector generates several signals that are evaluated by the microprocessor, including the energy of each pulse. The analog value of this pulse energy is stored by a sample-and-hold circuit, and it becomes the laser output power value until it is replaced by the value of the next measured pulse. This value is available via the RS-232 interface and the ANALOG IN port on the *L-Series* power supply.

On lower repetition rate models, the pulse energy monitor is an integral part of the *Explorer's* advanced control features. These include the OptoSync output, Burst mode and First Pulse Suppression (FPS) features. (Burst mode, FPS and OptoSync are described in more detail later in this chapter.)

On higher repetition rate models, these advanced pulse control features are also available, but the user must measure the pulsed output externally in order to adjust FPS.

Information about using these features is provided in Chapters 6 and 7, which describe how to operate the *Explorer* laser.

Replaceable Output Window

A problem common to all laser systems (especially those that emit ultraviolet) is the degrading effects caused by focusing intense light on the optical components within the system. With this in mind, 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 Chapter 8, "Maintenance and Service," for instructions on when and how to change the window.

The output window on green *Explorer* models should not need to be replaced under normal circumstances.

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 40 W of heat that 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* 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 inside the housing continuously measures the laser head temperature, and its feedback is part of an active servo-loop that is used to set the fan RPM. For more information, refer to "Thermal Management" in Chapter 5, and "Controlling the Laser Head Temperature" in Chapter 7.

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 thermoelectric coolers (TEC), 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 requires a 24 ±2 Vdc, 4 A electrical source, and it is capable of suppling up to 10 A of diode laser drive current. A small fan inside the supply ensures proper cooling. The rugged *L-Series* design ensures reliable operation even in harsh environments. The *L-Series* power supply has been certified to comply with the requirements of the RoHS Directive (the Restriction of Hazardous Substances) of the European Union.

Spectra-Physics offers an optional wall-plug, auto-ranging, ac/dc converter to provide 24 V power the *Explorer* laser. Contact your Spectra-Physics representative for more information.

System Control

As a component in a master system, the *Explorer* is controlled using either the serial command language or analog signals described in Chapter 7 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 Chapters 6 and 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 is a schematic of the main logic components in the laser head and *L-Series* power supply. The microprocessor inside the *L-Series* power supply controls the power supply itself and communications with the laser head. The laser head has its own microprocessor for controlling laser head functions such as maintaining the harmonic crystal temperature, controlling diode laser current and receiving and storing operating parameters.

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.

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, thus ensuring that they are secure. In the event that the power supply is swapped out, the operating parameters remain unchanged.

The laser head's permanent memory contains unit-specific identification information and parameters such as maximum diode laser current. The contents of permanent memory cannot be changed in the field.

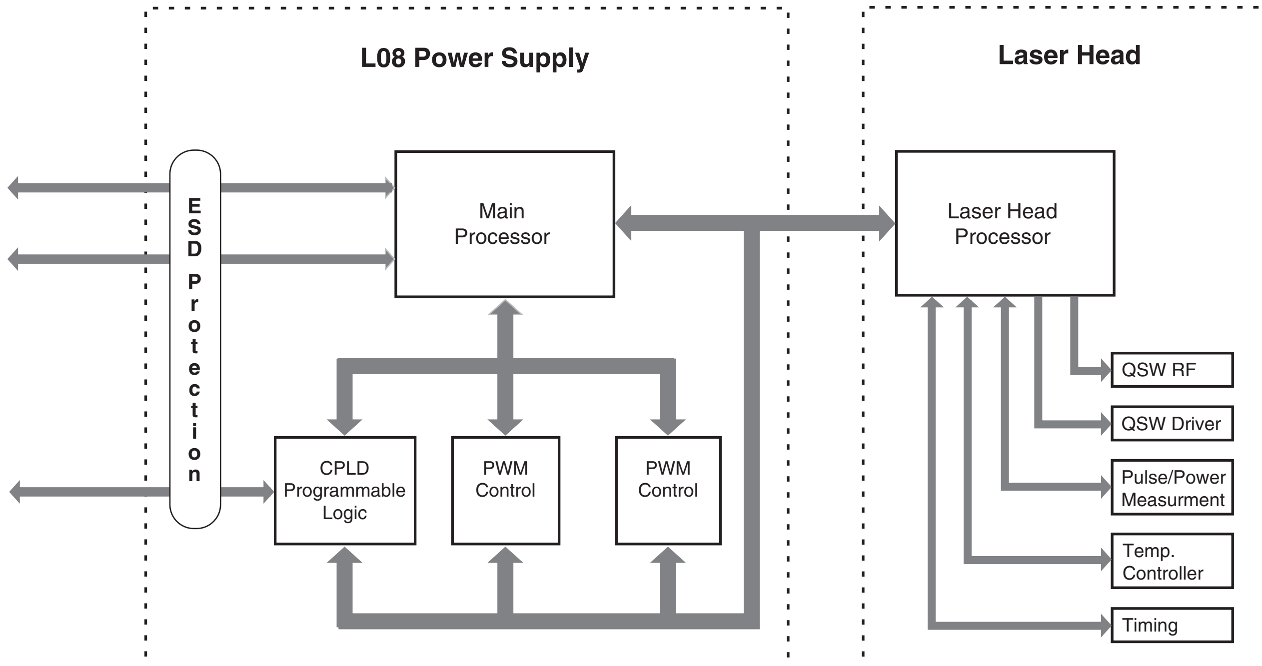


Figure 3-2: ***Explorer*** **System Control Hardware**

Laser Performance

The energy of individual pulses increases in a fairly linear manner as the diode current is increased. However, pulse duration 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).

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

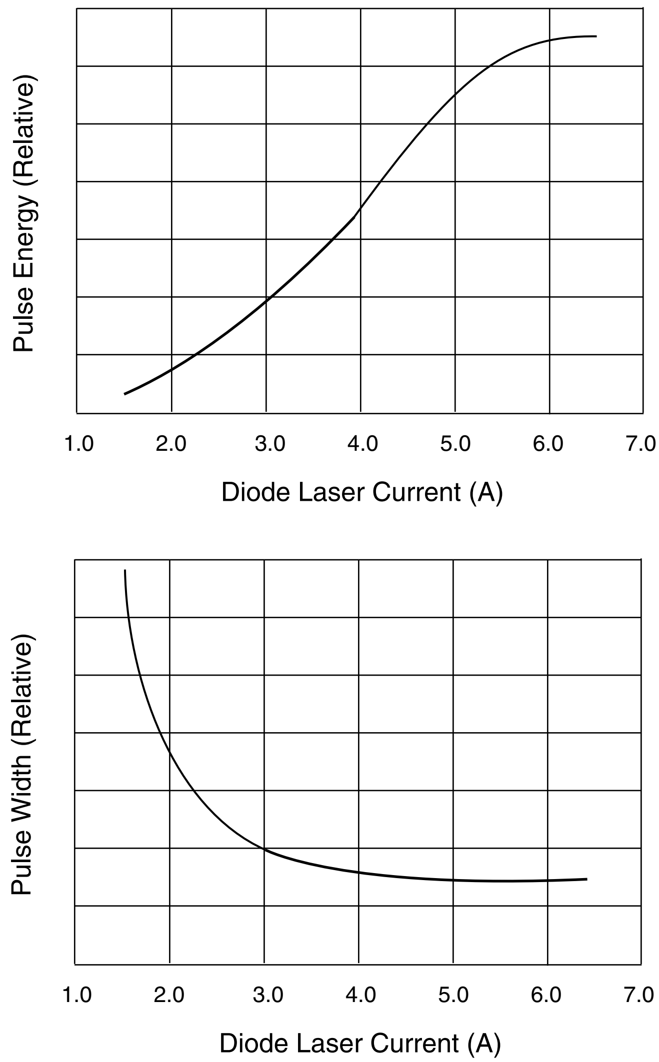


Figure 3-3: Variation of Energy and Pulse Width vs. Current

At a given diode laser pump current, the individual pulse energy itself will decrease as the repetition rate is increased as shown in Figure 3-4. The lower the diode laser pump current (i.e., the lower the average output power), the less pronounced this effect will be.

Pulse width broadens in a strictly linear manner when the pulse repetition rate is increased.

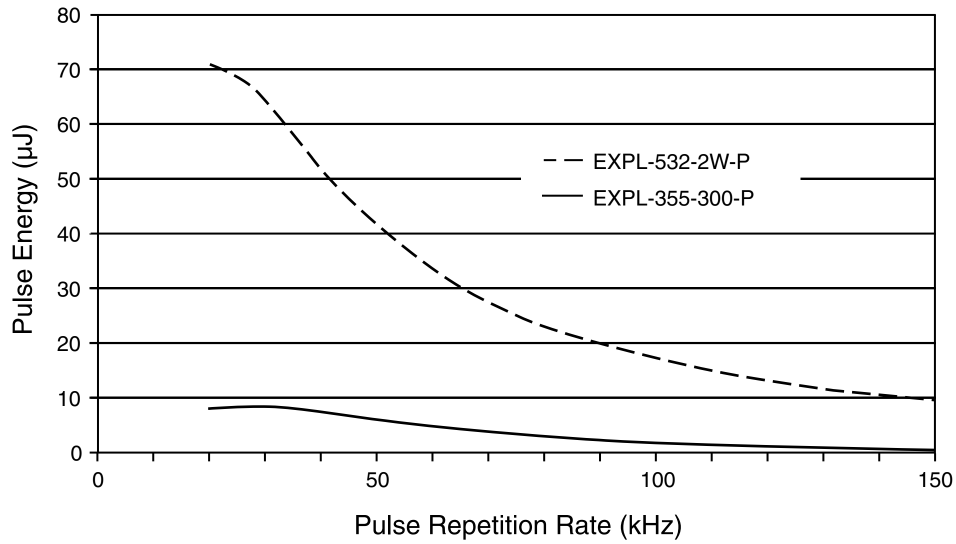


Figure 3-4: Pulse Energy vs. Pulse Repetition Rate

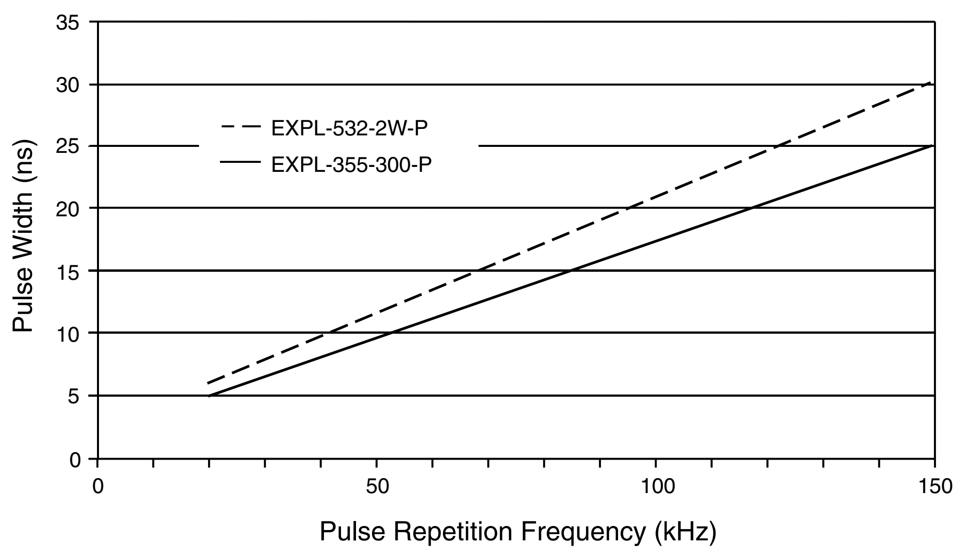


Figure 3-5: Pulse Width vs. Pulse Repetition Rate

Control Features

OptoSync Output

The OptoSync output provides a TTL level signal that is in high coincidence with the production of individual pulses. 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 30 to 100 ns, depending on the pulse energy and pulse width. For some applications, this OptoSync delay is unimportant. Other applications may lend themselves to data collection techniques that compensate for this delay.

Refer to "OptoSync" on page 7-21 for more details regarding the use of these trigger outputs.

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.

Refer to "Advanced Control of the Pulsed Output" on page 6-14 and "Control of the Pulsed Output" on page 7-12 for examples of how Burst mode can be implemented.

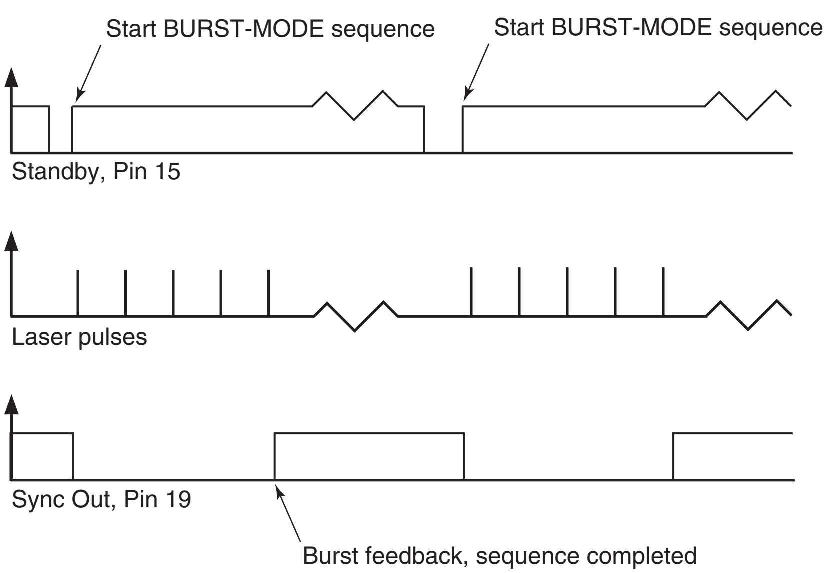


Figure 3-6: Burst Mode Timing Example

First Pulse Suppression

Users who operate high pulse repetition rate lasers (greater than 20 kHz) often have a problem when the first pulse is much greater than the rest. This first pulse anomaly can be avoided by using the *Explorer's* First Pulse Suppression (FPS) feature. FPS allows the user to adjust the first pulse in a train so that it has approximately the same energy as the rest of the pulses. FPS reduces the pump energy for the first pulse by reducing the time allowed for light to circulate within the laser resonator before the first pulse is emitted, thereby reducing the disproportionally large amount of energy initially absorbed by the laser crystal.

FPS implementation requires the monitoring and measurement of the energy of individual pulses. This capability is built into the lower repetition rate range versions of the *Explorer*[1] laser system. The higher repetition rate models require the user to provide an external measurement of the pulse energy in order to implement FPS.

Refer to "Advanced Control of the Pulsed Output" on page 6-14 and "Control of the Pulsed Output" on page 7-12 for examples of how FPS can be implemented.

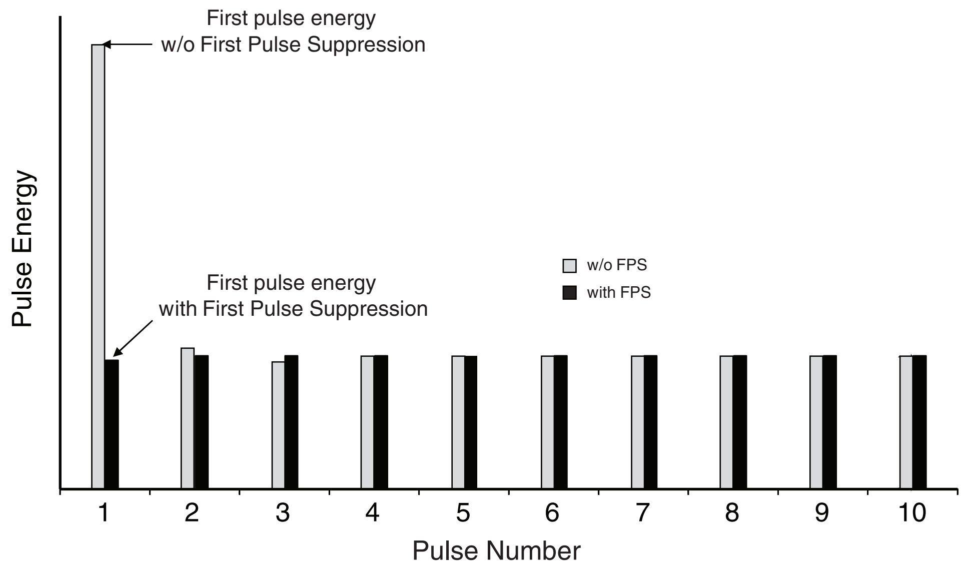


Figure 3-7: The First Pulse Effect at High Repetition Rates

[1] *Only EXPL-xxx-yyy-E models.*

Specifications

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

Table 3-1: *Explorer* Performance Specifications[1]

Model Part Number	EXPL-355-300	EXPL-532-2W	EXPL-532-200
General Characteristics			
Wavelength	355 nm	532 nm	532 nm
Gain Medium	Nd:YVO_4	Nd:YVO_4	Nd:YAG
Output power	> 300 mW[2]	> 2 W[2]	> 2 W[3]
Pulse width (FWHM)	< 15 ns[4]	< 15 ns[4]	< 15 ns[5]
Pulse Repetition rate	20−150 kHz[6]	20−150 kHz[6]	single-shot−60 kHz
Leakage power			
@ 1064 nm	< 1 mW	< 1 mW	< 1 mW
@ 532 nm	< 1 mW		
Beam Characteristics			
Spatial mode	TEM_{00}	TEM_{00}	TEM_{00}
Beam Quality (M^{2})	< 1.3	< 1.3	< 1.2
Polarization Ratio	> 100:1 (vertical)	> 100:1 (horizontal)	> 100:1 (horizontal)
Beam Waist Diameter[7]	0.17 mm ±15%	0.21 mm ±10%	0.20 mm ±10%
Waist Location	(70 ±20) mm	(70 ±20) mm	(70 ±20) mm
Beam Divergence[8]	(3.0 ±0.5) mrad	(3.5 ±0.5) mrad	(3.5 ±0.5) mrad
Beam Ellipticity	< 1.2	< 1.2	< 1.2
Astigmatism	< 0.2	< 0.2	< 0.2
Stability			
Pulse energy stability	< 4%[4]	< 3%[4]	< 3%[5]
Long-term power stability (non-cumulative)	< ±2%/1 hr (±1°C)	< ±2%/1 hr (±1°C)	< ±2%/1 hr (±1°C)
Warm-up time[9]	< 10 min	< 10 min	< 10 min
Static Alignment Tolerance			
Beam Position	< ± 0.25 mm	< ± 0.25 mm	< ± 0.25 mm
Beam Angle	< ± 1 mrad	< ± 1 mrad	< ± 1 mrad

[1] *Due to our continuous product improvement program, specifications may change without notice.*
[2] *Measured at 50 kHz.*
[3] *Measured at 10 kHz.*
[4] *Measured at 50 kHz and nominal average power.*
[5] *Measured at 10 kHz.and nominal average power.*
[6] *Range varies with models.*
[7] *Specified at the beam waist with beam diameter at 1/e2 points.*
[8] *Diameter at 1/e2, full angle*
[9] *Cold start to > 95% of full power.*

Table 3-2: Electrical and Cooling Specifications

Operating voltage	24 Vdc ±2 V
Power consumption	
typical	< 50 W @ 25°C
maximum	< 75 W
Maximum inrush current	< 4 A
Cooling	
L-Series power supply	Air-cooled
Explorer Laser head	Air- and conduction-cooled
Laser head thermal heat dissipation	< 40 W
Operating temperature (< 80% relative humidity)	
Laser head	18 to 35°C
Power supply	18 to 35°C
Storage temperature (< 90% relative humidity, non-condensing)	– 20 to + 60°C

Table 3-3: Dimensions and Weight

***Explorer* Laser Head**	
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)
***L08* Power Supply**	
Size (L x W x H)	164 x 130 x 66 mm (6.46 x 5.12 x 2.56 in.)
Weight (typical)	0.9 kg (2.0 lb)
Laser Head Cable Length[1]	2.0 m (6 ft)

[1] *Length is approximate; flexible 5 m cable available on request.*

Outline Drawings

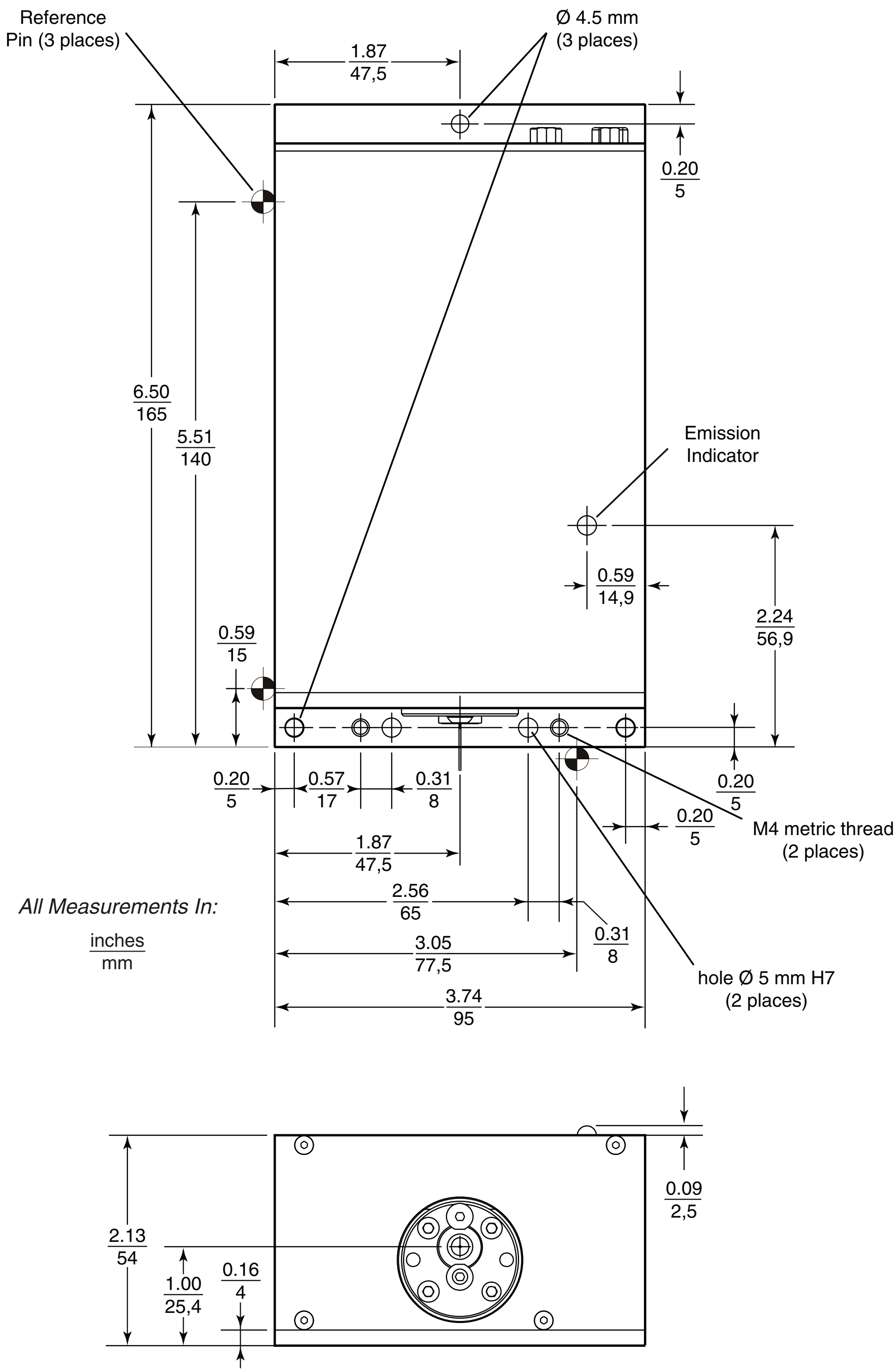


Figure 3-8: Outline Drawing, *Explorer* Laser Head

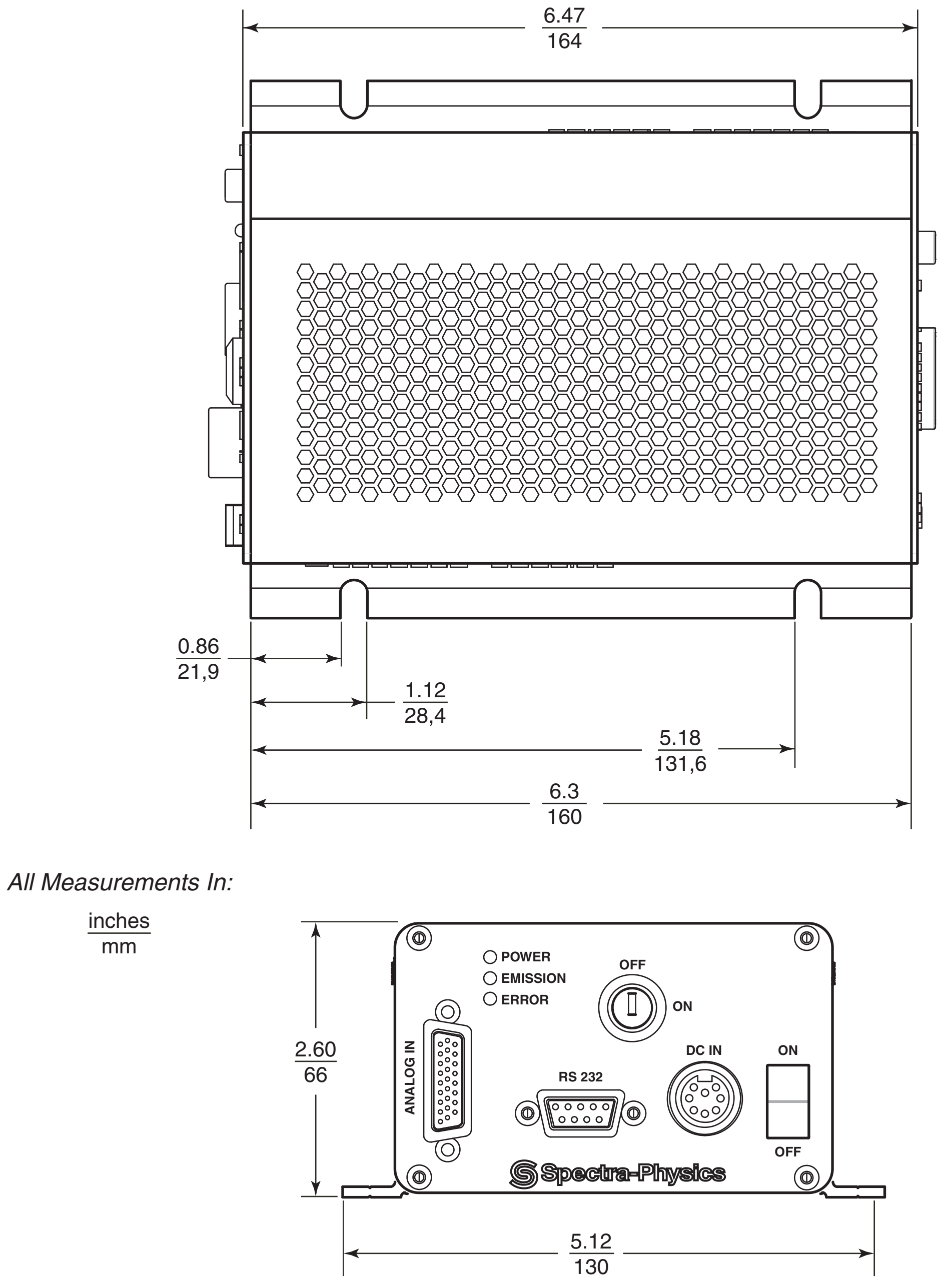


Figure 3-9: Outline Drawing, *L-Series* Power Supply

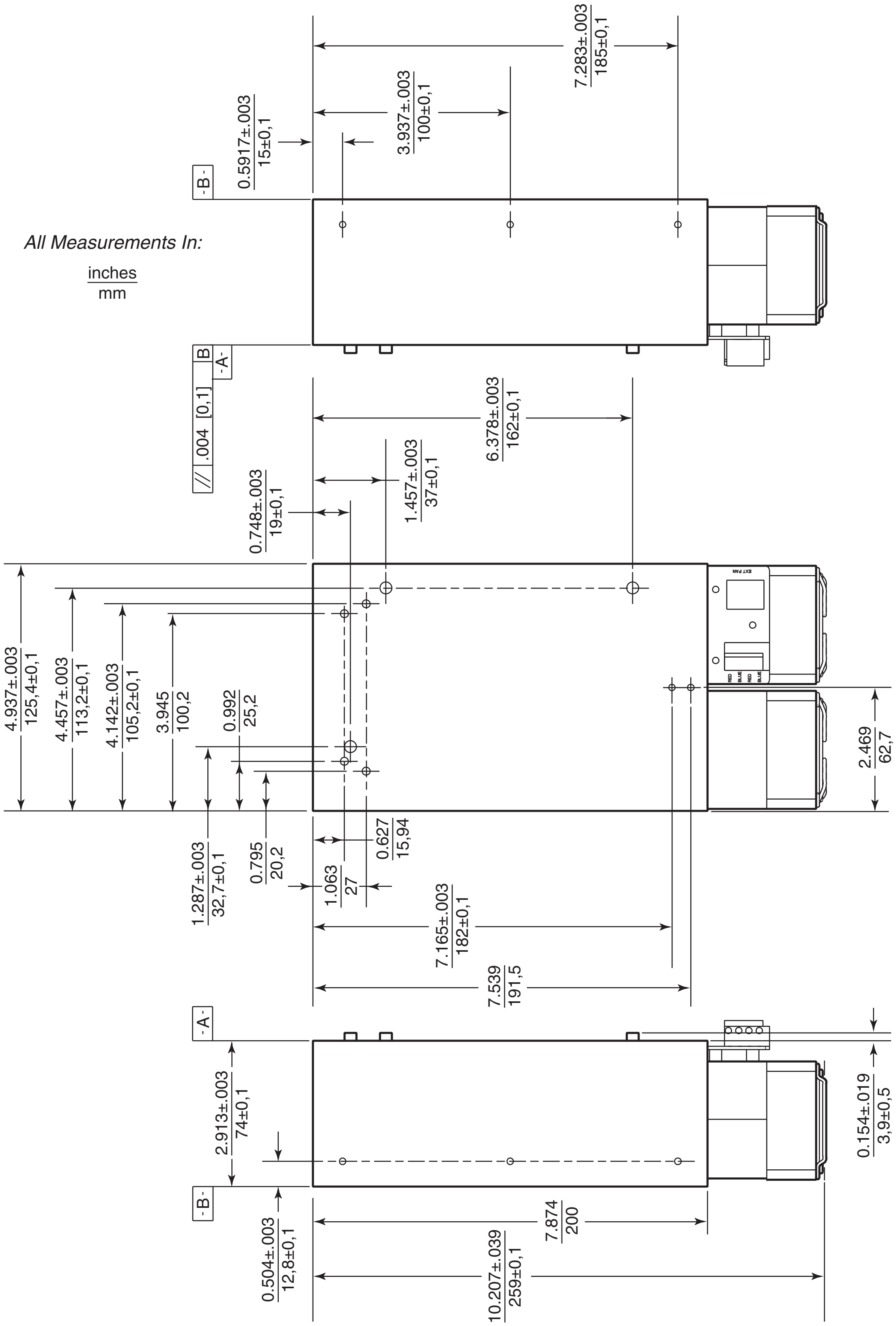


Figure 3-10: Outline Drawing, Heatsink Assembly

Interlock Block Diagram

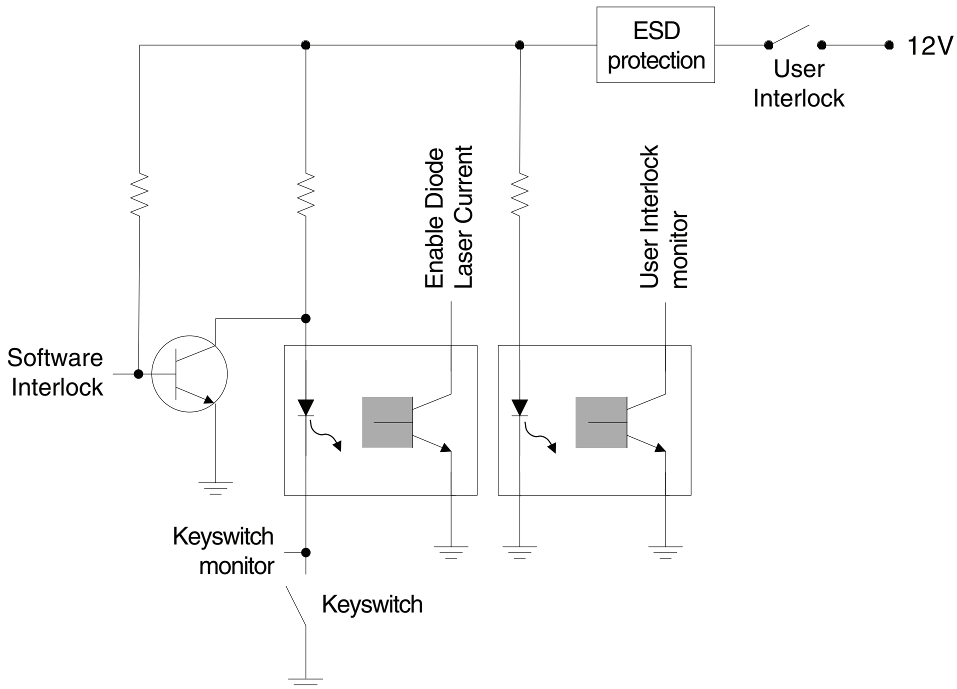


Figure 3-11: Interlock Safety Block Diagram

Chapter 4 Controls, Indicators and Connections

This section describes the user controls, indicators and connections of the *Explorer* laser head and power supply. Connector types are also listed. For a functional description of the ANALOG IN connector, refer to Table 7-2.

To control the system using either the *L-Win* control software provided with the laser 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* 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* laser head. The laser head is designed for integration into a master OEM system that possesses 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.

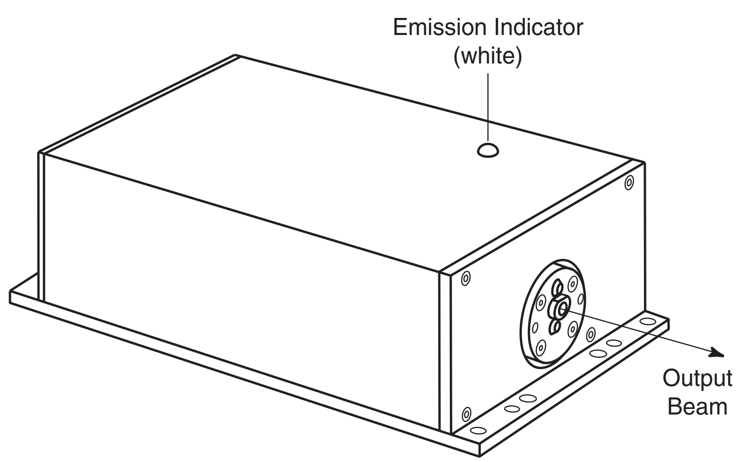


Figure 4-1: *Explorer* Laser Head Emission Indicator

Connections

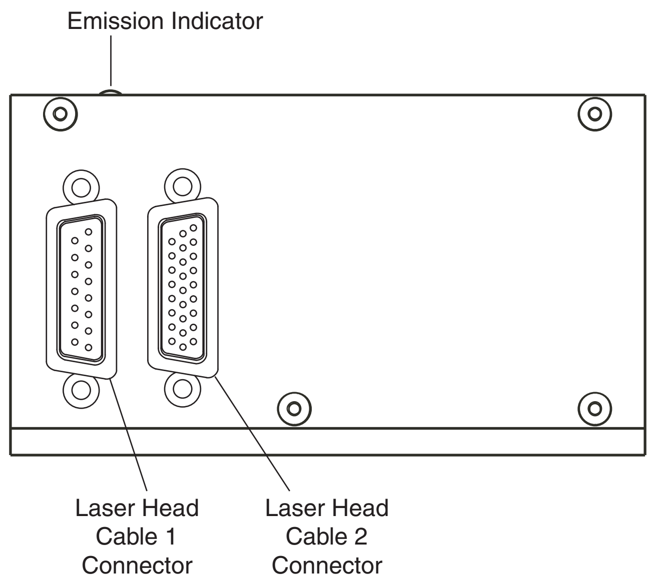


Figure 4-2: *Explorer* Laser Head Rear Panel Connections

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 current for the thermoelectric coolers (TEC) that cool 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

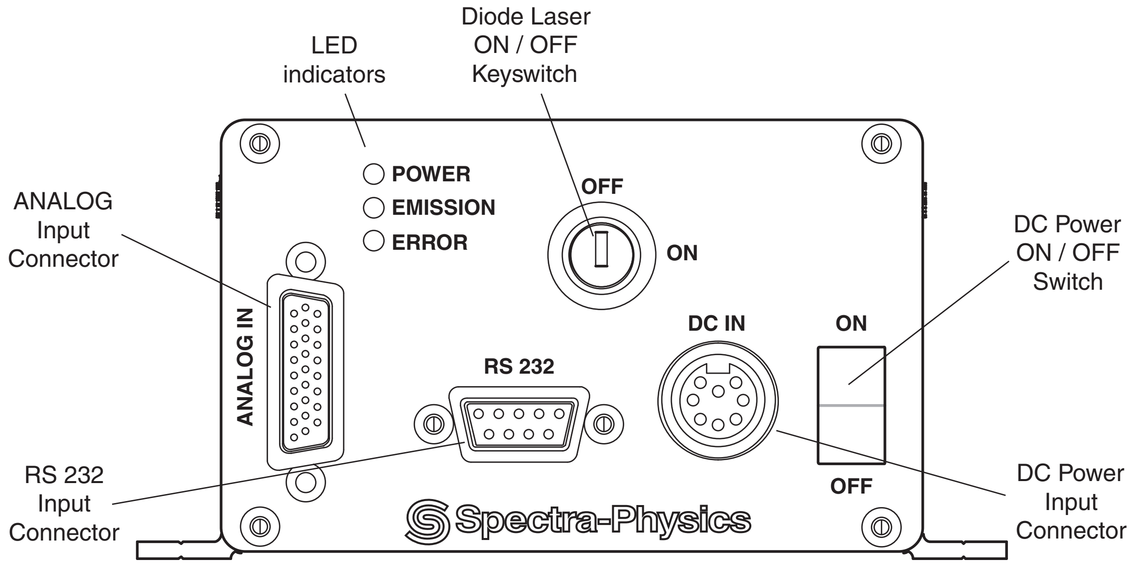


Figure 4-3: Power Supply, Front Panel

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 in order to control the laser remotely.

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

While the ERROR LED is on, the *Explorer* 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 the master OEM system and/or is not in use, turn the keyswitch to OFF and remove the key to prevent unauthorized use of the laser.

The function of this switch depends upon the software 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 in order to control the laser remotely.

Front Panel Indicators

POWER indicator (yellow)—turns on when the power 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. This happens right after the keyswitch is turned on and an appropriate serial *On* command or analog signal is provided.

ERROR indicator (red)—turns on when the software has detected an error condition. It is normal for this indicator to turn on when the power switch is turned on and it will remain on for about 5 minutes during the warm-up sequence 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.

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

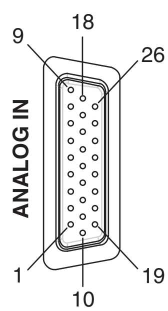


Figure 4-4: ANALOG IN Connector

Note In order for the laser to turn on, pins 7 and 8 of this connector must be shorted together, either directly (as when using the supplied shorting jumper) or through a user-supplied, normally-closed interlock switch.

Warning! 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. Refer to Table 7-2 on page 7-16 for a complete description of these pins, and to "The Analog Interface" on page 7-15 for instructions on how to use this connector to control advanced features of the *Explorer* laser.

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 below for a complete description of these pins, and to “Serial Communication” on page 7-2 for instructions on how to control the laser using this connector.

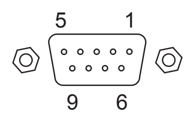


Figure 4-5: The 9-Pin RS-232 Port Connector

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

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

DC IN power connector (8-pin, high-current connector, female)—provides attachment for the cable from the 24 ±2 Vdc, 4 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 below 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. An internal relay switch is closed when emission is on.

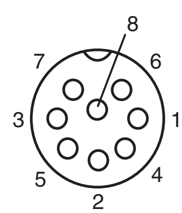


Figure 4-6: DC IN Power Connector

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

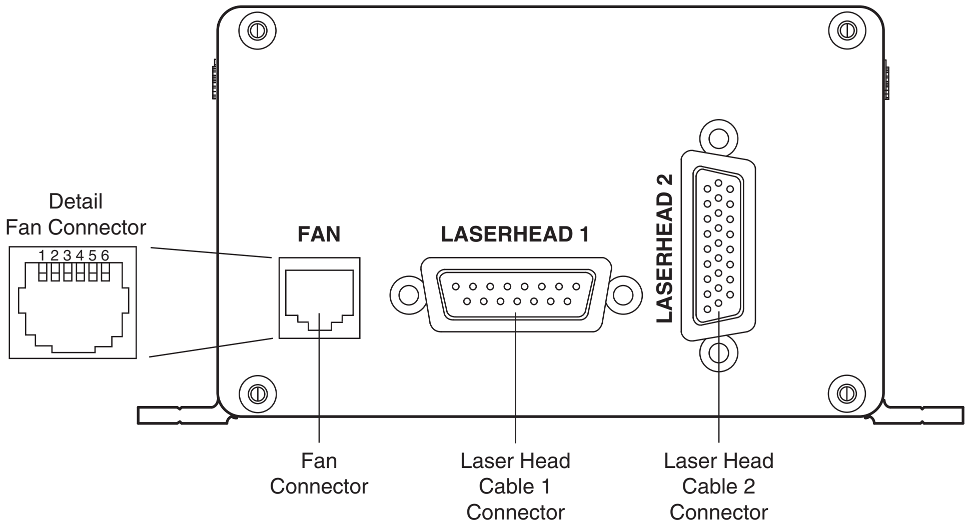


Figure 4-7: Power Supply, Rear Panel

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* laser head. The FAN connector is an 8-pin Western Modular socket. It provides up to 250 mA at 13 Vdc. Table 4-3 below describes the pins of this connector.

Table 4-3: FAN Connector Pinout

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

Warning! Use this connector for connecting to a cooling fan only! Never connect any other equipment (e.g., telecommunication devices) to this connector.

LASERHEAD 1 connector (15-pin, D-sub, female)—provides attachment for a control cable that connects 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 a control cable that connects 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.

Chapter 5 Installation

Thermal Management

Proper heat conduction is essential to allowing the *Explorer* 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 30 W of waste heat. At the maximum specified operating temperature of 35° C, the heat load that must be removed is about 40 W. The laser head should be mounted on a heatsink capable of maintaining its baseplate temperature below 40° C but 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 the included silicone thermal pad).

Warning! Never use thermal grease when mounting the laser head on the heatsink. Doing so will contaminate the laser package and the output window.

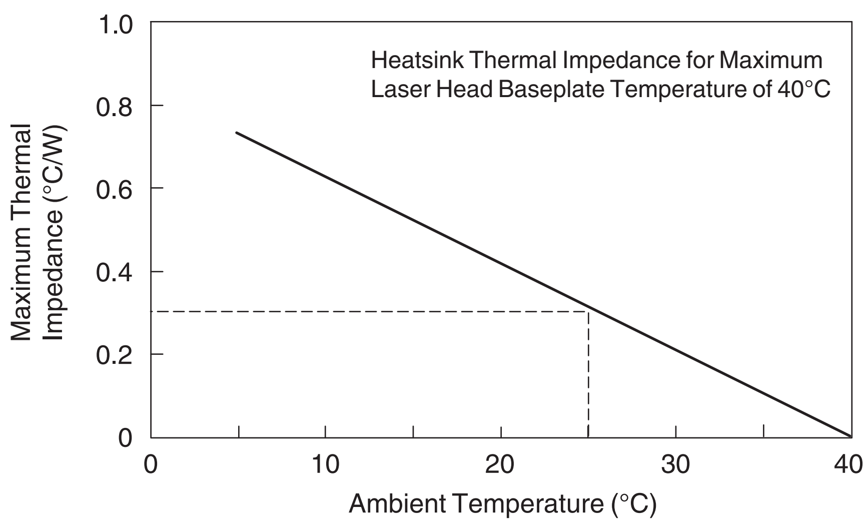


Figure 5-1: Laser Head Heatsink Thermal Impedance Requirement

Spectra-Physics offers an optional heatsink with an auxiliary fan that can be attached to the laser head and controlled through the *L-Series* power supply. Refer to the fan connector description under “Rear Panel Connections” on page 4-6 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. The lower the environmental temperature, the lower the fan speed will be. A temperature setting below ambient will result in the fan operating at a 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 to operate 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 by restarting the laser after the laser head temperature has dropped below 40°C (typical) again. Refer to “System Temperature Management” on page 7-10 for information on setting other temperature limits.

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.

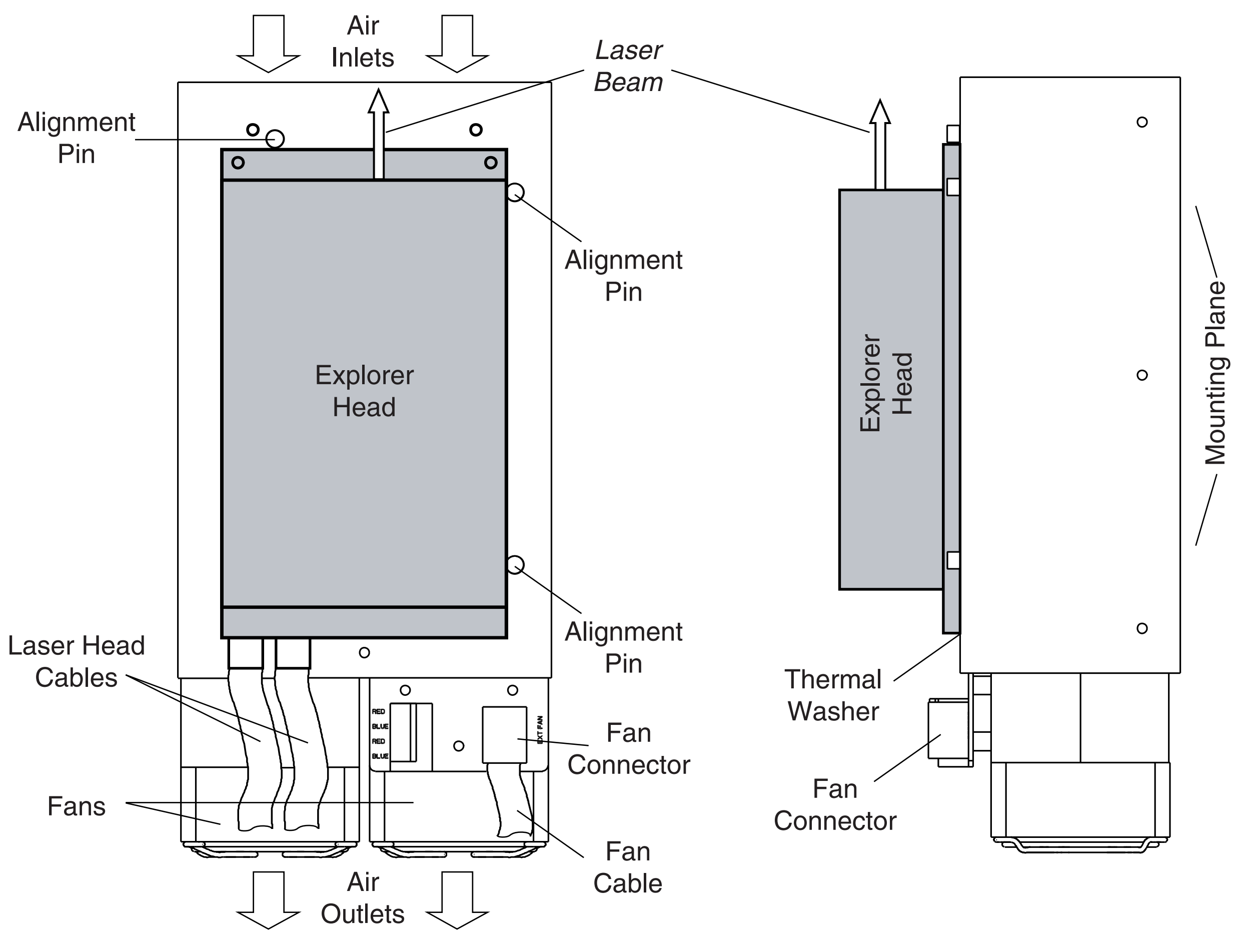


Figure 5-2: Air Flow through the Spectra-Physics Heatsink

Mounting the Hardware

Following standard practice, mount the laser head on a suitable heatsink as described in the preceding section.

Warning!

Never use thermal grease when mounting the laser head on the heatsink. This will contaminate the laser package and the output window.

Use three 8-32 (SAE) or M4 (metric) bolts and washers to mount the laser head. Tighten the bolts and torque them to 1 N·m (9 in-lb). Refer to "Outline Drawings" on page 3-12 for dimensions and hole locations.

Using the slots shown in Figure 3-9, mount the power supply to a suitable surface using four ¼-20 (SAE) or M6 (metric) bolts and washers.

Connecting the System

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

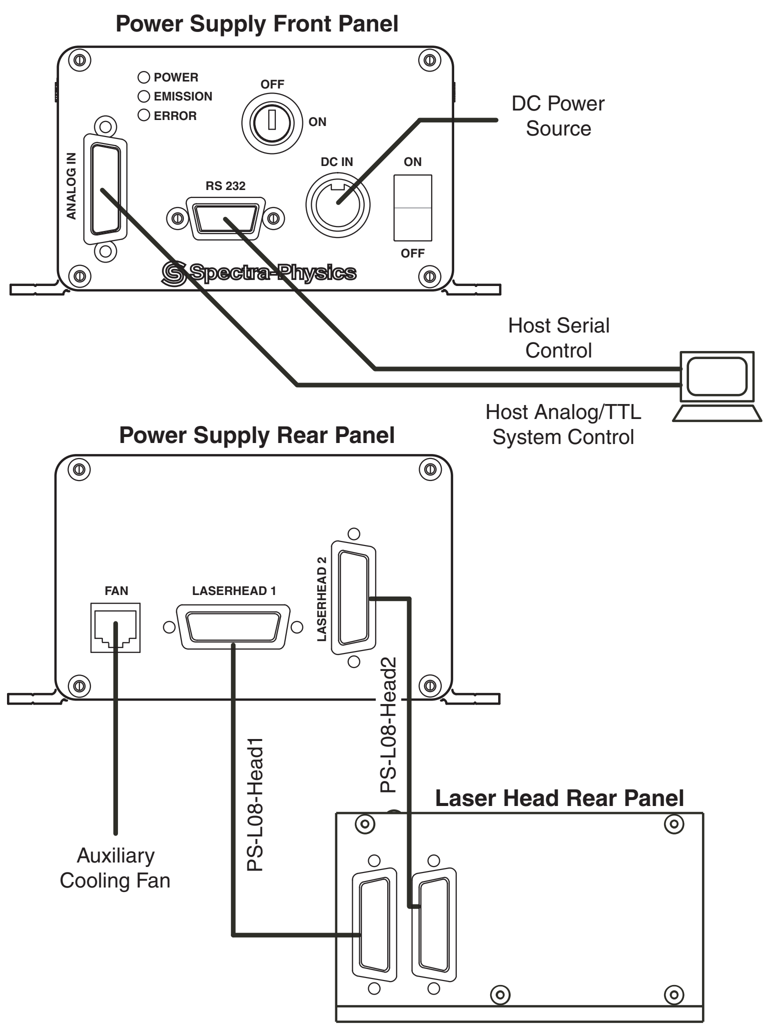


Figure 5-3: System Interconnect Drawing

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 4 A) between the DC IN connector on the power supply and the DC power source. We recommended using 2 pins of the +24 Vdc line and 2 pins of the return line to lighten the current load. Refer to Figure 4-6 on page 4-5 for pin descriptions.

   Make sure that the required voltage of 22–26 Vdc at 4 A is 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 at 1 A.
4. It is recommended that the control circuitry provided for a user-supplied fan be used to maintain proper heatsink temperature. Refer to the description of the FAN connector under "Rear Panel Connections" on page 4-6 for details about using this option.
5. Attach a standard 9-pin M/F serial cable between the RS-232 connector on the front of the power supply and the serial port on your computer. Do NOT use a null modem cable! 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 7-2 for a functional description of each pin.

Note

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 used in a circuit to shut the laser off if a normally closed 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. Figure 7-4 on page 7-20 provides an example circuit.

Laser Alignment

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

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

Danger! Laser Radiation

Eyewear Required

Spectra-Physics *Explorer* lasers are *Class IV—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 ultraviolet beam at 355 nm is invisible and is, therefore, especially dangerous.* Residual light at 1064 nm, 808 nm and 532 nm wavelengths might also be present.

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

Chapter 6 provides instructions for operating the *Explorer* 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. If an earlier version of the *L-Win* software is installed on the computer, it should be upgraded to the version shipped with the laser system (or to a newer version if software upgrades are provided by Spectra-Physics). Earlier versions may not be compatible with this laser system, or they may not provide full functionality.

1. Insert the CD into the computer 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*[1] runtime libraries onto the computer hard drive.

After installation, a new program group will be present in your Windows Start menu as Spectra-Physics Laser Control -> L-Win. This manual as well as corrections and addenda will also be copied to your computer and will be accessible via the Windows Start menu.

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.

[1] *LabView is a trademark of National Instruments, Inc.*

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 typically takes a few 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.

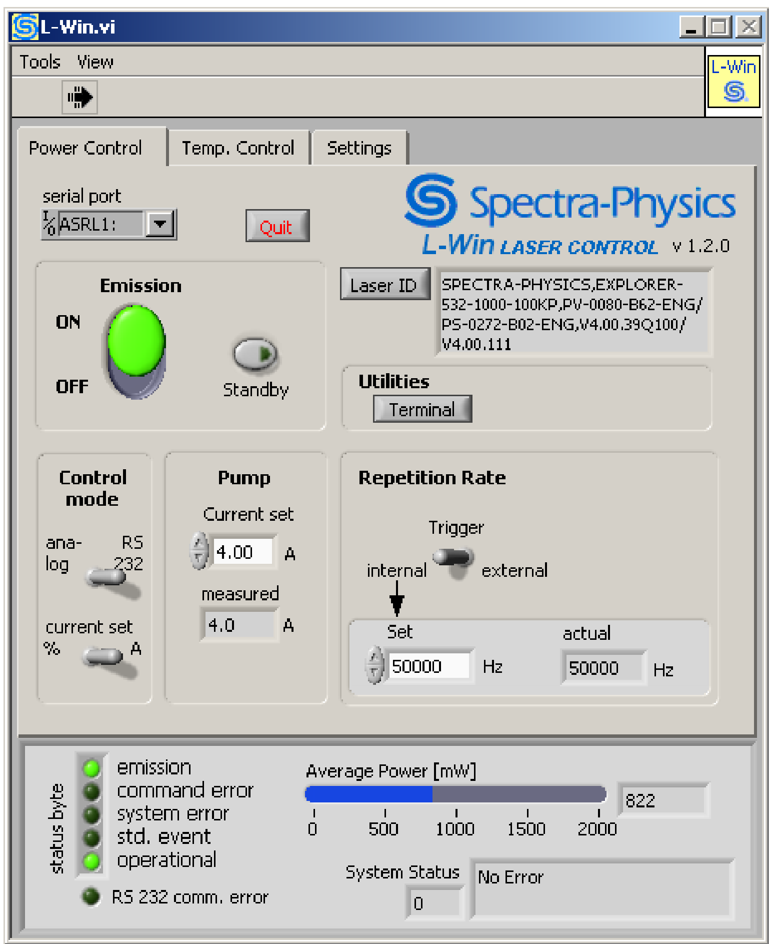


Figure 5-4: The *L-Win* Power Control Display

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 will start either at the pre-stored factory settings or the user-stored pre-set values.
7. Click on the Emission button to turn on the laser. The blue EMISSION lamp on the power supply and the white indicator on the laser head will turn on, indicating that the laser is capable of producing laser light.
8. The *Explorer* laser head will begin emitting laser 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 the specified wavelength and pulsed output in the 100 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 below to leave the crystal ovens 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 button to turn off the laser.
2. Leave the power supply keyswitch and power switch in the ON position.

Long-term

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

Chapter 6 Operating Using the L-Win Software

Danger! Laser Radiation

Eyewear Required

Spectra-Physics *Explorer* lasers are *Class IV—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 ultraviolet beam at 355 nm is invisible and is, therefore, especially dangerous.* Residual light at 1064 nm, 808 nm and 532 nm wavelengths might also be present.

L-Win is a *LabView*[1]-based graphical user interface (GUI) that provides a simple and direct method of controlling the *Explorer* laser as a stand-alone system from a personal computer. For example, it can be used when installing or servicing the laser system.

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* displays, 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

The procedures in this chapter assume that the *Explorer* 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 that 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 has been installed and appears to be functioning,
- the power supply is turned on, the keyswitch is on and the laser has 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.

1 *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 in "Initial Turn On/Turn Off Using the L-Win Software" on page 5-5 for starting the laser from 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.

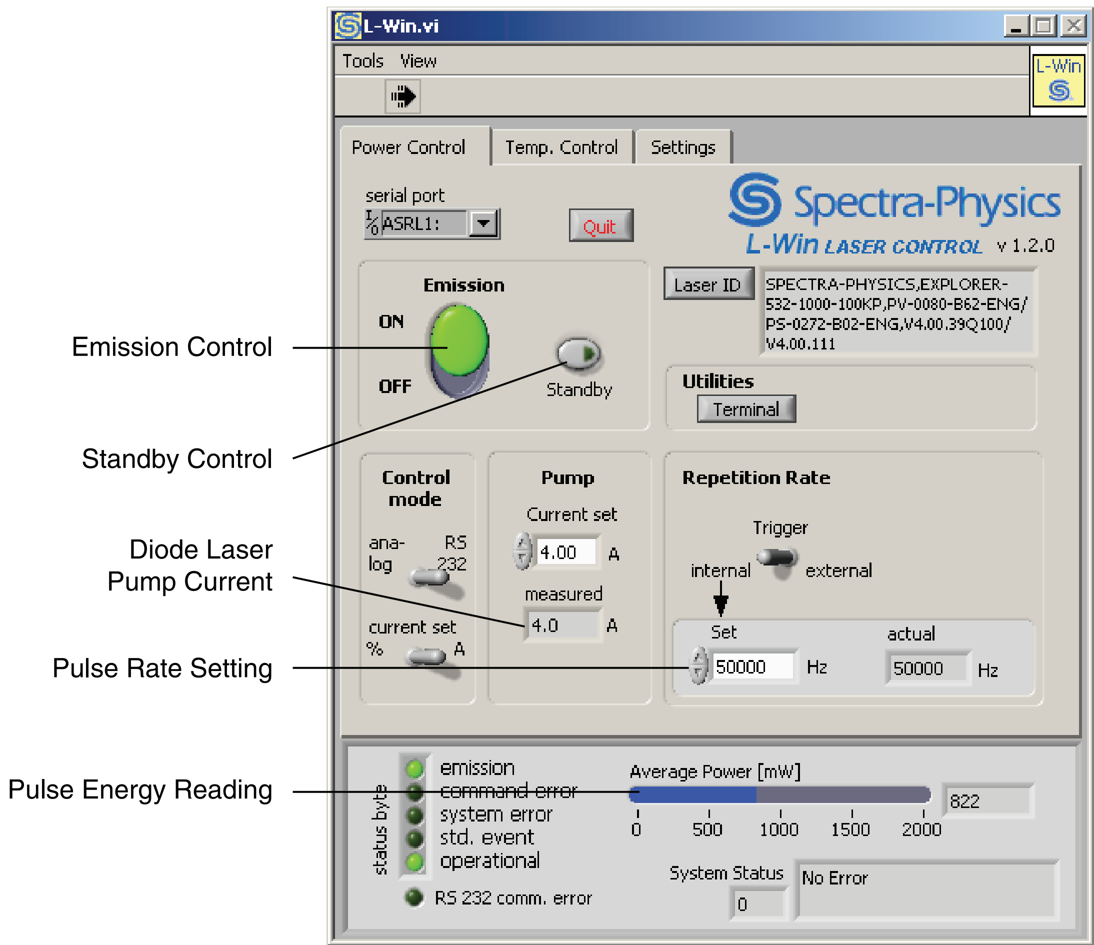


Figure 6-1: The *L-Win* Main Display

To start the laser, set the Trigger switch to Internal and click on the Emission button. The button will turn green, the power supply and laser head emission indicators will turn on immediately, and a pulsed beam at the displayed pulse repetition rate will be emitted after a 3-second safety delay.

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

Note

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

Adjusting the Pulse Energy and Average Power

To change the pulse energy (and the average power) 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 Explorer Output" on page 6-17 for more information.

The energy of individual pulses[1] or the average power[2] 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 once a 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, depending on the *Explorer* model, from single-shot to 60 kHz or from 20 kHz to 150 kHz (there may be a small difference between the set rate and the actual repetition rate—refer to "Changing the Pulse Repetition Frequency" on page 7-5 for more information).

Note that external triggering is also available. Refer to "External Q-Switch Triggering" on page 7-19 for more information.

Setting the Laser to Standby

Click on the Standby button to set 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.

[1] *Only EXPL-xxx-yyy-E models.*
[2] *Only EXPL-xxx-yyy-P models.*

Sleep Mode

If the system enters Sleep mode, most commands become inactive. For safety reasons, this can happen if one of the temperature controllers fails, for example. The Emission button is deactivated and “Sleep Mode!” is displayed in the Emission control field (see Figure 6-2).

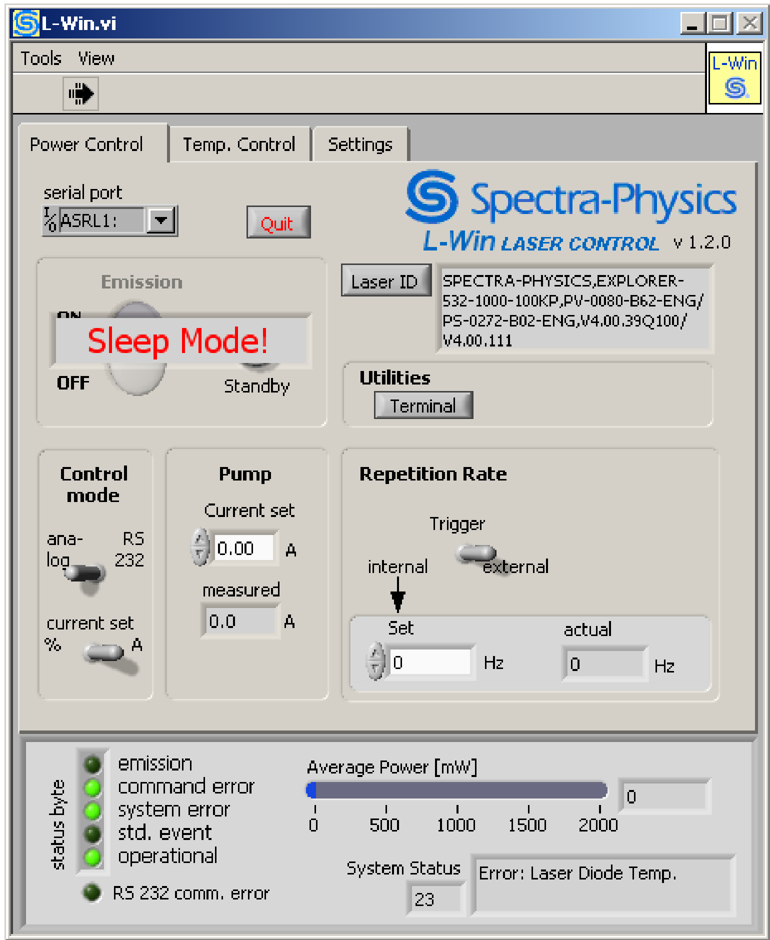


Figure 6-2: Sleep Mode

Sleep mode can be activated by using the software command *Mode: Sleep 1*. To exit Sleep mode, use the command *Mode:Sleep 0* or turn the power supply off then on if the unit was put into Sleep mode by the system itself.

Saving and Using Pre-Set Operating Parameters

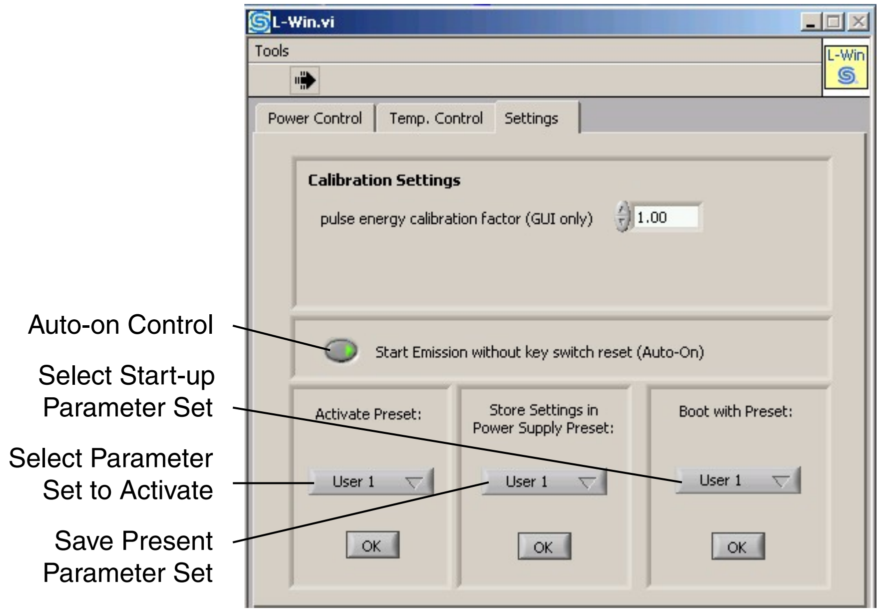


Figure 6-3: Settings Tab—Selecting Operating Parameters

Note

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

Clicking on the Settings tab in the Main display causes the Settings display to be shown (Figure 6-3). This display 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 be activated the next time the system is booted. Save these settings to make this change permanent.

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!

Monitoring and Adjusting Performance[1]

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 6-4 and Figure 6-5).

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 Main display 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 is on 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.

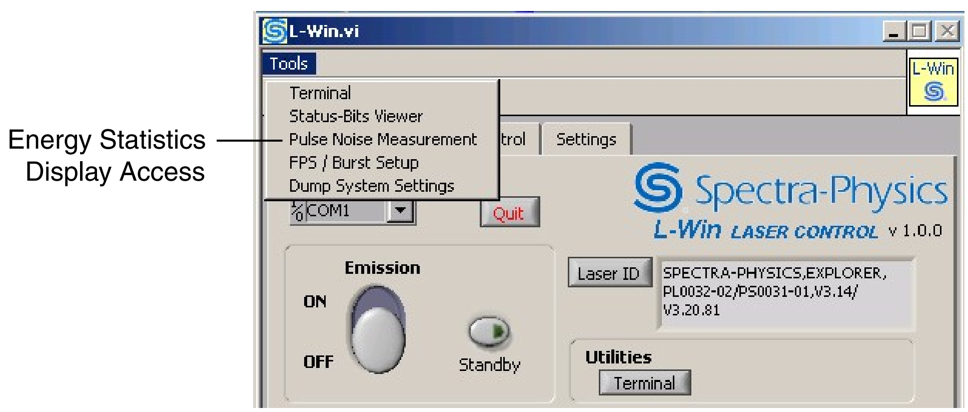


Figure 6-4: Tools Menu—Accessing the Energy Statistics Display

[1] *Only EXPL-xxx-yyy-E models.*

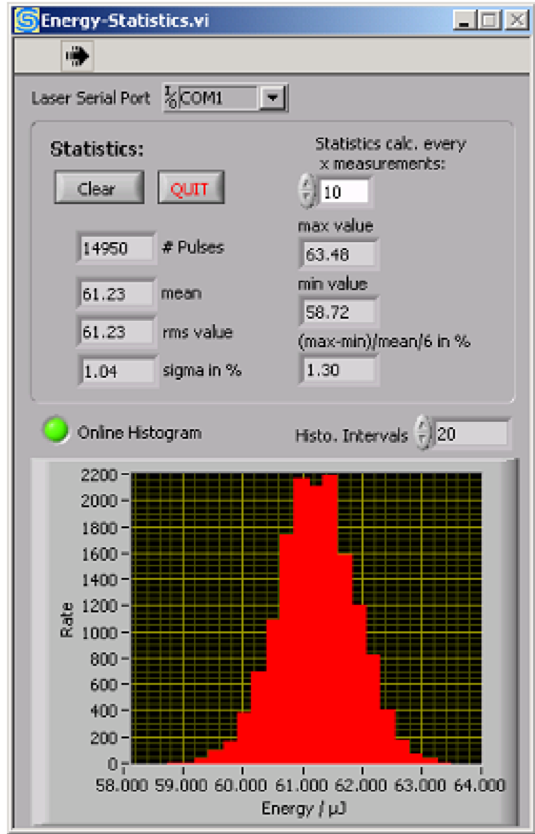


Figure 6-5: Energy Statistics Display

System Settings

Calibrating the Pulse Energy Monitor Readings or Average Power Monitor Readings

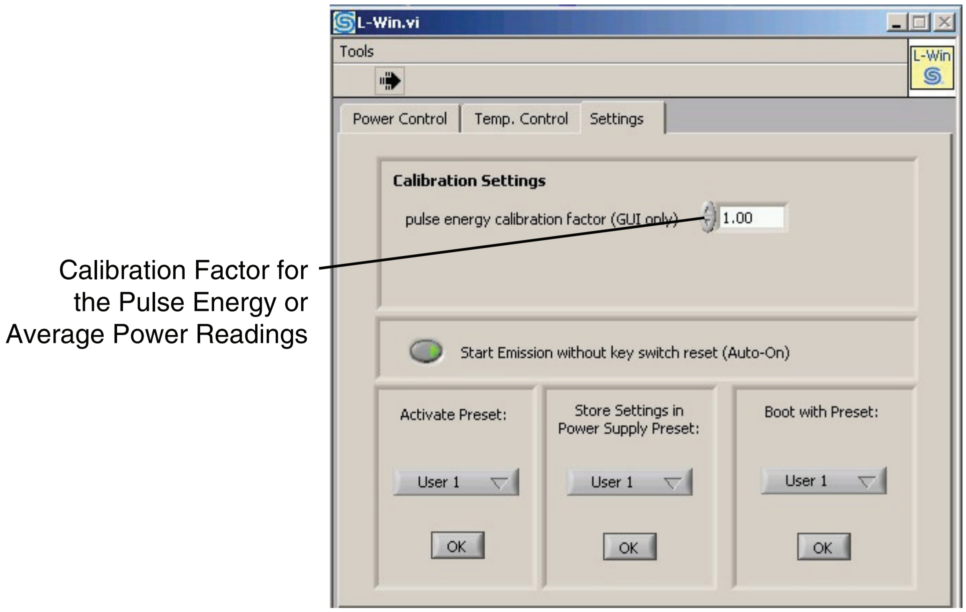


Figure 6-6: Settings Tab—Calibration Factor

The Pulse energy calibration factor or Average Power 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* laser.

This factor can be changed to correct the displayed values to correspond with an external energy (power) meter. This calibration only adjusts the *L-Win* display readings. It does not calibrate the values reported by the pulse energy monitor itself. To permanently change the internal calibration of the power/pulse energy monitor, see Appendix A, “Energy/Power Measurement Calibration.”

Tracking Operating Hours

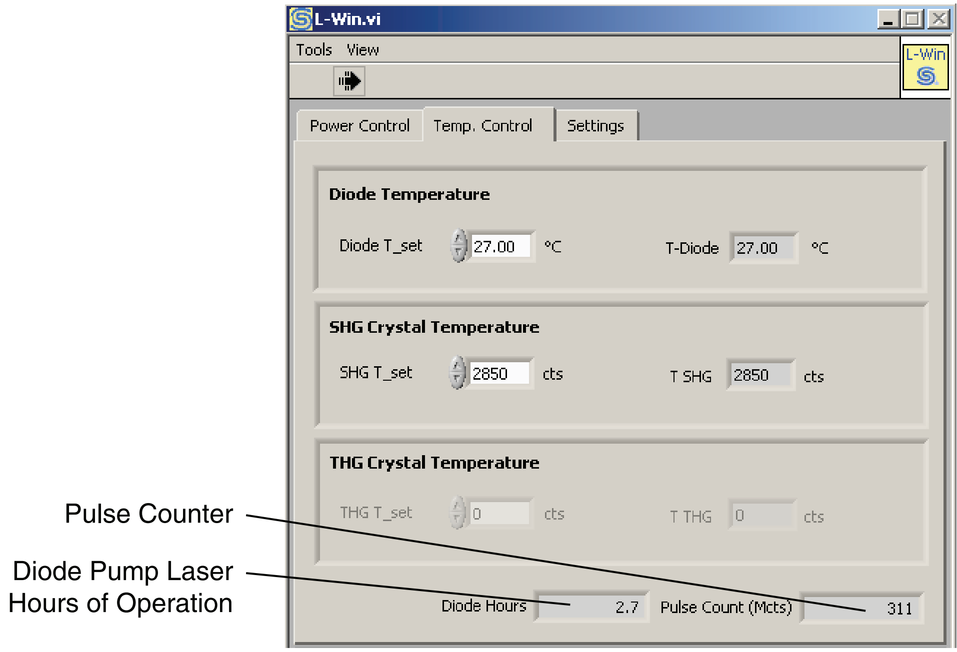


Figure 6-7: Tracking Operating Hours

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 for monitoring the lifetime of the nonlinear crystals in the laser head.

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

Selecting Analog Control

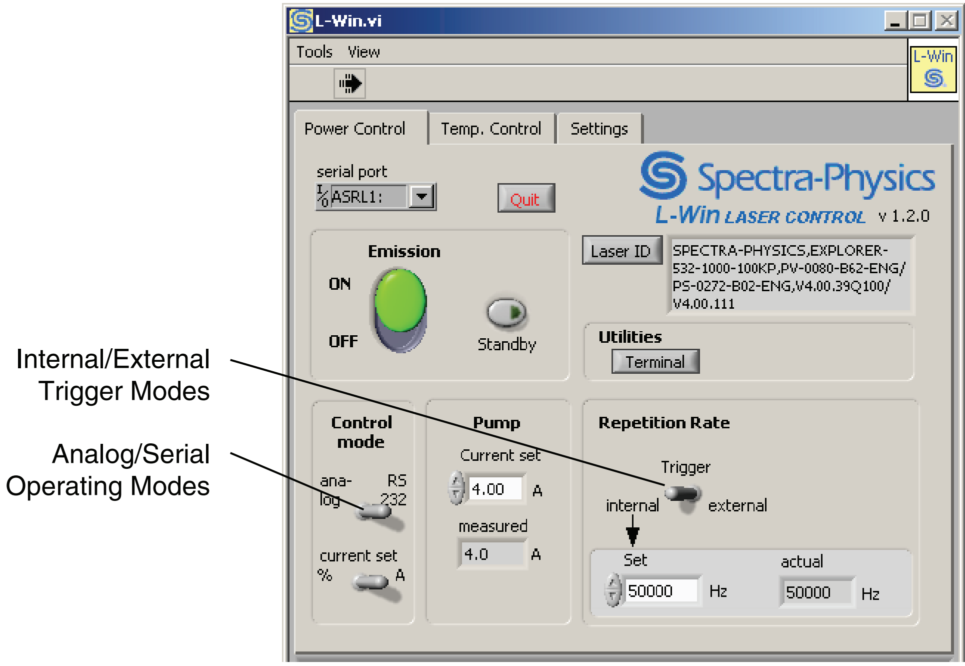


Figure 6-8: Selecting Analog Control or the Q-Switch Trigger Source

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 via analog voltages applied to the ANALOG IN connector. While in this mode, the controls for emission on/off are disabled on the *L-Win* displays. Refer to “The Analog Interface” on page 7-15 and “Basic Analog Operation” on page 7-18 in 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. Refer to “Basic Serial Operating Control” on page 7-3 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 switch to external. The external trigger signal is input through the ANALOG IN connector on power supply. Refer to “The Analog Interface” on page 7-15 and “Basic Analog Operation” on page 7-18 for information about operating the laser using analog signals.

Component Temperature Adjustment

To function properly, the diode pump laser and the harmonic crystals in the laser head depend strongly on operating at their correct temperatures. The temperatures of these components are controlled and stabilized using closed-loop monitor/driver circuits. The Temp. Control display provides controls for the pump diode and the second and third harmonic (SHG and THG) crystals (depending on *Explorer* model). The temperatures are set in °C for the diode laser, and in counts (depending on *Explorer* model) for the crystals.

Warning!

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

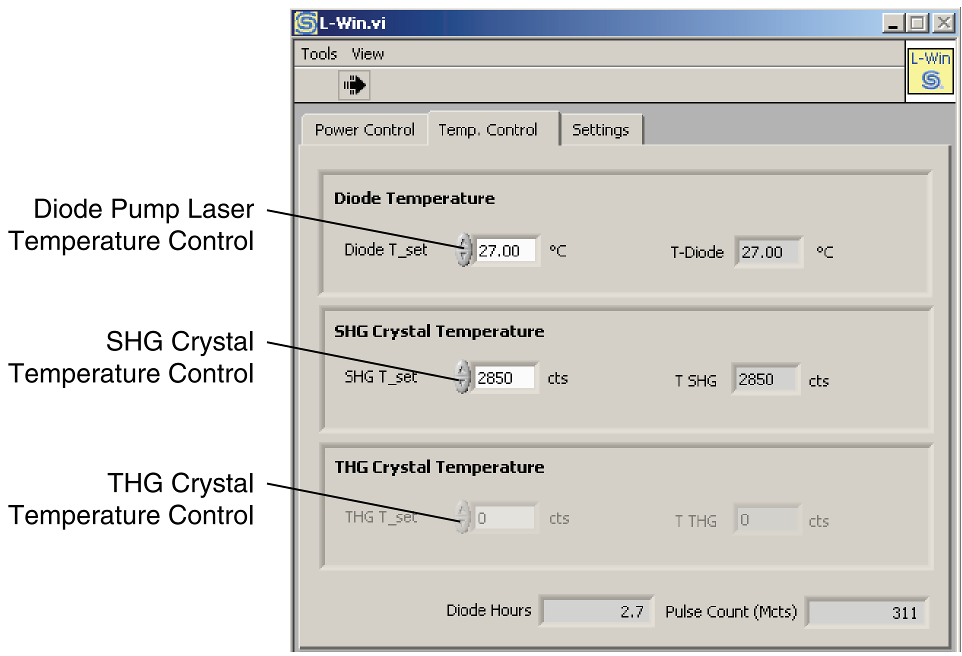


Figure 6-9: Temperature Control Display

When the *L-Win* software is started, the system enters Standard mode. The set temperature and the measured temperature can be displayed, but it is not possible to change the temperature setting while in this mode. To change the temperature setting, switch to Expert mode by selecting *View/GUI Mode* from the *L-Win* Main menu (Figure 6-10).

Warning!

Do not change the temperatures of these components unless instructed to do so by an authorized Spectra-Physics service representative.

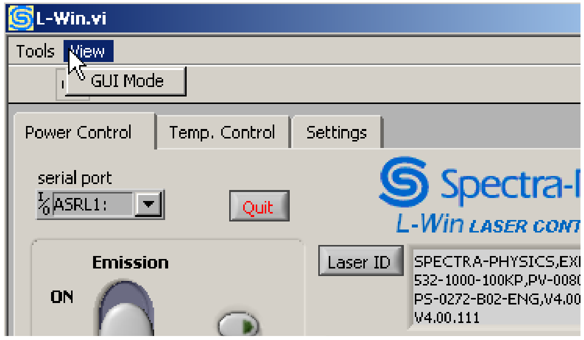


Figure 6-10: Selecting the GUI Mode

Upon selecting "GUI Mode," a dialog box with a warning message appears (Figure 6-11).

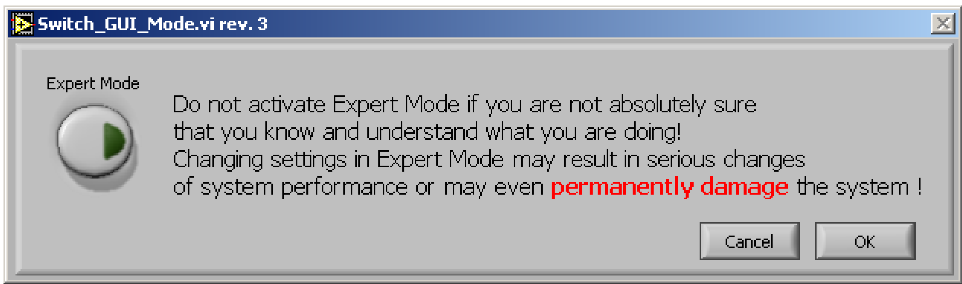


Figure 6-11: Warning—Entering Expert Mode

To enter Expert mode, press the Expert Mode button (it turns red) and confirm by clicking on OK. The temperature controls are now activated. To return to Standard mode, select *View/GUI Mode* again and press the Expert Mode button once more (it turns black) or restart the *L-Win* software.

Depending on the *Explorer* model, the THG crystal may not be available. When this is the case, the temperature control fields display "0" and are grayed out as shown in Figure 6-9.

Before changing the diode laser temperature, record the present values for operating current and temperature, as well as the other laser parameters (output power, etc.), in the event that they need to be restored later. To maintain the diode laser wavelength at its optimum value of 808 nm, make small adjustments to the diode laser temperature (in maximum increments of 0.5 °C), then wait a few seconds to see what effect the change has on pulse energy or average power before continuing.

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 set points by activating the preset "Factory 1."

Setting the SHG and THG Temperatures

Note

The *Explorer* models that produce output at 532 nm do not contain a THG crystal; only the SHG crystal temperature can be adjusted.

1. Before making any changes to the crystal temperatures, record the starting values for the temperature settings in case you need to return to these settings.
2. 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.
3. Continue making small changes to the THG crystal temperature until a maximum pulse energy output has been achieved.
4. Next, change the SHG crystal setting, again by small increments, waiting for the laser output to stabilize before making further changes.
5. 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.
6. When optimum output has been achieved, log the new temperatures along with the current and energy or power readings. These settings can be saved in either User 1 or User 2 (see "Saving and Using Pre-Set Operating Parameters" on page 6-5).
7. Return to the Main display to resume laser emission.

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 resume laser emission.

Advanced Control of the Pulsed Output

Burst Control[1]

The *Explorer* laser allows pulses to be grouped in packets that are separated by periods of no laser output. This is called Burst mode. To set up Burst mode, select FPS/Burst Setup from the Tools menu as shown in Figure 6-12.

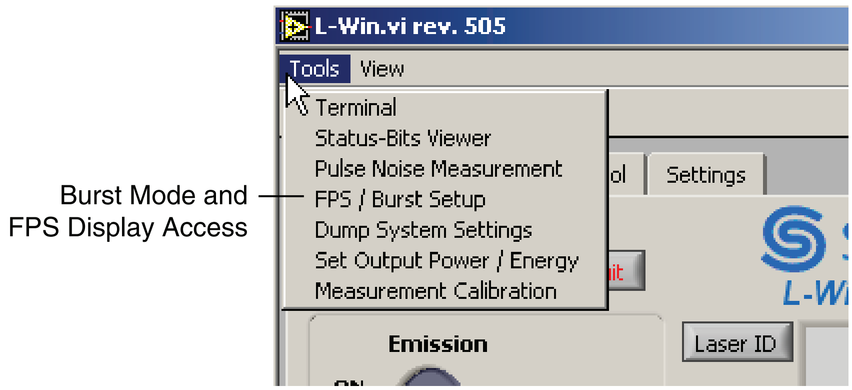


Figure 6-12: Tools Menu

The Burst mode display will appear as shown in Figure 6-13.

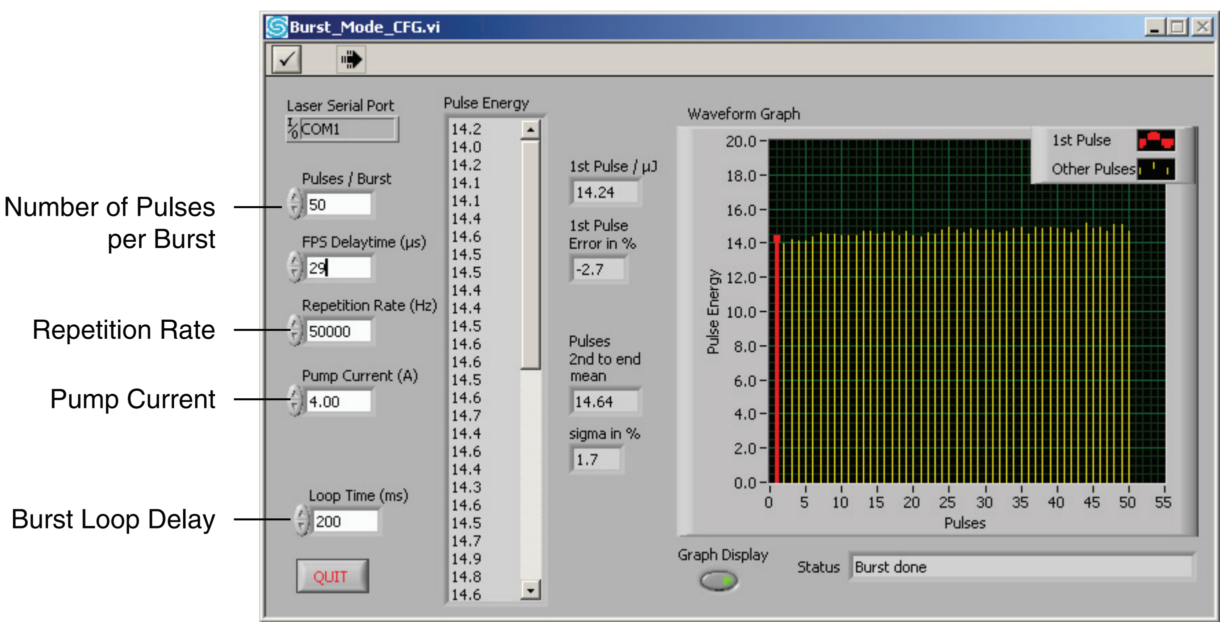


Figure 6-13: Burst Mode and FPS Display

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

[1] *Only EXPL-xxx-yyy-E models.*

To select Burst mode:

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 6-13 has 50 pulses (at 50 kHz) per burst, so a burst will span 1 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 6-13) will result in an interval of 200 ms between bursts (in addition to the time the burst is emitted). (Note that Loop Time is a parameter only in *L-Win*, and is not supported by *Explorer* firmware or commands.)

Clicking on the STOP button ends 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 high repetition rates. 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 3-9 for a further description of the first pulse effect.

Note

The first pulse suppression feature can be used independently from burst mode, e.g., when using external gating via TTL signals on the ANALOG IN port. In this case, the burst mode setup tool can be used to setup the correct FPS timing.

Useful operating modes of the *Explorer* laser using FPS are “FPS with Gating” and “FPS with Burst mode.” Refer to “Control of the Pulsed Output” on page 7-12 for more information.

For convenience, both the current and the pulse repetition frequency can be changed using the FPS and Burst mode display (Figure 6-14).

FPS with Models with an Internal Pulse Monitor[1]

To use FPS, set the FPS Delay Time parameter (in microseconds) so that the first pulse has approximately the same energy as subsequent pulses in a

[1] *Only EXPL-xx-yyy-E models.*

burst. The recommended starting value of the FPS delay time is the inverse of the applied pulse repetition frequency. For example, if the pulse repetition frequency is 50 kHz, the recommended FPS starting value is 20 µs. 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.

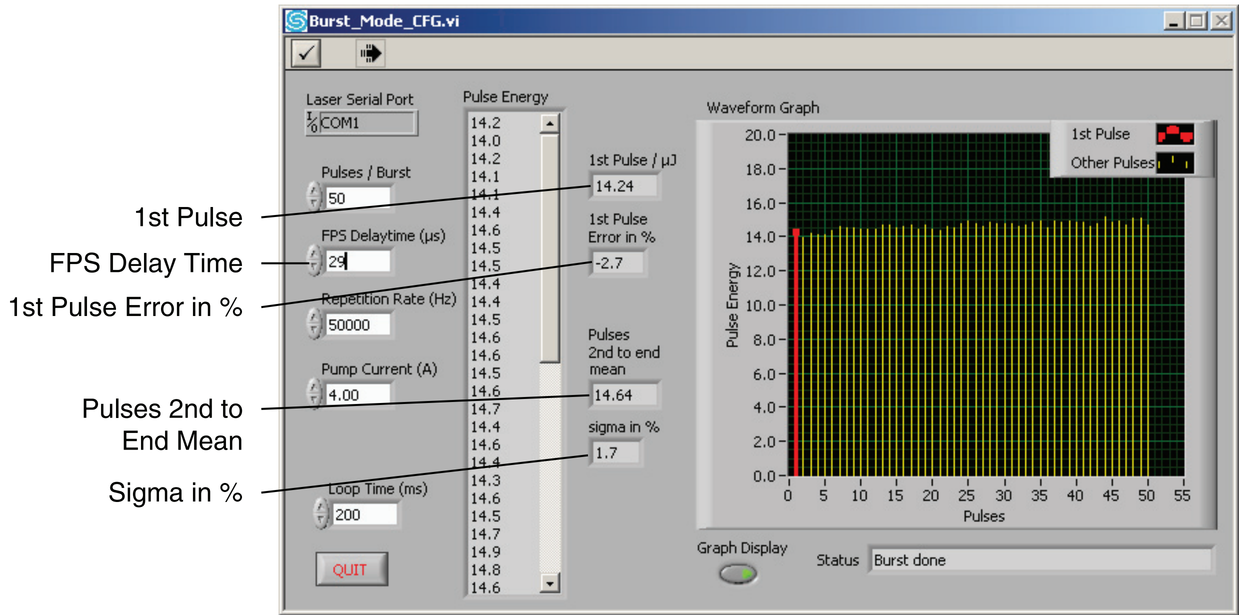


Figure 6-14: FPS and Burst Mode Display

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 a burst, chronologically. The Pulses 2nd to end mean field displays the calculated average energy of the first 50 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 not display the waveform graph.

Important Notes on Controlling Explorer Output

Explorer laser output power is controlled by changing the diode laser current. Diode current can be varied as needed, but the maximum diode laser current allowed 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.

Changing diode current will change the temperature of the diode laser and, hence, the wavelength of its emission. Failure to maintain the diode emission at the proper wavelength can actually cause a decrease in output 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, which 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* 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.

Chapter 7 Operating with Commands and Signals

Danger!
Laser Radiation

Eyewear Required

Spectra-Physics *Explorer* lasers are *Class IV—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 ultraviolet beam at 355 nm is invisible and is, therefore, especially dangerous.* Residual light at 1064 nm, 808 nm and 532 nm wavelengths might also be present.

The *Explorer* 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 IN interface on the *L-Series* 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* 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 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* laser system using the serial command/query language described in Appendix B. The latest version of the command language 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 for 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 Explorer Output" on page 6-17 before making significant changes to the operation of the *Explorer*.

Serial vs. Analog Control

Before the laser can be operated using serial commands, on/off control must be transferred to the RS 232 serial port.

The following commands enable and disable any command signals applied to the ANALOG IN interface:

MODE:RMT 1	puts the system in a mode where the system is controlled only by commands sent via the serial port. Any signals at the ANALOG IN interface are ignored.
MODE:RMT 0	puts the system in analog mode where the laser system is the controlled by signals applied to the ANALOG IN interface the in addition to any serial commands.

Use the following query to determine if the laser is in Serial or Analog mode:

MODE:RMT?

1	the system is in Serial mode.
0	the system is in Analog mode.

Turning the Laser On and Off

If the power switch and the keyswitch are both on and control has been transferred to remote operation, turn the laser on and off by entering:

ON	emission begins after a safety delay of about 3 seconds; laser emission indicators on the laser head and power supply 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
WDOG 0	turns off the watchdog timer.

To query the status of the watchdog timer, enter

WDOG?

25	where "25" is the interval time in seconds

Adjusting the Pulse Energy or Average Power

To read the actual pulse energy in µJ, use the query:

READ:PENER?[1]

To read the actual average power in mW, use the query:

READ:POW?

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

DIOD1:CURR <f>[2] where <f> is a decimal value for current in Amps.

Example:

DIOD1:CURR 4.56
READ:DIOD1:CURR?
4.56 diode current = 4.56 A.
DIOD1:CURR? returns the value last commanded.

The current can also be set as a percentage of its maximum allowed value thus allowing the operator to change the current relative to its present value.

Use the following command to change the current as a percentage of maximum current:

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

In necessary, the maximum current value can be found using the query:

DIOD1:MAXC? returns the diode laser current limit in Amps. This diode current limit is set at the factory and cannot be changed.

Changing the Q-Switch Trigger Source

The QSW:PRF command sets the pulse repetition frequency (see "Changing the Pulse Repetition Frequency" on page 7-5). It can also be used to set the Q-switch trigger input to an external source applied to the power supply ANALOG IN connector.

To change to an external Q-switch trigger source, enter the command:

QSW:PRF 0

Details for using an external trigger source are provided in "The Analog Interface" on page 7-15.

To return to the internal trigger, enter a number between 20000 and the number returned by QSW:PRF:MAX? (the maximum frequency).

Monitoring the System Status Byte

The system status byte returns a summary of important status information about the *Explorer* laser. Appendix C describes each of the byte bits.

To monitor the system status byte, enter the query:

*STB?

[1] *Only EXPL-xxx-yyy-E models.*
[2] *Only EXPL-xxx-yyy-P models.*

Example:

*STB?

1 where "1" (bit 0 of the status byte is set) indicates that laser emission is present. Refer to Table C-1 on page C-1 for other responses.

Tracking Diode Laser Operating Hours

The system monitors diode laser operating hours of operation, which is useful in tracking the lifetime of the diode laser and harmonic crystals.

To find out the total time the system has operated, enter the query:

READ:DIODE1:HOUR?

Example:

READ:DIODE1:HOUR?

456.2HrsD1 total operation time is returned in hours.

Changing the Pulse Repetition Frequency

The QSW:PRF command sets the pulse repetition frequency (PRF).

To set the pulsed output to 50 kHz (for example), enter the command:

QSW:PRF 50000

To return the last commanded value for the PRF, enter the query:

SW:PRF?

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

READ:QSW:PRF?

Because of the minimum interval of the timer clock, there is an inaccuracy regarding the frequency adjustment. However, the real frequency f_{real} can be calculated from the adjusted frequency f_{adj} using the following equation:

$$f_{real} = \frac{4\ MHz}{round\left(\frac{4\ MHz}{f_{adj}}\right)}$$

The command READ:QSW:PRF? returns the real frequency. The maximal difference between the real frequency and the adjusted frequency can be calculated from the equation:

$$\Delta f_{max} = \max\left|f_{real} - f_{adj}\right| = f_{adj} - \left|\frac{4\ MHz}{\frac{4\ MHz}{f_{adj}} + 0.5}\right|$$

The correction is shown graphically in Figure 7-1.

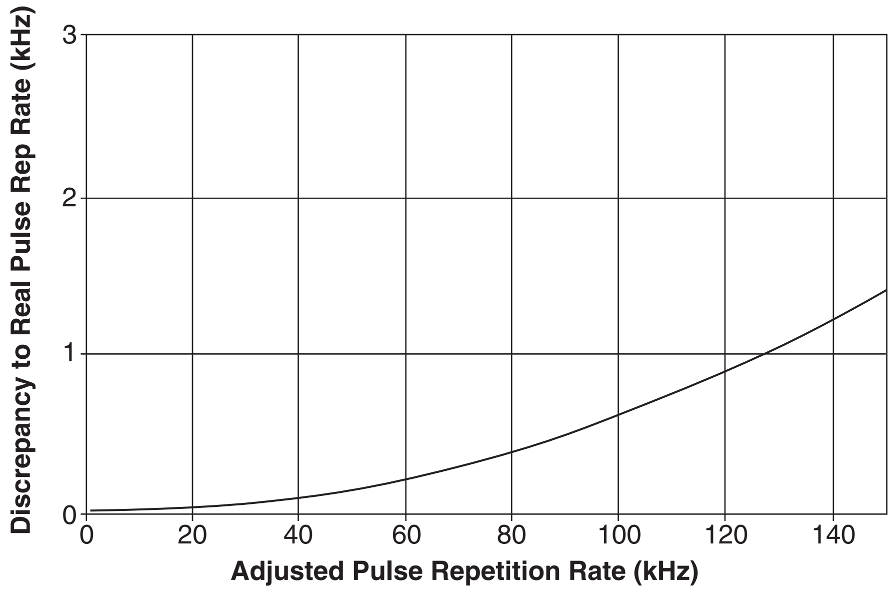


Figure 7-1: Repetition Rate Correction

Setting the Laser to Standby or Sleep Mode

There are two Standby modes for the *Explorer* laser: Standby and Sleep. The modes differ in the time required for the laser to return to normal operation, and the amount of energy used.

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. Use this mode when the laser is to be used again soon.

To enter Standby mode, enter the command:

MODE:STBY 1

To see if the laser is in Standby mode, enter the query:

MODE:STBY?

1	Standby mode is on
0	Standby mode is off

To return from Standby mode, enter:

MODE:STBY 0

Sleep Mode

Sleep mode turns off the diode laser, the Q-switch and temperature control for the diode and crystals. Everything else is still on. This allows the system to be returned to operation via a software command instead of requiring a hardware start using the keyswitch. Use this mode when the laser is not to be used for quite some time (e.g., over-night).

To enter Sleep mode, enter the command:

MODE:SLEEP 1

To return from Sleep mode, enter:

MODE:SLEEP 0

To see if the laser is in Sleep mode, enter the query:

MODE:SLEEP?

1	Sleep mode is on
0	Sleep mode is off

Note

Sleep can only be activated when laser emission is off.

While in Sleep mode, all commands to the laser, except status queries and MODE:SLEEP 0, are ignored.

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 operating parameters. Two sets can be saved by the user; two are read-only factory pre-sets. The parameters are loaded automatically at boot-up and can also be activated after operation has begun.

A user set comprises the parameters listed in Table B-7. In addition to parameters that are specific for one of the four parameter sets, a set of global parameters exists (see Table B-8). These are also stored each time a specific parameter set is stored.

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

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

To use one of the two user-saved sets or one of the read-only 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 will be used the next time the system is booted, enter the command:

CONFIG:PARSET:BOOT <n> where <n> specifies 1, 2, 3 or 4 to correspond 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. Use CONFIG:PARSET:STOR 1 or CONFIG:PARSET:STOR 2 to make this setting permanent.

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 only 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 be turned on using software commands without having to switch the keyswitch off and on again.

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" on page 7-15 for a description 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). Appendix B provides more detailed information about the Analog Port Status Byte.

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 that 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:POLAR. The command CONFIG:APORT:POLAR 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:POLAR? 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.

Component Temperature Adjustment

Warning!

Changing the temperature of the following components can cause serious damage to the laser. Consult Spectra-Physics before making any adjustments to these temperatures.

In order to function properly, the diode pump laser and the harmonic crystals in the laser head all depend strongly on operating at the correct temperature. These components are actively cooled or heated via closed-loop control circuits. The laser system also provides the ability to actively control an optional fan to cool the laser head mounting baseplate.

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 ±0.05°C.

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

DIOD1:TEMP <f> where <f> is a decimal number: $18.0 \le f \le 35.0$

Example:

DIOD1:TEMP 29.2

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

READ:DIOD1:TEMP?

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

DIOD1:TEMP?

Setting the SHG and THG Crystal Temperatures

Note

The *Explorer* models that produce output at 532 nm do not contain a THG crystal, so only the SHG crystal temperature will be adjusted.

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

Warning!

Do not change the temperatures of these components unless instructed to do so by an authorized Spectra-Physics service representative.

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

Example:

READ:SHG:TEMP?

1649

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 temperatures during operation. If a laser head or power supply over-temperature condition is detected, 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 serial commands or the Status Viewer display of *L-Win*.

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

Table 7-1: System Response to Over Temperature Conditions

Component	Temperature[1]	Action
Laser head	< 18°C	Issue error #37 (WARNING UNDERTEMP HEATSINK) Laser remains fully operational
Laser head	> 35°C	Issue error #39 (WARNING OVERTEMP HEATSINK) Laser remains fully operational
Laser head	> 40°C	Safety shutdown (Sleep mode is activated) Clear error #38 (WARNING OVERTEMP LASERHEAD) Issue error#34 (ERROR LASER HEAD OVERTEMP)
Laser head	unit returns to < 50°C	Clear error #34 (ERROR LASER HEAD OVERTEMP) User may exit Sleep mode: MODE:SLEEP 0
Power supply	> 50°C	Issue error #38 (WARNING OVERTEMP POWERSUPPLY) Laser remains fully operational
Power supply	> 55°C	Safety shutdown (Sleep mode is activated) Clear error #38 (WARNING OVERTEMP POWERSUPPLY) Issue error #33 (ERROR POWERSUPPLY OVERTEMP)
Power supply	unit returns to < 50°C	Clear error #33 (ERROR POWERSUPPLY OVERTEMP) User may exit Sleep mode

[1] *All temperatures listed are typical values.*

Controlling the Laser Head Temperature

The fan control has two modes, drive mode and control mode.

In Drive mode, a percentage value of the maximum voltage (13 V) can be set. In this mode, the speed of the fan is independent of the laser head temperature.

In Control mode, the fan speed is dependent on the laser head temperature, which can be set by the user.

To set the fan control mode, enter the command:

HEAD:FANCONT:MODE <n>   where drive mode is n = 0 and Control mode is n = 1.

To read the current fan control mode, enter query:

HEAD:FANCONT:MODE?

To set the fan speed, enter the command:

HEAD:FANCONT:PVOLT <f>   where <f> is an integer between 0 and 100.

Example:

HEAD:FANCONT:PVOLT 50

To read the fan speed, enter the query:

HEAD:FANCONT:PVOLT?

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

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

Example:

HEAD:FANCONT:TEMP 33.5

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

READ:HEAD:BAS:TEMP?

Note

the laser head temperature can be kept at a constant temperature by the heatsink and fan only when the ambient temperature is about 10° lower than the laser head temperature set point.

Control of the Pulsed Output

Burst Control

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

The number of pulses in a burst is set using the command:

BURST:CNTS <n> where <n> is a decimal number $1 \le n \le 4000$.

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

Burst mode can only be initiated using serial commands. However bursts can be started using analog signals applied to the ANALOG IN port.

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 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:RMT 1	Place the laser in computer control.
QSW:PRF 50000	Set the pulse repetition rate (In this example, 50 kHz)
DIOD1:CURR 4.0	Set diode current
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* laser allows the trigger output, which is available for synchronizing equipment to the laser output, to be extended for the duration of the burst, i.e., pin 19 (*External Sync*) is low for the whole duration of the pulse burst as shown in Figure 7-10 on page 7-26.

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.

Figure 7-10 shows both trigger options.

FPS Operation

The first pulse of a burst will become anomalously large at high pulse repetition rates. (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.[1] It returns the energy values of the first 50 pulses, in counts, after the ON, BURST, or READ:PENER:HIST? command has been sent. (A returned value of "0" means the laser has not emitted a pulse in this session.)

As an example, a return might look like this:

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 20 kHz, the recommended FPS starting value is 50 µs.

FPS:DELAY <n> sets the FPS delay time, where <n> is an integer value in microseconds up to 2000.

Example:

FPS:DELAY 50

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.

For laser heads without an internal pulse energy detector,[2] the user must measure the pulse energy of the first pulse using an external meter. However, the adjustment of the FPS delay time is the same as described above.

Automatic Pulse Energy or Power Adjustment

The automatic pulse energy or average power setting procedure allows the diode laser current to be automatically adjusted to achieve the desired pulse energy or output power (see Table B-3 for the ranges of automatic energy or power adjustment). Note that maximum output power or pulse energy varies with the pulse repetition rate as shown in Figure 3-4 and Figure 3-5 on page 3-7.

The duration depends on the model and the requested pulse energy or power. The maximum duration is 50 seconds.

To use this feature:

1. Turn on the laser using either the ON command (computer mode must be activated) or an external signal applied to the EXT_DIODE_ON pin (pin 10) of the ANALOG IN port. Either internal or external triggering may be used.

[1] *Only EXPL-xxx-yyy-E models.*
[2] *Only EXPL-xxx-yyy-P models.*

2. Wait until the laser system temperature has stabilized before starting the pulse energy adjustment procedure (i.e., wait until operational bit 12 is activated; use the command STAT:COND:OPER? to query this pin).

For EXPL-xxx-yyy-E Lasers

Start this procedure using the command CONT:PENER <n_1>,<n_2>,<n_3> where <n_1> is the requested pulse energy[1], <n_2> states the desired pulse repetition frequency and <n_3> determines whether the user parameters will be stored after completion.

If this procedure is successful, the requested diode current and repetition rate are set as the new input values (if internal triggering mode is on). These values can be verified by using the command CONT:PENER?, which displays the new diode current and pulse energy.

If this procedure fails, the command CONT:PENER? displays a question mark "?". Review the chart in Figure 3-4 on page 3-7 to make sure the laser is capable of delivering the energy requested for the given pulse frequency.

For EXPL-xxx-yyy-P Lasers

Start this procedure using the command CONT:POW <n_1>,<n_2>,<n_3> where <n_1> is the requested average pulse power[1], <n_2> states the desired pulse repetition frequency and <n_3> determines whether the user parameters will be stored after completion.

If this procedure is successful, the diode current and repetition rate are set as the new input values (if internal triggering mode is on). This can be verified by using the command CONT:POW?, which displays the new diode current and power.

If this procedure fails, the command CONT:POW? displays a question mark "?". Review the chart in Figure 3-4 on page 3-7 to make sure the laser is capable of delivering the power requested for the given pulse frequency.

[1] *See Table B-3 for the valid n_1 range.*

The Analog Interface

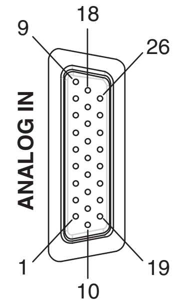


Figure 7-2: The 26-Socket ANALOG IN Connector

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.

Caution!

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 IN interface accommodates a variety of control modes and timing requirements, and it is used in conjunction with serial commands that are executed through the RS 232 interface. The ANALOG IN interface provides the following controls:

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

To use this interface, communication must first be established with the *Explorer* using either the *L-Win* software or through serial commands from a host system. Analog control is enabled by setting the Control mode switch to analog on the *L-Win* Main display or by executing the serial command MODE:RMT 0.

A default state description of the pins of the ANALOG IN interface is given in Table 7-2. “Configuring Analog Control” on page 7-8 describes how the functions of some of the pins can be set to a different polarity. Table 7-2 is followed by examples of how to use the ANALOG IN interface to perform some of the more common laser operations.

The configuration and status of the pins of the ANALOG IN interface are set and queried using serial commands. 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 7-8 for more information about using these bytes.

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

Table 7-2: ANALOG IN Pin Description

Pin	Type	Description	Function
1	Output, Analog	*Pulse Energy* *Output Power*	Pulse Energy monitor/Average Energy monitor Scale[1]: 0 – 4 V Tolerance: +5%/−10% Maximum load: 2 kΩ
2	Input, Analog	*I_EXT*	External diode current control Active if ILD_SOURCE (Pin 18) is pulled low (high)[2] Scale: 0 – 4 V 0%−100% of diode current limit
3	N/A		Do not connect!
4	N/A		Do not connect!
5	N/A		Do not connect!
6	N/A		Do not connect!
7	Output, Power	*USR_ILK*	+12 V line with 470 Ω 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 Ω (see Note)
9	Output, Digital	*EMISSION(L)*	Open-Collector (OC) line, pulls low when laser emission is active, TTL level (see Figure 7-4).
10	Input, Digital	*EXT_DIODE_ON*	Internal pull-up[3]. Pull and keep low (high)[4] to trigger the diode laser on. Release high (low)[4] 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 7-4).
12	N/A		Do not connect!
13	Output, Digital	*ILK_FAULT*	Open-Collector (OC) line, pulls low when the laser interlock is open, TTL level (see Figure 7-4).
14	Output, Digital	*PULSE_ MONITOR* *OPTO_SYNC*	Pulls low (high)[2] when an optical pulse has been detected. May not appear at <5% maximum specified pulse energy. 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. Delay wrt. optical pulse: 45 ns typical Jitter wrt. optical pulse: 1 ns typical

Table 7-2: ANALOG IN Pin Description

Pin	Type	Description	Function
15	Input, Digital	*STANDBY*	Internal pull-up[3]. Pull low (high)[3] to force the laser diode into standby current level, e.g., it blanks laser output. Timing: 2nd order lag: Delay time (50%): 5 μs (typ.) Rise time: 5 μs (+20%−80%, typ.)
16	N/A		Do not connect!
17	Input, Digital	*EXT_GATE*	Internal pull-up.[3] Pull low (high)[4]to gate the pulse trigger (blanks laser output).
18	Input, Digital	*ILD_SOURCE*	Internal pull-up.[3] Pull low (high)[4] to switch to an external current control (use I_EXT pin to set the diode current).
19	Output, Digital	*SYNC_OUT*	TTL-level pulse[2] that is synchronous with the leading edge of the trigger (see Figure 7-7 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		Do not connect!
21	Input, Digital	*EXT_TRIG*	Internal pull-up.[3] Generates a single Q-switch pulse,[1] 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		Do not connect!
24	Digital reference	*DGND*	Ground for Pins 9, 10, 11, 13, 14, 15, 17, 18, 19, 21.
25	N/A		Do not connect!
26	Reference	*EARTH*	PS chassis ground. Low impedance DC-path to supply return (power interface).

[1] *See Table B-3 for calculating the pulse energy or average power.*
[2] *The default polarity is "falling edge" (high/low), but it can be changed to "rising edge" (low/high) using the serial command CONFIG:APORT:POLAR <n>*
[3] *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.*
[4] *The default active level is low, but it can be changed to active high using the serial command CONFIG:APORT:POLAR <n>.*

Basic Analog Operation

Turning the Laser On and Off

Setting the laser emission control to “Analog Interface” (MODE:RMT 0) through the RS 232 interface allows the *Explorer* laser to be turned on and off using a single analog control signal on pin 10 (active-low). The laser uses either the last commanded diode current set point or the default preset values after turn-on as the operating parameter.

The output of pin 11 is pulled low when the laser has reached a stable operating condition (i.e., the TECs for the nonlinear crystals and the diode laser have reached the default temperature set points). This signals that the laser is ready for use.

To turn the laser on using pin 10, pin 11 must be low and pin 13 (INTERLOCK active indicator) must be high, otherwise laser emission is inhibited.

Once pin 10 has gone low, pin 9 (the EMISSION indicator) reports active-low immediately, and laser emission occurs about 3 seconds after activating pin 10. If pin 9 does not report active-low immediately after activating pin 10, an internal system error may have occurred. Refer to the troubleshooting procedures provided in Chapter 8 for resolution.

The output of pin 11 can be used to control an emission indicator. Refer to Figure 7-4 for an example of a circuit that implements this function.

Using the Control Inputs

An example of a simple circuit used to pull one of the *Explorer* analog pins low is shown in Figure 7-3. Note that pin 24 is the ground pin on the ANALOG IN connector. This circuit can be used with pin 10 to turn on the diode laser. It can also be used with other pins that are described later in this section.

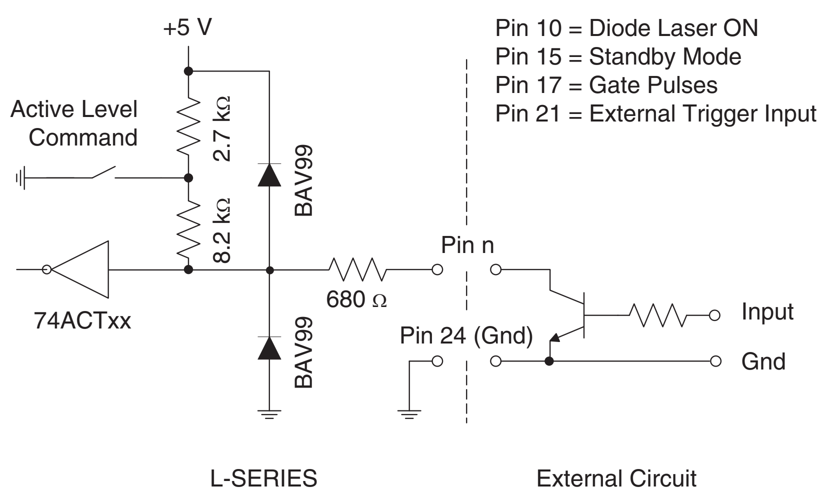


Figure 7-3: Laser Control Circuit Example

Adjusting the Pump Diode Current Using Analog Signals

Pin 2 of the ANALOG IN port can be used to adjust the diode laser current set point. 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 DIOD1:MAXC?).

To activate analog diode laser control, pin 18 on the ANALOG IN port must be pulled low prior to enabling laser emission on pin 10. During emission, the mode of operation cannot be changed. Figure 7-3 shows an example of a circuit that can be used to supply the trigger signal.

External Q-Switch Triggering

Internal triggering is the default setting for the *Explorer* laser. To switch to external triggering, send the serial command QSW:PRF 0, which 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 applied to pin 21 should be a TTL level, falling edge input (default setting, see Appendix B and Table B-4) from single-shot to 60 kHz or 20 to 150 kHz, depending on the *Explorer* model. Figure 7-3 shows an example of a circuit that can be used to supply the trigger signal.

Note

Explorer lasers are designed for pulse repetition rates above 20 kHz. Lower frequencies can result in unstable laser operation. To avoid instability, decrease the pump diode current or increase the pulse repetition rate.

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). Again, see Figure 7-3 for an example of a circuit that can be used to control this function.

Monitoring Laser Status

Using the Indicator Outputs

Figure 7-4 shows an example of a circuit that can be used to turn one of three *Explorer* analog interface indicators on and off. 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 will indicate that the *Explorer* is emitting optical pulses).

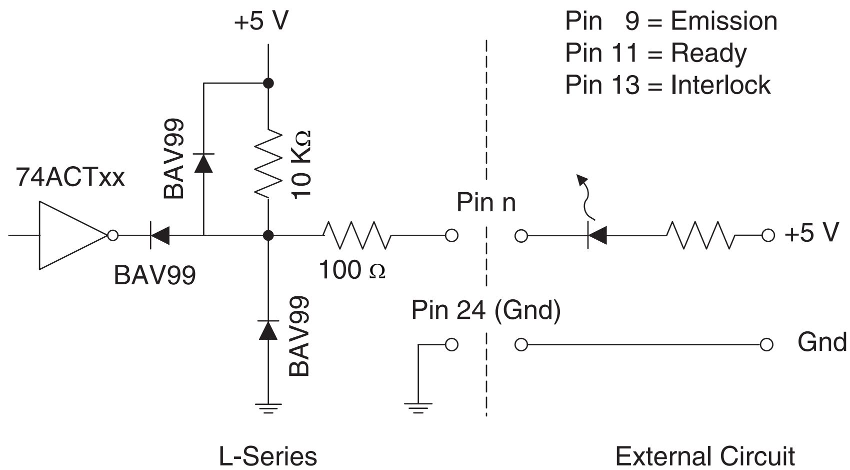


Figure 7-4: Laser Indicator Circuit Example

Note that pin 24 is the reference ground pin on the ANALOG IN connector and should be used with pins 9, 11 and 13.

Pulse Energy Monitor/Average Power Monitor

Figure 7-5 shows the circuit for the output signal at Pin 1 of the ANALOG IN port. Pin 1 provides a calibrated feedback signal from the power detector that is integrated into the laser head (see Table B-3). The resolution of the output signal is 12-bit, which corresponds to a maximum signal of 4.095 V. For the *EXPL-xxx-yyy-E* laser, 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. For the *EXPL-xxx-yyy-P* laser, average output power via pin 1 is refreshed about every 1 ms asynchronously to the optical pulses.

Note that pin 22 is the ground pin on the ANALOG IN connector that should be used with pin 1.

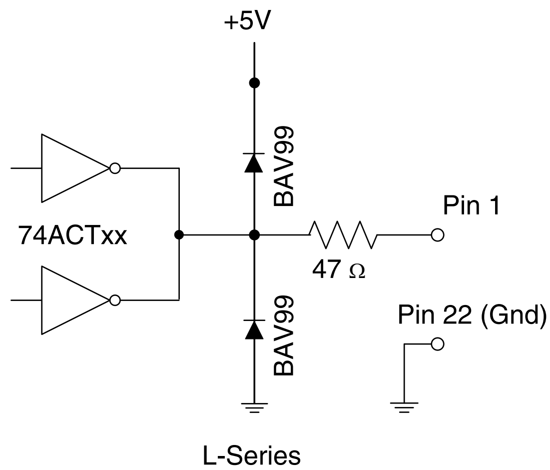


Figure 7-5: ***Pulse Energy/Average Output Power*** **Circuit**

External Sync

The *External Sync* output on pin 19 is synchronized to the internal Q-Switch trigger and can be used as a trigger pulse for synchronizing measurement equipment to the pulsed laser output. Figure 7-6 shows the circuit for the output signal at pin 19. The timing and jitter of the trigger signals is shown in Figure 7-7.

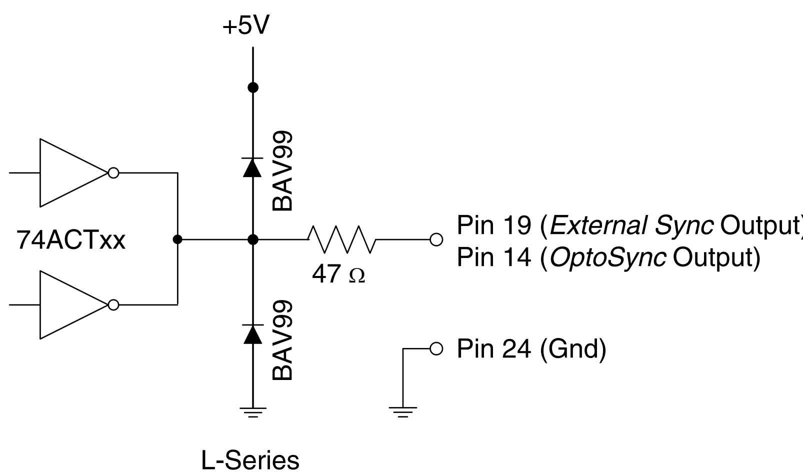


Figure 7-6: ***External Sync Out*** **and** ***OptoSync*** **Circuit**

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. Figure 7-6 shows the circuit for the output signal at pin 14. Figure 7-7 shows a timing chart. *OptoSync* triggering *follows* the laser pulse by about 30 to 100 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.

Danger! Laser Radiation

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!*

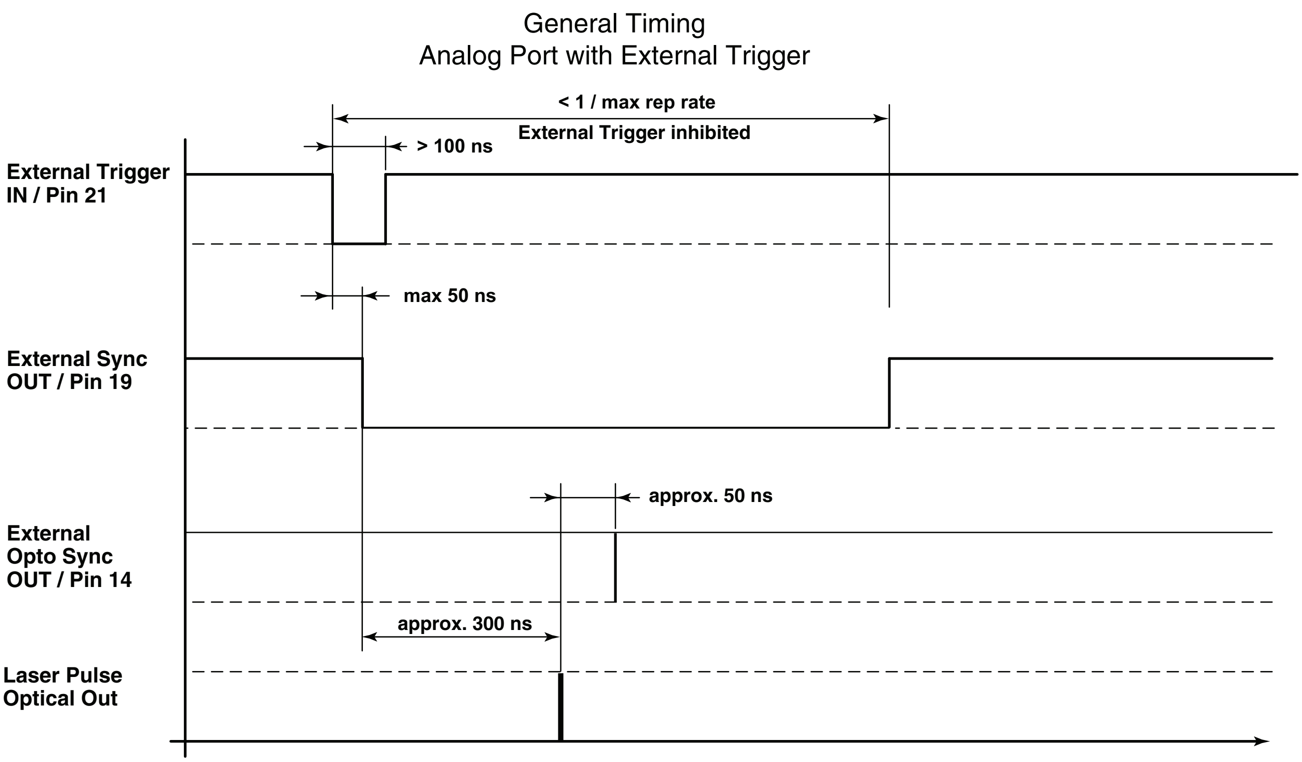


Figure 7-7: *Explorer* Trigger Timing

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 7-3 summarizes the two operating methods.

Table 7-3: Operating Mode Summary

Method A: Internal pulse trigger, external gating	
Advantage	Safe, fast gating; no optical output power during off time
Disadvantage	Additional user-supplied circuitry required to synchronized gating
Main commands	QSW:PRF <n>, n = repetition rate
Pin used	17

Method B: External pulse trigger, external gating	
Advantage	Easy set up; no optical output power during off time; fast repetition rate changes; optional synchronization
Disadvantage	Pulse clock has to be provided externally
Main commands	QSW:PRF 0 external trigger mode
Pins 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 signal 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 a TTL signal 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).

A timing diagram for Methods A and B is shown in Figure 7-8.

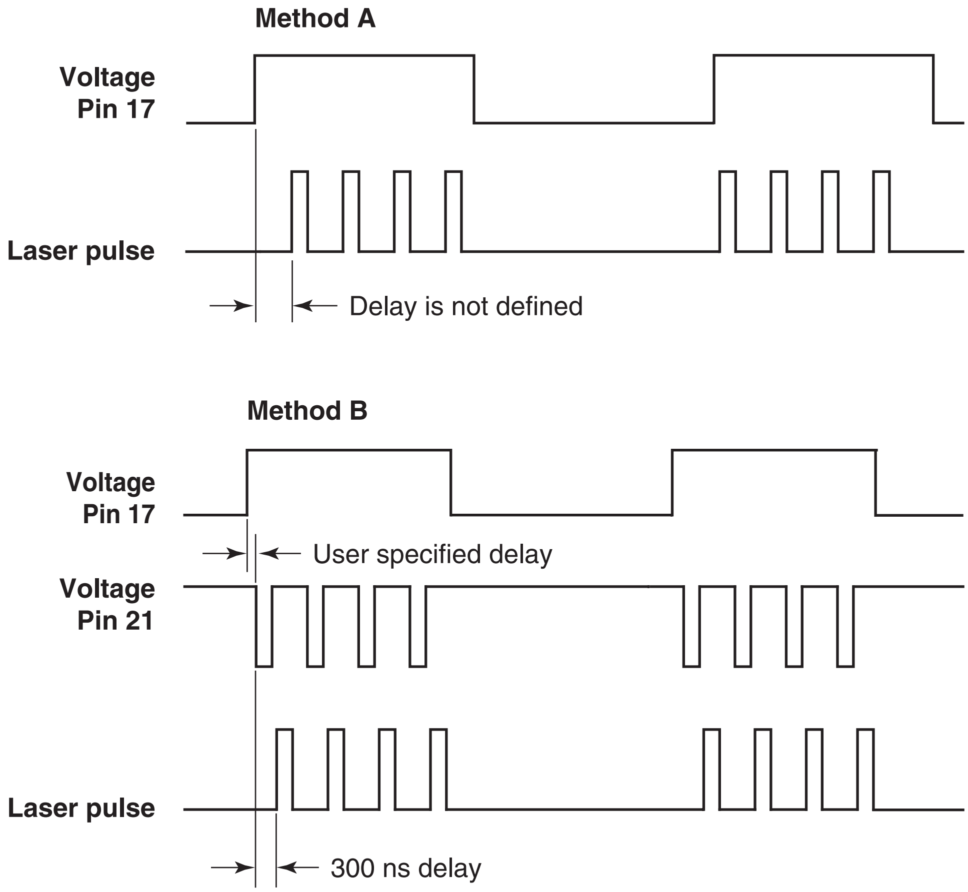


Figure 7-8: Timing Diagrams for Methods A and B

Advanced Control of the Pulsed Output

Figure 7-9 and Figure 7-10 illustrate the timing relationships using either Standby (pin 15) or Gate (pin 17) to control internal triggering. Figure 7-9 shows operation using FPS but not Burst mode, while Figure 7-10 shows operation using both FPS and Burst.

Gating

The laser output pulses can be shut off by pulling pin 17 low. Figure 7-3 shows an example circuit.

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

Burst Output

Burst mode timing is illustrated in Figure 7-10 on page 7-26.

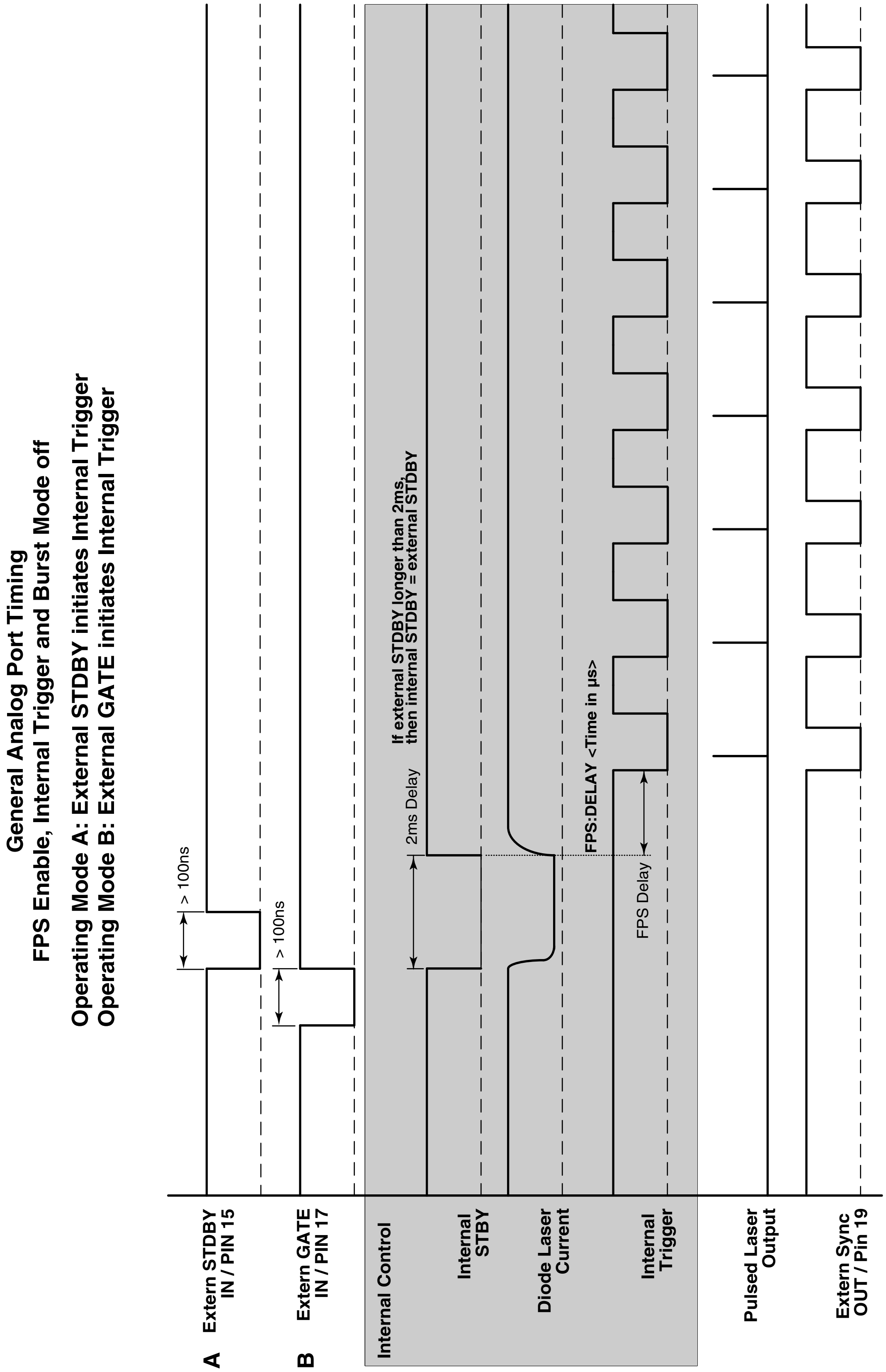


Figure 7-9: External Triggering with FPS and without Burst

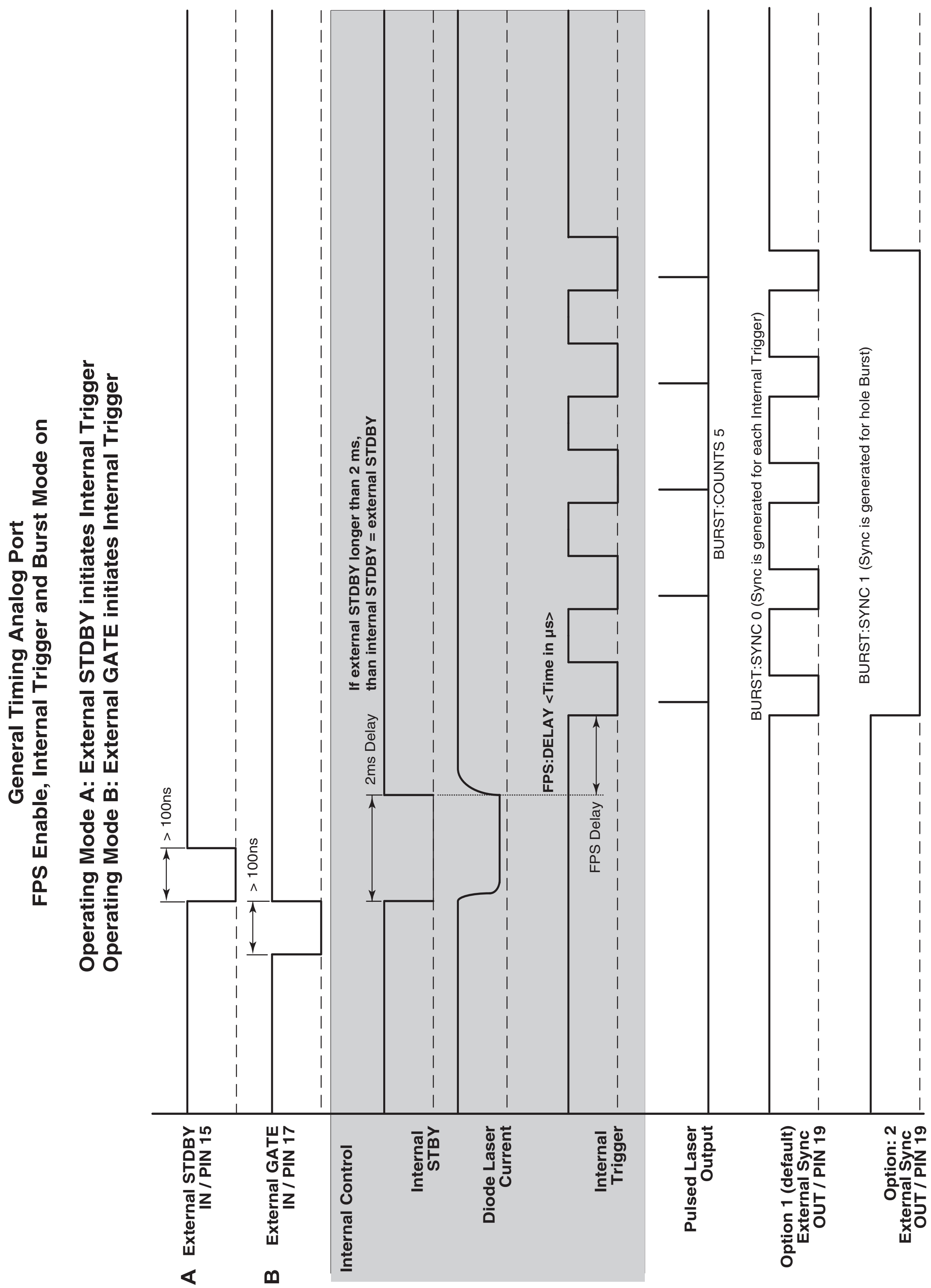


Figure 7-10: External Triggering with FPS and Burst

Chapter 8 Maintenance and Service

Danger! Laser Radiation

Eyewear Required

Spectra-Physics *Explorer* lasers are *Class IV—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 ultraviolet beam at 355 nm is invisible and is, therefore, especially dangerous.* Residual light at 1064 nm, 808 nm and 532 nm wavelengths might also be present.

Warning!

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 *Explorer* systems.

Troubleshooting

Any error that occurs will cause the ERROR indicator on the *L-Series* power supply to turn on. This troubleshooting guide is intended to assist 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

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

Symptom: Low power

Possible Causes	Corrective Action
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 base plate is properly heatsinked.
Reflected laser light is destabilizing the laser	Ensure that light reflected from any external optical elements does not directed back through the window of the laser head.
Nonlinear crystals require temperature optimization	Refer to the section "Setting the SHG and THG Temperatures" in Chapters 6 and 7.
Diode pump laser has reached its end of life	Contact your Spectra-Physics service representative.

Symptom: High optical noise

Possible Causes	Corrective Action
Laser head temperature is outside the operating range	Verify that the laser head base plate 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 the diode laser pump current.
Frequency is too low or pump diode current is too high	Increase the frequency or decrease the pump diode current.

Symptom: Bad transverse mode

Possible Causes	Corrective Action
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 base plate is properly heatsinked.
Nonlinear crystals require temperature optimization	Refer to the section "Setting the SHG and THG Temperatures" in Chapters 6 and 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 base plate is properly heatsinked.
Nonlinear crystals require temperature optimization	Refer to the section "Setting the SHG and THG Temperatures" in Chapters 6 and 7.
Frequency is too low or pump diode current is too high.	Increase the frequency or decrease the pump diode current.

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.

Removing and Cleaning the Output Window

Danger! Laser Radiation

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

If a significant amount of scattered laser 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 replaceable window that permanently seals the laser cavity. Solvents used for cleaning the outer window while it is still 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.

Warning!

Observe the following when removing the output window:

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

Tools required

- gloves
- 2 mm Allen key
- tweezers

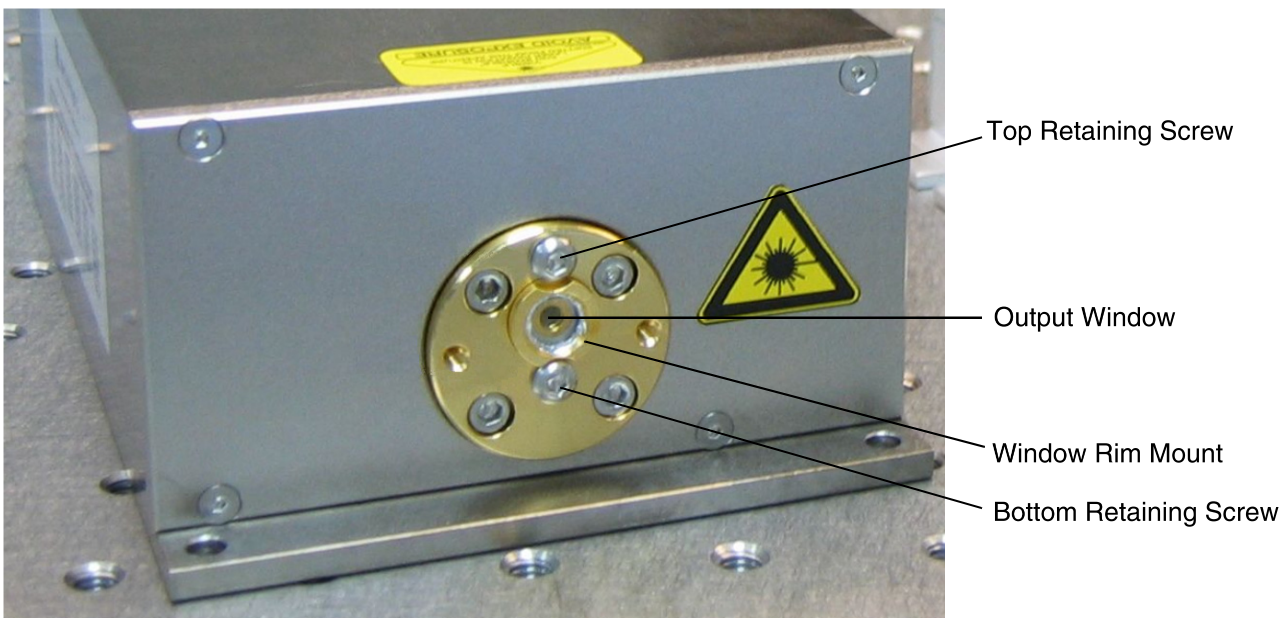


Figure 8-1: Output Window Assembly

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!*

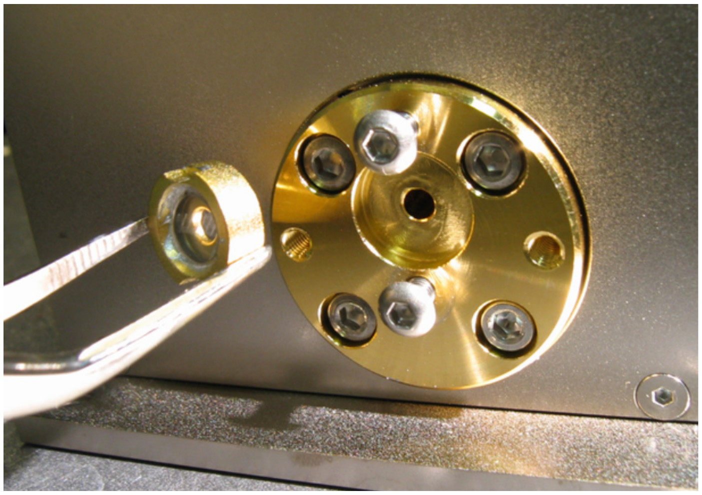


Figure 8-4: Remove the window assembly.

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 screw head gently touches the window mount (Figure 8-5). Make sure that the screw head 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* diode-pumped, Q-switched 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.

Warning! 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	
355 nm systems	EXPL-355-OW
532 nm systems	EXPL-532-OW
Cable – Laser head cable 1, 15-pin[1]	PS-L08-XX-HEAD1
Cable – Laser head cable 2, 26-pin[1]	PS-L08-XX-HEAD2
Explorer 355 nm DPSS Laser Head	
20 kHz – 60 kHz	ICT-355-300-E
20 kHz – 150 kHz	ICT-355-300-P
Explorer 532 nm DPSS Laser Head	
single-shot – 60 kHz	ICD-532-200-E
20 kHz – 60 kHz	ICD-532-1W-E
	ICD-532-2W-E
20 kHz – 150 kHz	ICD-532-1W-P
	ICD-532-2W-P
L-Series Power Supply, 8A, Extended Model	PS-L08

[1] *Where XX is 05 = 0.5 m, 10 = 1 m, 20 = 2 m and 50 = 5 m*

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.

Warning!

Equipment must be returned in the original shipping containers to secure instruments during shipment or the laser warranty is void. If shipping boxes have been lost or destroyed, new ones must be ordered. We can return instruments only in Spectra-Physics containers.

Service Centers

Belgium

Telephone: 0800-11 257
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China

Newport Corporation
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[1]*And all European and Middle Eastern countries not included on this list.*

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(800) 775-5273 (Sales) or
(408) 980-4300 (Operator)
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E-mail: service@spectra-physics.com
sales@spectra-physics.com
Web site: www.spectra-physics.com

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

Appendix A L-Win GUI Reference

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

L-Win Main Display

The *L-Win* Main display consists of:

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

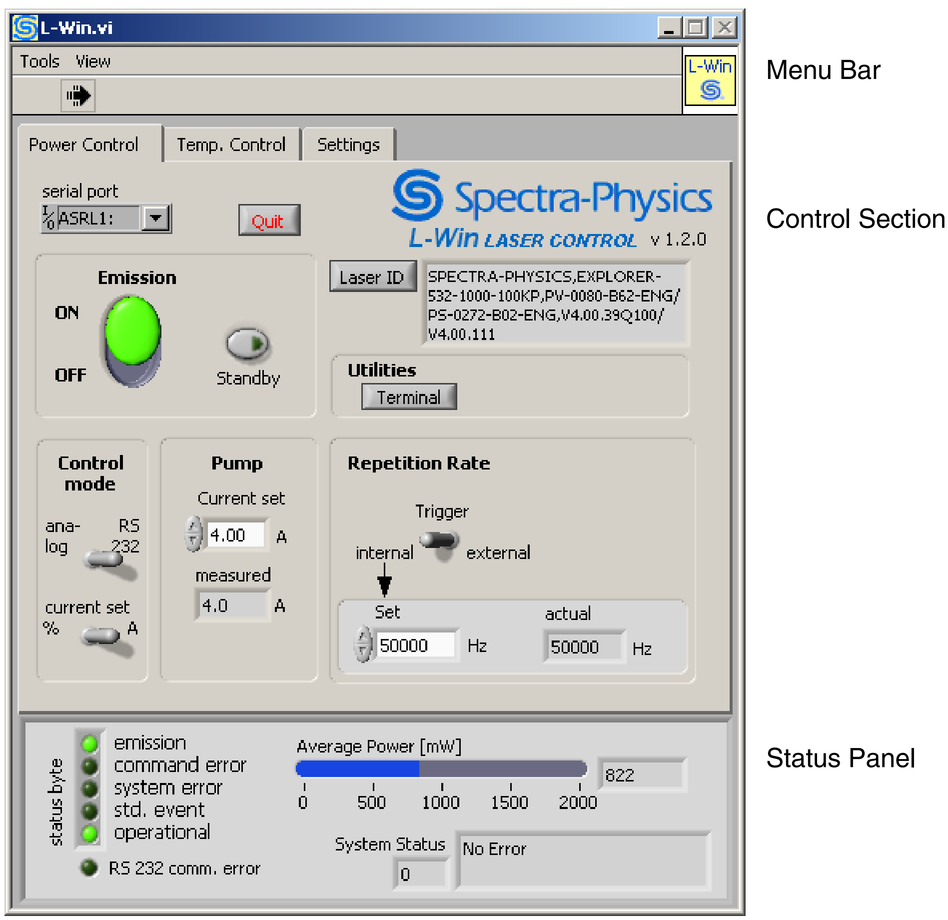

Figure A-1: *L-Win* Main Display

Status Panel

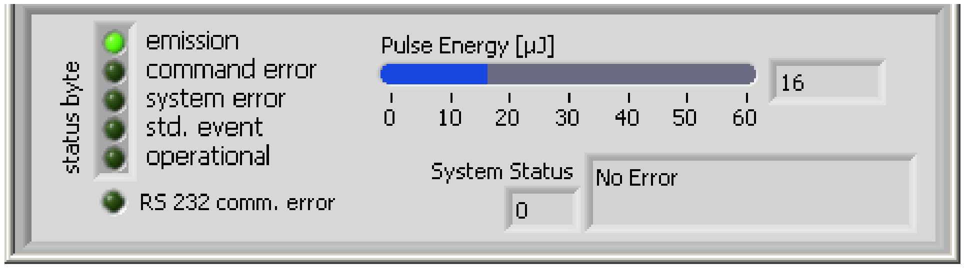

Figure A-2: Status Panel, Pulse Energy

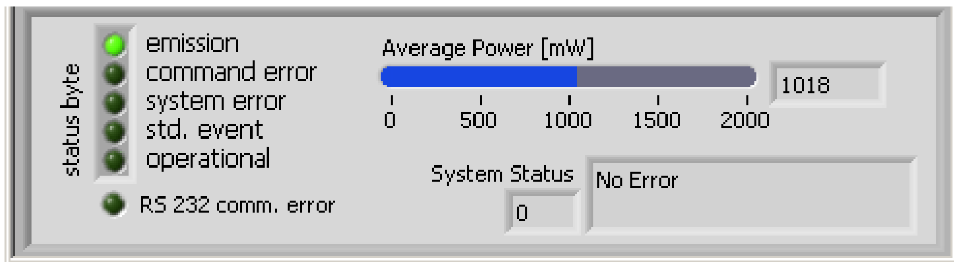

Figure A-3: Status Panel, Average Power

The Status Panel displays system status information. There are two possible editions, one for lower rep-rate systems that shows pulse energy (Figure A-2), and one for higher rep-rate systems that shows average output power (Figure A-3). 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—turns on when laser emission is present.

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

System error indicator—turns on when a system fault is detected, such as a temperature fault.

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

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

RS 232 comm. error indicator—turns on 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 µJ (low rep-rate systems only).

Average Power bar and number field—displays the internally measured average power in mW (higher rep-rate systems only).

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-8 for status codes.

Control Section

Power Control Tab Display

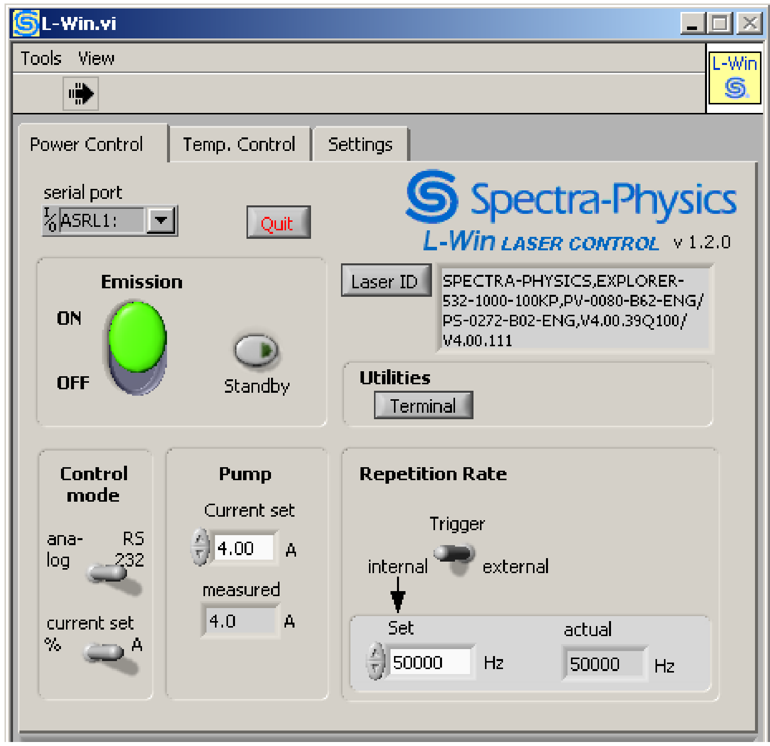

Figure A-4: Power Control Tab Display

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

Laser ID field—displays the laser identification string (serial query *IDN?) that 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.

Note

On most computer systems, the serial ports will be named ASRL1::INSTR, ASRL2:INSTR, etc., in the Serial Port field instead of COM1, COM2, etc.

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 button—provides a switch to turn the laser on and off. Click on it once to turn on the laser, and the Emission indicator turns green if no error is present. Actual emission will occur after a 3-second safety delay. Click on it again to turn the laser off immediately.

Standby button—sets the diode laser to standby current (which is below the threshold for lasing) and turns on the indicator (it turns yellow). Clicking this button again will return the laser to normal operation, and the indicator will turn off (it turns gray).

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 IN 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 (which is the value returned by DIOD1: MAXC?).

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 IN port).

Repetition Rate: Set/Actual fields—sets the pulse repetition frequency and displays the measured frequency when Internal Trigger mode is selected.

Temperature Control Tab Display

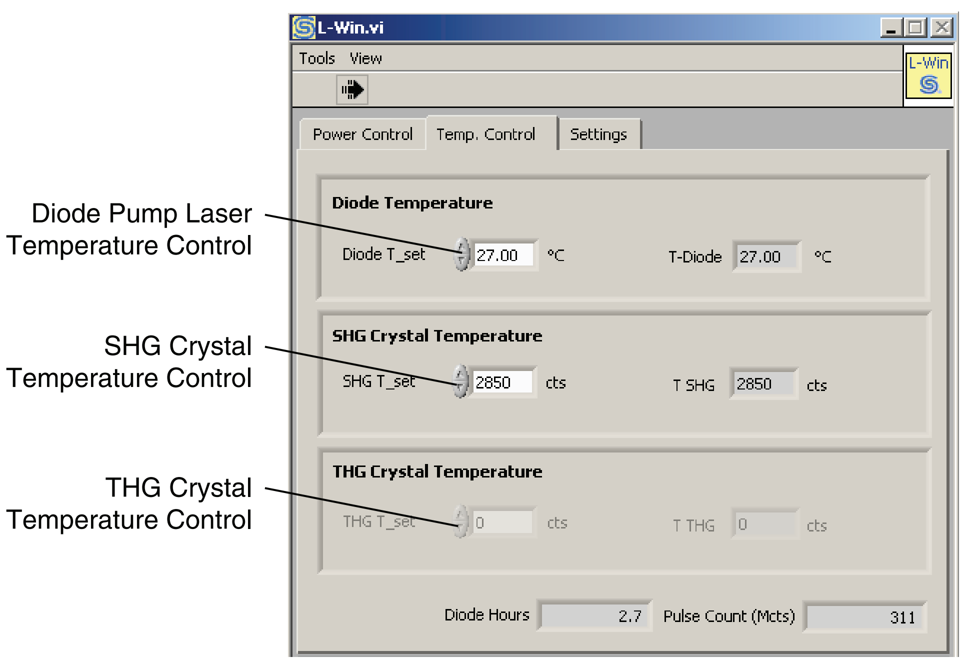

Figure A-5: Temperature Control Tab Display

The Temp Control tab display 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 constantly in a range of ±0.05°C and ±3 counts, respectively.

Depending on laser model, the THG crystal may not be available. When this is the case, the temperature controls are displayed with "0" and are greyed out as shown in Figure A-5.

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

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

THG temperature fields—provide a means to set the desired temperature of the third harmonic crystal and to 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 or Mcts) field—displays the total number of pulses, in thousands of pulses (kcts) for low rep-rate systems or millions of pulses for high rep-rate systems (Mcts), that the laser has emitted during its lifetime. The pulse counter is set to "0" prior to shipment.

Note: Upon GUI start-up, the system enters Standard mode where the set temperatures and the measured temperatures are displayed, but the temperatures cannot be changed. To change temperature settings, switch to Expert mode by selecting *View/GUI Mode* from the *L-Win* Main display (Figure A-6).

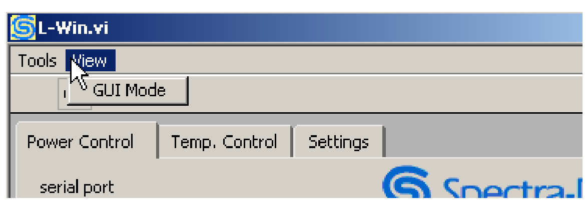

Figure A-6: Selecting the GUI Mode

Upon selecting "GUI Mode," a dialog box with a warning message appears (Figure A-7).

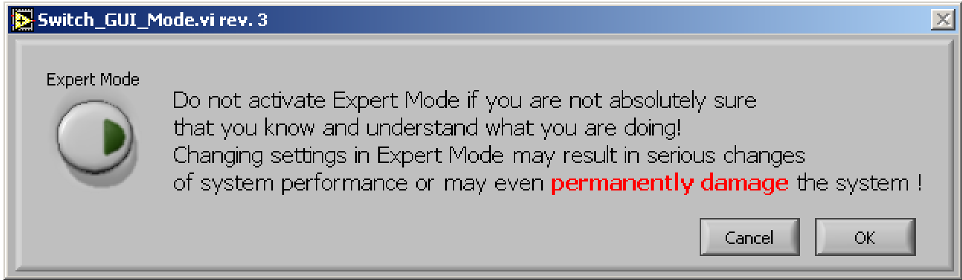

Figure A-7: Warning—Entering Expert Mode

To enter Expert mode, click on the EXPERT MODE button (it turns red) and confirm by clicking on OK. The temperature controls are now activated. To return to Standard mode, select *View/GUI Mode* again and click on the EXPERT MODE button once more (it turns black) or restart the *L-Win* software.

Before changing the diode laser temperature, record the present values for operating current and temperature, as well as the other laser parameters (output power, etc.), in the event they need to be restored later. To maintain the diode laser wavelength at its optimum value of 808 nm, make small adjustments to the diode laser temperature (in maximum increments of 10 counts), then wait a few seconds to see the effect the change has on pulse energy or average power before continuing.

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 set points by activating the preset "Factory 1."

Settings Tab Display

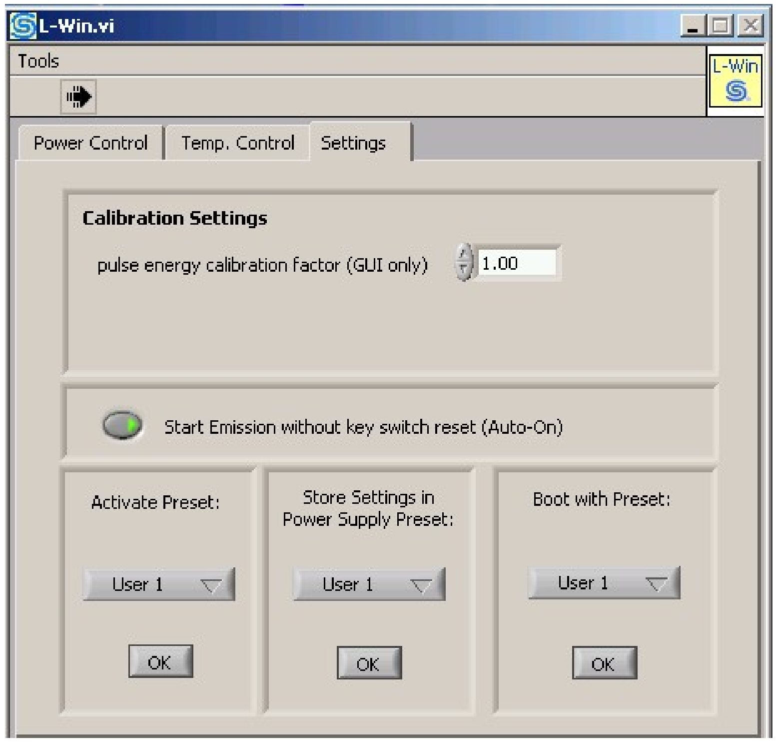

Figure A-8: Settings Tab Display

The Settings tab display has controls for setting, storing and loading system parameter sets, called “presets,” that are defined by the user or by 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 or average power 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? (READ:POW?). 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 button 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 cannot be changed, 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 the next time the laser system is turned on.

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

Menu Bar

Tools Menu

Depending on laser type, the tools menu looks different. For systems with average power measurement (Figure A-9), there are no “FPS/Burst setup” or “Pulse Noise Measurement” selections.

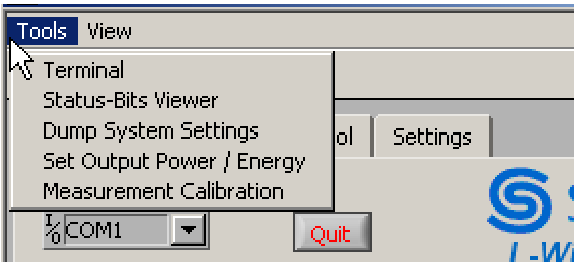

Figure A-9: Tools Menu, Average Power

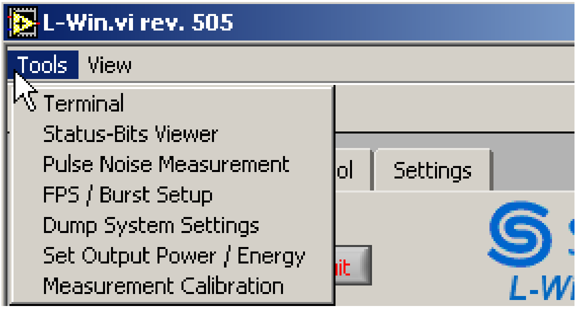

Figure A-10: Tools Menu, Pulse Energy

The Tools pull-down menu provides the following functions:

Terminal—opens a terminal emulation program window (see “Terminal Display” on page A-9) that 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.

Status-Bits Viewer—provides tools for troubleshooting the system by displaying various status and error bits of the system components. Refer to “Status Bits Viewer” on page A-11.

Pulse Noise Measurement—displays performance statistics, such as pulse-to-pulse stability. Refer to “Monitoring and Adjusting Performance” on page 6-6.

FPS/Burst Setup—allows adjustment and performance monitoring of the FPS and Burst mode settings. Refer to “FPS and Burst Control Display” on page A-14 and “Advanced Control of the Pulsed Output” on page 6-14.

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

Set Output Power/Energy—opens a new window where the output pulse power (high rep-rate systems) or average energy (low rep-rate systems) can be set. Refer to “Set Output Power/Energy” on page A-12.

Measurement Calibration—opens a new window where the output pulse power (high rep-rate systems) or average energy (low rep-rate systems) that is displayed on the Main menu can be calibrated against an external source. Refer to “Energy/Power Measurement Calibration” on page A-13.

Terminal Display

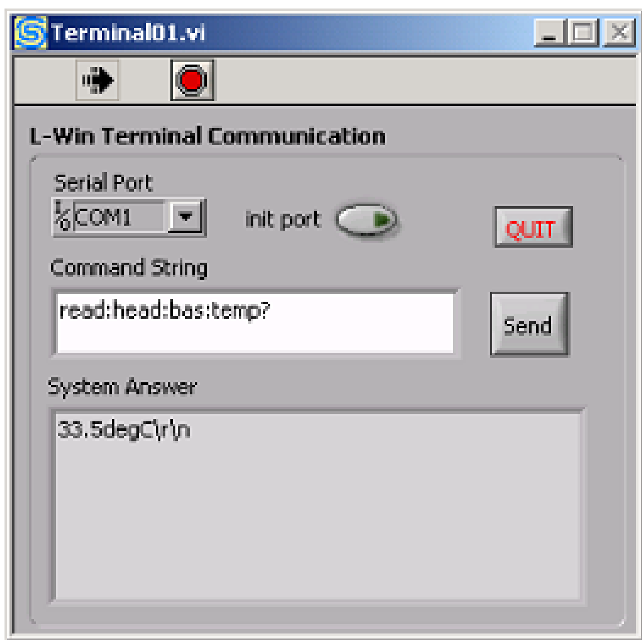

Figure A-11: Terminal Display

The Terminal display 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 as described in "Serial Communication" on page 7-2.

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

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.

init port button—initializes communication with the power supply. The indicator is "on" (red) 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 the operator to enter serial commands and queries.

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

System Answer field—displays a log of the system responses to the sent commands or queries.

Status Bits Viewer

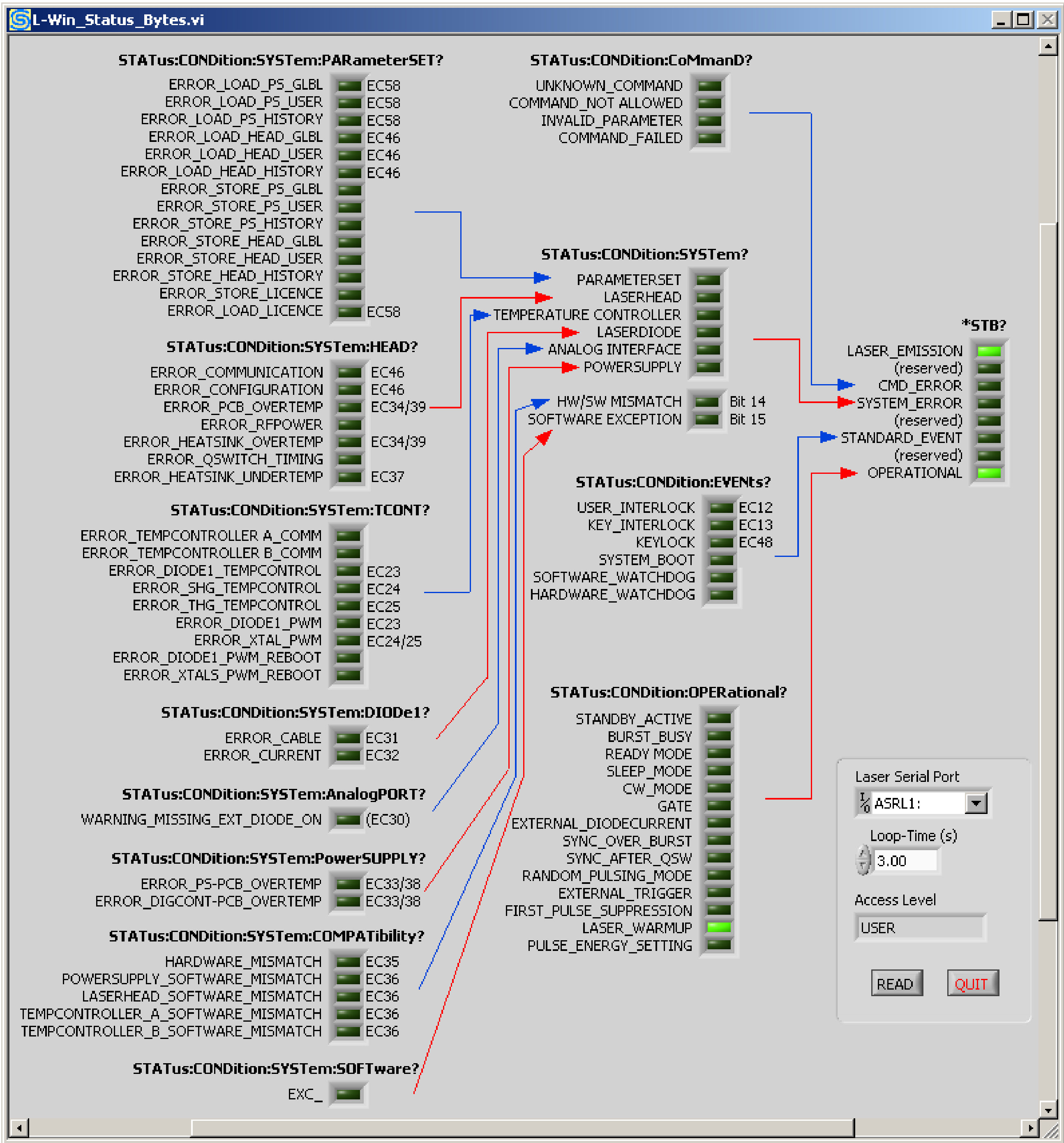

Figure A-12: Status and Error Display

The Status and Error display shows all the 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, the serial command to retrieve the corresponding information is shown.

Laser Serial Port field—shows the active serial port for communication with the system.

Loop Time field—sets the time interval to be used for automatic status inquiries. The default value is 3 seconds.

Access Level field—displays the active access security level.

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

QUIT button—closes the window.

Set Output Power/Energy

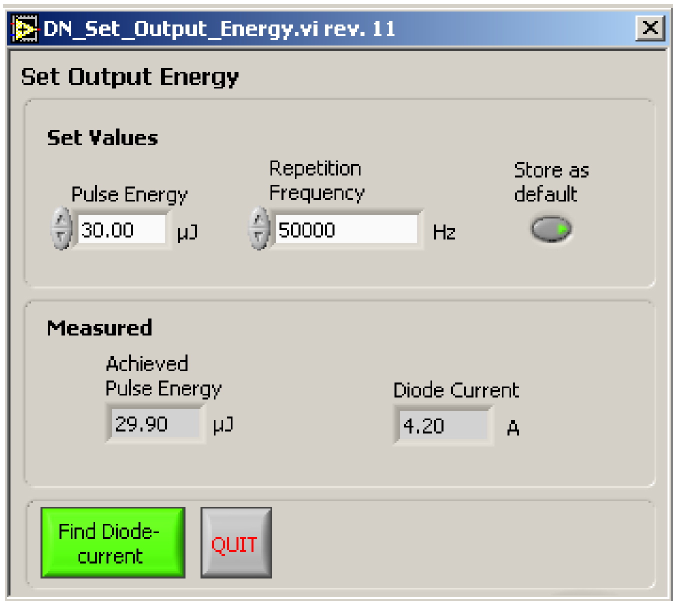

Figure A-13 Set Output Energy Display

This tool uses the command CONT:POW <n_1>,<n_2>,<n_3> or CONT:PENER <n_1>,<n_2>,<n_3> to set the average power or pulse energy output of the laser. Refer to the command description in Appendix B.

To use this tool:

1. Enter the set points for power/pulse energy and repetition frequency in the Set Values block.
2. Press the Store as default button if the new diode current setting is to be stored as the default for the first user parameter set User Set 1.
3. Press the Find Diode Current button to send the command to the laser system. The laser will search for the pump diode current required to achieve the desired output power/pulse energy. This may take 2 to 5 seconds.
4. The achieved power/pulse energy and the required diode current will be displayed in the Measured block.

In the event this process was not successful, an error message box will be displayed.

Energy/Power Measurement Calibration

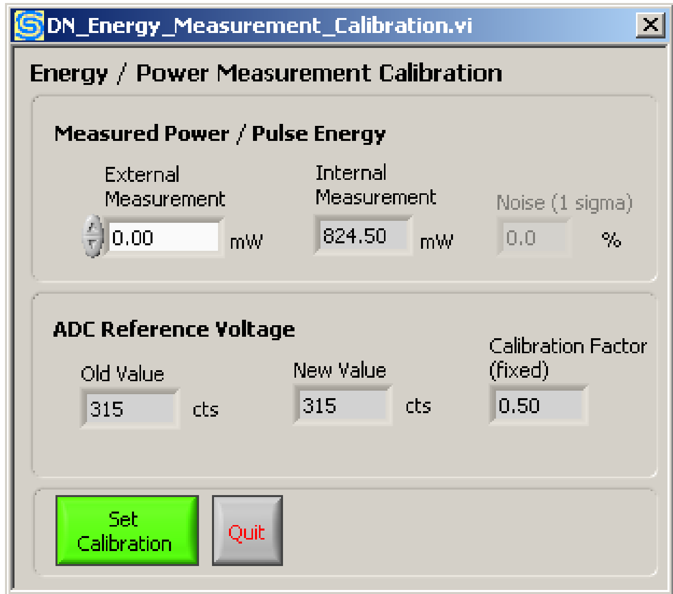

Figure A-14: Energy/Power Measurement Calibration Display

Use this tool to change the internal system calibration and, therefore, the power/energy readout via both the RS-232 serial port and the analog port voltage calibration on Pin 1. Do not confuse this tool with the GUI calibration factor on the Settings tab, which only calibrates the GUI power display.

External Measurement field—allows the user to enter the measured output power/pulse energy from an external, calibrated meter. After a value has been entered and the Set Calibration button is pressed, a new calibration reference voltage will be calculated (see below).

Internal Measurement display—shows the average power or pulse energy (averaged over ~100 pulses) as internally measured using the current calibration factor stored in the laser head.

Noise display—displays the pulse energy noise in a window (1 sigma value). Refer to “Pulse Noise Display” on page A-16. This display is only active on models with single pulse energy measurement (*EXPL-xxx-yyy-E* lasers).

ADC Reference voltage

Old Value display—shows the current reference voltage calibration value (in counts).

New Value display—shows the new reference voltage calibration that was calculated after the externally measured power/pulse energy was entered.

Calibration Factor (fixed) display—shows the internal calibration factor. This is variable is non-changeable for certain systems and is for Spectra-Physics use only.

Set Calibration button—allows the operator to activate the new reference voltage calibration (the calculated New Value). After pressing this button, the Old Value equals the New Value, and the value displayed as Internal Measurement should be the same as that shown in External Measurement.

Note The new calibration can be permanently stored in one of the user definable parameter sets (User Setting 1 or 2). The power/energy calibration is a global parameter that is the same for all parameter sets.

Quit button—quits the application and closes the window.

FPS and Burst Control Display

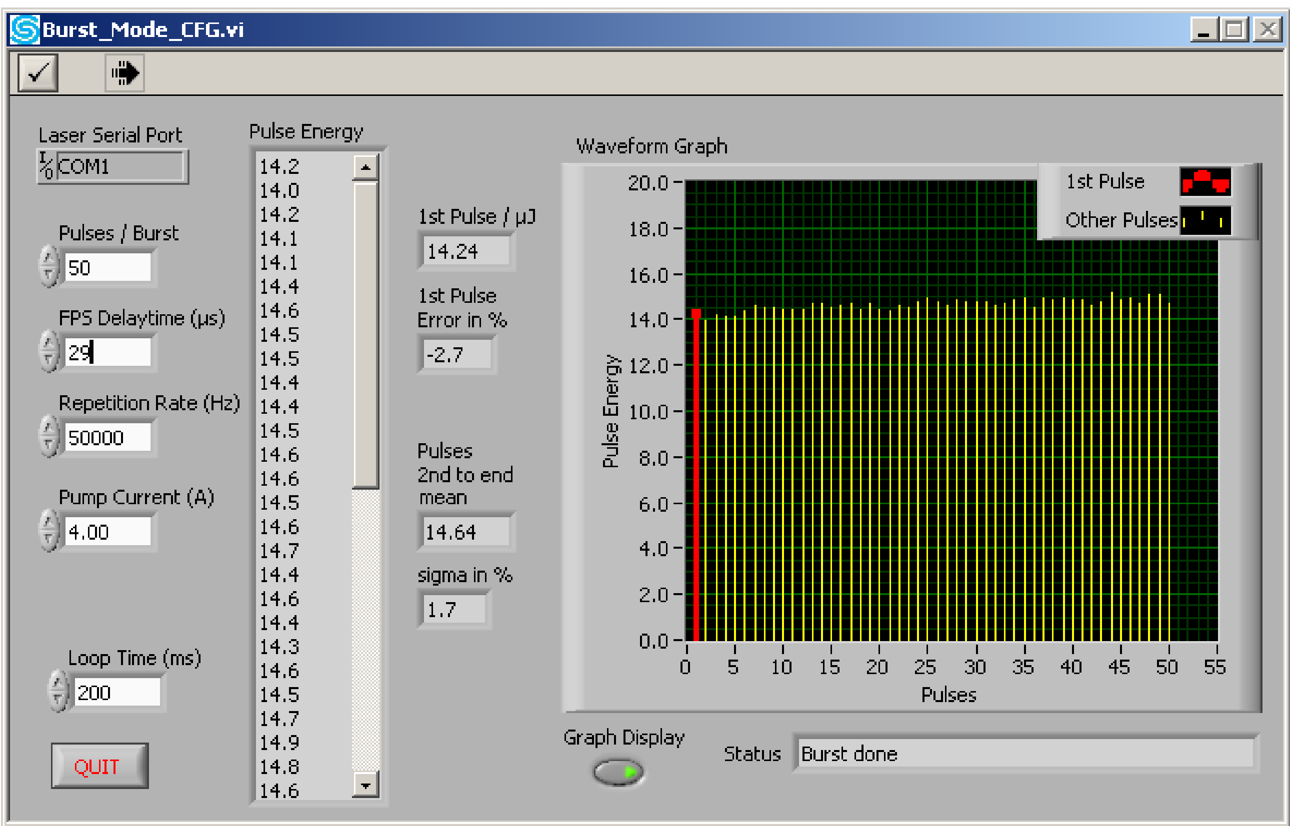

Figure A-15: FPS and Burst Control Display

The FPS and Burst Control display 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. Note: this display only applies to *EXPL-xxx-yyy-E* lasers.

Laser Serial Port field—shows the active serial port for communication with the system.

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

FPS Delay Time field—sets the FPS delay interval (in microseconds). 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 Hertz).

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

Status field—displays Burst mode status.

Loop Time field—sets the delay time between the end of one burst until the next burst command is sent to the system (in milliseconds).

For example, setting the interval to 200 ms will cause an interval of approximately 200 ms plus (number of pulses per burst times the 1/ pulse repetition frequency) between two bursts. Please note that the interval between two bursts is not very precise because the system status is polled via RS232 commands. For more precise burst timing, use TTL triggering on the ANALOG IN port or, for less precision, use the BURST command via RS232 using a well-defined software timing loop.

STOP button—closes the window.

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

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—displays the 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 Display

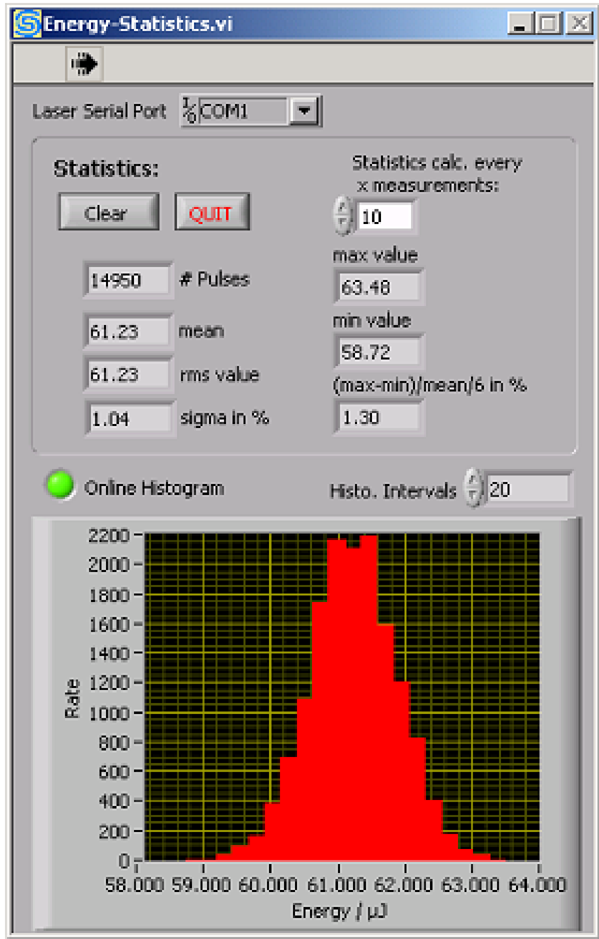

Figure A-16: Pulse Noise Display

The Pulse Noise display 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. Note: this display only applies to *EXPL-xxx-yyy-E* lasers.

Used concurrently with this display, the *L-Win* Main display can be used to improve performance by adjusting operational parameters such as diode laser current and repetition rate.

Laser Serial Port field—shows the active serial port for communication with the system.

Clear button—clears all data fields.

QUIT button—closes the display.

 # 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 that of the first pulse.

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

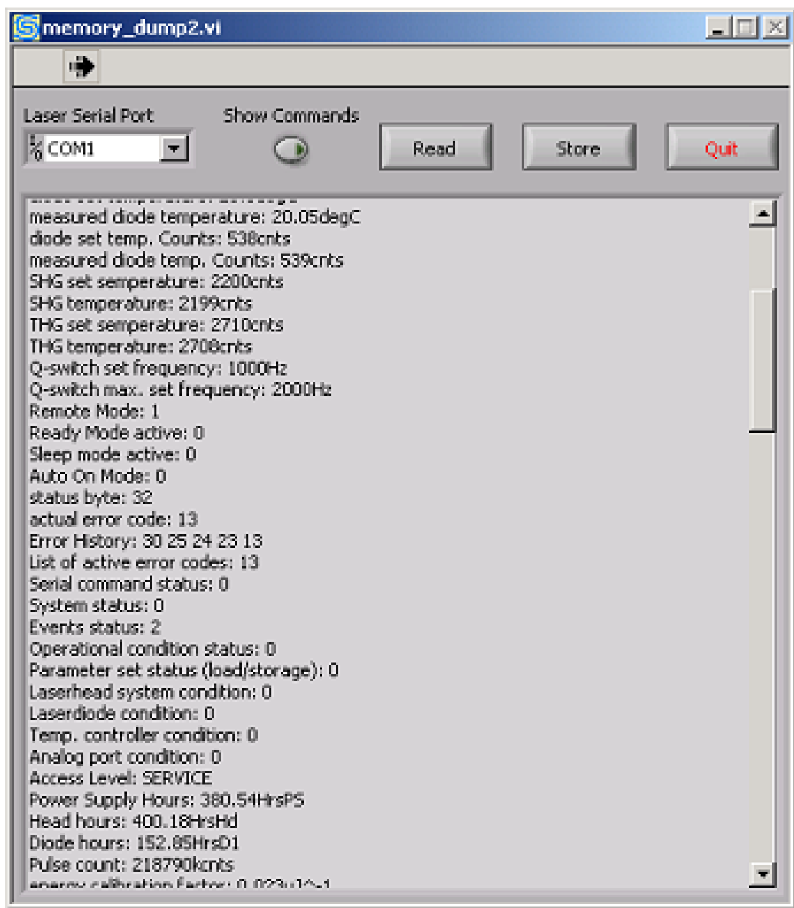

Figure A-17: System Settings Summary

The System Settings Summary display 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. Please note that some queries will be answered by “?” because not all parameters are accessible in user mode.

Appendix B Explorer Programming Guide

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 <CR> and line feed <LF>.

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 appendix contains the following sections:

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

System Identification and General Setup

*IDN?

This command returns the product identification string.
Returned 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-532-1000-100KP,PL-0332-02/PS-0129-01,V4.00.44/V4.01.154<CR><LF>

If the laser head communication fails:
SPECTRA-PHYSICS, EXPLORER-532-1000-100KP,XXXXXXX/PS-0129-01,-999V4.01.154< CR><LF>

MODE:RMT <n> MODE:RMT?

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:RMT 1<CR>
Places the system in Computer mode, and the laser is turned on by sending the ON command while the power supply key switch is in the ON position.
→MODE:RMT 0<CR>
Places the system in Local (analog) mode, and the laser is turned on by turning the key switch to the ON position or by processing the EXTERNAL_DIODE_ON line of the analog interface.
→MODE:RMT?<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 (i.e., 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 (i.e., 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> (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.)

Laser Operation

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

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).

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" 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)

Diode Current

DIOD1:CURR <f>
DIOD1:CURR?

This command sets the diode laser current in Amps.
0 < f < maximum diode laser current value, in Amps (i.e., the value returned by DIOD1:MAXC?), in the form xx.xx. Commands with values outside this range are rejected.

Examples:
→DIOD1:CURR 4.56<CR> (Set the diode laser current to 4.56 Amps.)
←<CR><LF>

→DIOD1:CURR?<CR>
←4.56A1<CR><LF> (The diode laser current has been set to 4.56 Amps.)

READ:DIOD1:CURR?

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

Example:
→READ:DIOD1:CURR?<CR>
←4.56A1<CR><LF>

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 DIOD1:MAXC?
Unit: %1

Examples:
→PCUR 34.6<CR>
←<CR><LF>

→PCUR?<CR>
←34.6%1<CR><LF>

READ:PCUR? <n>

This command reads the actual diode laser current in % of the diode current limit.
Unit: %1

Example:
→READ:PCUR?<CR>
←67.6%1<CR><LF>

DIOD1:STANDBYC?

This command reads the diode laser standby current in Amps.

Example:
→DIOD1:STANDBYC?<CR>
←0.5A1<CR><LF>

DIOD1:MAXC?

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

Example:
→DIOD1: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.
$100 \leq n \leq 4000$
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.
$100 \leq n \leq 4000$
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>

DIOD1:TEMP <f> DIOD1:TEMP?

This command sets the diode laser temperature in degrees C.
18.0 <= f <= 38.0
Unit: degC

Examples:
→DIOD1:TEMP 29.2<CR>
←<CR><LF>

→DIOD1:TEMP?<CR>
←29.2degC<CR><LF>

READ:DIOD1:TEMP?

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

Example:
→READ:DIOD1:TEMP?<CR>
←29.2degC<CR><LF>

Q-Switch Repetition Rate

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

Table B-3: lists the PRF range for the Explorer models.

Examples:
→QSW:PRF 50000<CR> (Set the pulse frequency to 50000 Hz.)
←<CR><LF>

→QSW:PRF?<CR>
←50000Hz<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
Table B-3: lists the maximum pulse repetition frequencies for the Explorer models.

Examples:
→QSW:PRF:MAX?<CR>
←60000Hz<CR><LF>

QSW:PRF:MIN?

This command reads the minimum pulse repetition frequency.
Unit: Hz
Table B-3: lists the minimum pulse repetition frequencies for the Explorer models.

Example:
→ QSW:PRF:MIN?<CR>
← 20000Hz<CR><LF

Pulse Counts and Operating Hours

READ:QSW:CNTS?

This command reads the pulse counter in kilocounts or megacounts (depending on *Explorer* model).
Unit: kcnts or mcnts

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

READ:HEAD:HOUR?

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:HOUR?<CR>
←456.2HrsHd<CR><LF> (The laser head has been supplied with power for 456.2 hours.)

READ:PSUPPLY:HOUR?

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

READ:DIOD1: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.
Unit: HrsD1

Example:
→READ:DIOD1:HOUR?<CR>
←234.8HrsD1<CR><LF> (The diode laser has been operated for 234.8 hours).)

Analog Interface

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

This command sets the polarity of the analog interface lines (refer to Table B-5:).

Range <n>: 0 – 511

Individual bit position = 1: line is high active (rising edge)
Individual bit position = 0: line is low active (falling edge) (default)

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

→CONFIG:APORT:POLAR? <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)

Pulse Energy

(Commands related to pulse energy are only valid for EXPL-xxx-yyy-E models.)

READ:PENER?

This command reads the actual pulse energy in µJ.
Unit: µJ

Example:
→READ:PENER?<CR>
←21µJ<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 µJ may be calculated by multiplying by 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.)

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: µJ/cnt

Example:
→PENER:CALF?<CR>
← 0.5234µJ/cnt<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>

CONT:PENER <n_1>,<n_2>,<n_3>

This command starts an automatic pulse energy adjustment. The setting procedure lasts about 10 seconds.

<n_1> requested pulse energy, in µJ (The range of <n_1> depends on the Explorer model. See Table B-3:).

<n_2> pulse repetition rate (PRF) for which the adjustment is to be executed (see Table B-3: for the valid PRF range).

<n_3> determines if the automatically adjusted parameters are stored or not after completion of the setting procedure.
n = 0: The diode laser current is set to the adjusted current but not saved to the internal EEPROM. These settings can be manually stored by the user (CONFIG:PARSET:STOR <n>). This requires that the laser emission is disabled.
n = 1 or n = 2: The settings are automatically stored in the user set #1 or #2, respectively.

Note 1: The command is rejected if the laser is not switched on. During the adjustment procedure, queries about the diode current, pulse repetition frequency and temperatures are not valid.

Note 2: During the adjustment procedure, the status may be queried using the command STAT:COND:OPER? and checking if bit 13 (“Power setting”) is activated.

CONT:PENER 0	stops a launched adjustment procedure

Examples:

→CONT:PENER 20,50000,1<CR>	Request to set the pulse energy to 20 µJ@50kHz. After completion, the found parameters (diode current) are stored in the user parameter set #1.
←<CR><LF>	
→CONT:PENER 10,50000,1<CR> ←?<CR><LF>	Request to set the pulse energy to 10 µJ@50kHz. The request was denied because 10 µJ is outside the valid laser pulse energy range.

CONT:PENER?

This command reads the result of an automatic pulse energy adjustment.

Response:
<f>,<n>: determined diode current (in Amps), adjusted pulse energy (in µJ)
If the adjustment procedure failed, the command returns “?”.

Example:
→CONT:PENER?<CR>
←1.93A1,20µJ<CR><LF

Laser Power

(Commands related to laser power are valid for EXPL-xxx-yyy-P models only.)

READ:POW?

This command reads the actual laser power, in mW (EXPL-xxx-yyy-P models only).
Unit: mW

Example:
→ READ:POW?<CR>
← 500mW<CR><LF>

POW:CALF?

This command reads the calibration factor which is used to convert the laser power ADC counts (0 – 1023) to the displayed milliwatt values. The calibration factor is set at the factory.
Unit: mW/cnt

Example:
→POW:CALF?<CR>
←0.044mW/cnt<CR><LF>

POW:REFVOLT:CNTS <n>
POW:REFVOLT:CNTS?

This command modifies the reference voltage of the laser power ADC. It may be used to re-calibrate the displayed power to match the values read at the user's power meter. Higher reference voltage counts result in lower power values.
Range <n>: 200 – 1023
Unit: cnts

Example:
→POW:REFVOLT:CNTS 456<CR>
←<CR><LF>
→POW:REFVOLT:CNTS?<CR>
←456cnts<CR><LF>

CONT:POW <n_1>,<n_2>,<n_3>

This command starts an automatic laser power adjustment. The setting procedure lasts about 10 seconds.
<n_1>: requested laser power, in mW (the range of <n_1> depends on the Explorer model. See Table B-3:).
<n_2>: pulse repetition rate (PRF) for which the adjustment is to be executed (the range of <n_2> depends on the Explorer model. See Table B-3:).
<n_3>: determines if the automatically adjusted parameters are stored or not after completion of the setting procedure.
n=0: The diode laser current is set to the adjusted current but is not saved to the internal EEPROM. These settings can be manually stored by the user (CONFIG:PARSET:STOR <n>). This requires that the laser emission is disabled.
n=1 or n=2: The settings are automatically stored in user set #1 or #2, respectively.

Note 1: The command is rejected if the laser is not switched on. During the adjustment procedure, queries about the diode current, pulse repetition frequency and temperatures are not valid.

Note 2: During the adjustment procedure, the status may be queried using the command STAT:COND:OPER? and checking if bit 13 ("Power setting") is activated.

CONT:POW 0 — stops a launched adjustment procedure.

Examples:

→CONT:POW 50,20000,1<CR>	Request to set the laser power to 50 mW@20kHz. After completion, the found parameters (diode current) are stored in the user parameter set #1.
←<CR><LF>	
→CONT:POW 5,20000,1<CR>	Request to set the laser power to 5 mW@20kHz
←?<CR><LF>	Request is denied because 5 mW is outside the valid laser power adjustment range.

CONT:POW?

This command reads the result of an automatic laser power energy adjustment.
Response:
<f>,<n>: determined diode current (in Amps), adjusted laser power (in mW)
If the adjustment procedure failed, the command returns “?”.

Example:
→CONT:POW?<CR>
←1.93A,50mW<CR><LF

Data Administration

CONFIG:PARSET:STOR <n>

This command stores actual parameters as parameter set #<n> (refer to Table B-7: User Parameters).

Range <n>:
- n = 1: user parameter set #1
- n = 2: user parameter set #2

Example:
→CONFIG:PARSET:STOR 1<CR>
←<CR><LF>

CONFIG:PARSET:LOAD <n>

This command loads parameter set #<n> (refer to Table B-7: 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:ACT?

This command reads the active parameter set number (refer to Table B-7: 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-7: 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

Examples:
→CONFIG:PARSET:BOOT 1<CR>
←<CR><LF>

→CONFIG:PARSET:BOOT?<CR>
←1<CR><LF>

Status and Error Reporting

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:LIST?

This command reads a string of up to 16 status codes which are currently active (refer to Table C-3). 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). 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).

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).

Example:
→STAT:COND:CMD?<CR>
←0<CR><LF> (The last command was successfully completed.)

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: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: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:DIOD1?

This command reads diode laser status (refer to Table C-2).

Example:
→STAT:COND:SYST:DIOD1?<CR>
←2<CR><LF> (Diode laser current control error.)

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.)

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.)

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>
←8<CR><LF> (System is in SLEEP mode.)

Power Saving Modes

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>

Laser Head Temperature Control

HEAD:BAS:TEMP:MAX?

This indicates the warning level of the laser head base plate temperature in degrees C. An over-temperature warning will be issued if the temperature rises above this maximum, and a safety shutdown occurs if the temperature rises 5°C above the warning level.

Example:
→HEAD:BAS:TEMP:MAX? <CR>
←40degC<CR><LF>

READ:HEAD:BAS:TEMP?

This command reads the temperature of the laser head base plate in degrees C.
Unit: degC

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 either to Control mode, where the base plate temperature is regulated to the adjusted set point (refer to command HEAD:FANCONT:TEMP <f>), or to Drive mode, which provides a 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: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: degC
Range <f>: 18.0 degC ≤ f ≤ 34.0 degC

Examples:
→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. 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% (6.5 Volt).)
←<CR><LF>

→HEAD:FANCONT:PVOLT?<CR>
←50%<CR><LF>

HEAD:FANCONT:SPEED?

This command may be used to check to proper operation of the fan control. It returns the actual fan speed (in counts, range: 200 – 1023 counts).

Example:
→ HEAD:FANCONT:SPEED?<CR>
← 456cnts<CR><LF>

First Pulse Suppression (FPS)

FPS:DELAY <n>
FPS:DELAY?

This command sets the FPS delay time to <n> µsec.
Unit: µsec
Range <n>: $0 \leq n \leq 2000$
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>

Burst Mode

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>: $0 \leq n \leq 4000$
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>
→BURST:SYNC 1<CR> (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:RMT 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>

Table B-2: Serial Commands and Queries (listed alphabetically)

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:RMT 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>: $0 \leq n \leq 4000$
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:APORT:POLAR <n>
CONFIG:APORT:POLAR?

This command sets the polarity of the analog interface lines (refer to Table B-5:).
Range <n>: 0 – 511
Individual bit position = 1: line is high-active (rising edge)
Individual bit position = 0: line is low-active (falling edge) (default)

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

→CONFIG:APORT:POLAR? <CR>
←96<CR><LF>

CONFIG:PARSET:ACT?

This command reads the active parameter set number (refer to Table B-7: 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-7: 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

Examples:
→CONFIG:PARSET:BOOT 1<CR>
←<CR><LF>

→CONFIG:PARSET:BOOT?<CR>
←1<CR><LF>

CONFIG:PARSET:LOAD <n>

This command loads parameter set #<n> (refer to Table B-7: 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:LOAD 1<CR>
←<CR><LF>

CONFIG:PARSET:STOR <n>

This command stores actual parameters as parameter set #<n> (refer to Table B-7: User Parameters).
Range <n>: 1 – 2
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 (i.e., 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 (i.e., turning the key OFF and ON) is necessary to start laser emission with the ON command.

CONT:PENER <n_1>,<n_2>,<n_3>

This command starts an automatic pulse energy adjustment. The setting procedure lasts about 10 seconds.
<n_1> requested pulse energy, in µJ (The range of <n_1> depends on the Explorer model. See Table B-3:).
<n_2> pulse repetition rate (PRF) for which the adjustment is to be executed (see Table B-3: for the valid PRF range).
<n_3> determines if the automatically adjusted parameters are stored or not after completion of the setting procedure.
n = 0: The diode laser current is set to the adjusted current but not saved to the internal EEPROM. These settings can be manually stored by the user (CONFIG:PARSET:STOR <n>). This requires that the laser emission is disabled.
n = 1 or n = 2: The settings are automatically stored in the user set #1 or #2, respectively.

Note 1: The command is rejected if the laser is not switched on. During the adjustment procedure, queries about the diode current, pulse repetition frequency and temperatures are not valid.

Note 2: During the adjustment procedure, the status may be queried using the command STAT:COND:OPER? and checking if bit 13 (“Power setting”) is activated.

CONT:PENER 0 stops a launched adjustment procedure

Examples:
→CONT:PENER 20,50000,1<CR> Request to set the pulse energy to 20 µJ@50kHz. After completion, the found parameters (diode current) are stored in the user parameter set #1.
←<CR><LF>
→CONT:PENER 10,50000,1<CR> Request to set the pulse energy to 10 µJ@50kHz.
←?<CR><LF> The request was denied because 10 µJ is outside the valid laser power adjustment range.

CONT:PENER?

This command reads the result of an automatic pulse energy adjustment.

Response:
<f>,<n>: determined diode current (in Amps), adjusted pulse energy (in µJ)
If the adjustment procedure failed, the command returns "?".

Example:
→CONT:PENER?<CR>
←1.93A1,20µJ<CR><LF

CONT:POW <n1>,<n2>,<n3>

This command starts an automatic laser power adjustment. The setting procedure lasts about 10 seconds.
<n1>: requested laser power, in mW (the range of <n1> depends on the Explorer model. See Table B-3:).
<n2>: pulse repetition rate (PRF) for which the adjustment is to be executed (the range of <n2> depends on the Explorer model. See Table B-3:).
<n3>: determines if the automatically adjusted parameters are stored or not after completion of the setting procedure.
N = 0: The diode laser current is set to the adjusted current but is not saved to the internal EEPROM. These settings can be manually stored by the user (CONFIG:PARSET:STOR <n>). This requires that the laser emission is disabled.
n = 1 or n = 2: The settings are automatically stored in user set #1 or #2, respectively.

Note 1: The command is rejected if the laser is not switched on. During the adjustment procedure, queries about the diode current, pulse repetition frequency and temperatures are not valid.

Note 2: During the adjustment procedure, the status may be queried using the command STAT:COND:OPER? and checking if bit 13 ("Power setting") is activated.

CONT:POW 0	stops a launched adjustment procedure.

Examples:

→CONT:POW 50,20000,1<CR>	Request to set the laser power to 50 mW@20kHz. After completion, the found parameters (diode current) are stored in the user parameter set #1.
←<CR><LF>	
→CONT:POW 5,20000,1<CR>	Request to set the laser power to 5 mW@20kHz
←?<CR><LF>	Request is denied because 5 mW is outside the valid laser power adjustment range.

CONT:POW?

This command reads the result of an automatic laser power energy adjustment.
Response:
<f>,<n>: determined diode current (in Amps), adjusted laser power (in mW)
If the adjustment procedure failed, the command returns "?".

Example:
→CONT:POW?<CR>
←1.93A,50mW<CR><LF

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>

DIOD1:CURR <f>
DIOD1:CURR?

This command sets the diode laser current in Amps.

0 < f < maximum diode laser current value, in Amps (i.e., the value returned by DIOD1:MAXC?), in the form xx.xx. Commands with values outside this range are rejected.

Examples:
→DIOD1:CURR 4.56<CR> (Set the diode laser current to 4.56 Amps.)
←<CR><LF>

→DIOD1:CURR?<CR>
←4.56A1<CR><LF> (The diode laser current has been set to 4.56 Amps.)

DIOD1:MAXC?

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

Example:
→DIOD1:MAXC?<CR>
←5.5A1<CR><LF>

DIOD1:STANDBYC?

This command reads the diode laser standby current in Amps.

Example:
→DIOD1:STANDBYC?<CR>
←0.5A1<CR><LF>

DIOD1:TEMP <f>
DIOD1:TEMP?

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

Examples:
→DIOD1:TEMP 29.2<CR>
←<CR><LF>

→DIOD1:TEMP?<CR>
←29.2degC<CR><LF>

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> (Set FPS delay is 678 µsec.)
←<CR><LF>

→FPS:DELAY?<CR>
←678usec<CR><LF>

→FPS:DELAY 0<CR> (Disable FPS.)
←<CR><LF>

HEAD:BAS:TEMP:MAX?

This indicates the warning level of the laser head base plate temperature in degrees C. An over-temperature warning will be issued if the temperature rises above this maximum, and a safety shutdown occurs if the temperature rises 5°C above the warning level.

Example:
→HEAD:BAS:TEMP:MAX? <CR>
←40degC<CR><LF>

HEAD:FANCONT:MODE <n>
HEAD:FANCONT:MODE?

This command sets the operation mode of a connected fan either to Control mode, where the base plate temperature is regulated to the adjusted set point (refer to command HEAD:FANCONT:TEMP <f>), or to Drive mode, which provides a 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% (6.5 Volt).)
←<CR><LF>

→HEAD:FANCONT:PVOLT?<CR>
←50%<CR><LF>

HEAD:FANCONT:SPEED?

This command may be used to check proper operation of the fan control. It returns the actual fan speed (in counts, range: 200 – 1023 counts).

Example:
→ HEAD:FANCONT:SPEED?<CR>
← 456cnts<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: degC
Range <f>: 18.0 degC ≤ f ≤ 34.0 degC

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.
Returned 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-532-1000-100KP,PL-0332-02/PS-0129-01,V4.00.44/V4.01.154<CR><LF>

If the laser head communication fails:
SPECTRA-PHYSICS, EXPLORER-532-1000-100KP,XXXXXXX/PS-0129-01,-999V4.01.154< CR><LF>

MODE:RMT <n>
MODE:RMT?

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:RMT 1<CR>
Places the system in Computer mode, and the laser is turned on by sending the ON command while the power supply key switch is in the ON position.
→MODE:RMT 0<CR>
Places the system in Local (analog) mode, and the laser is turned on by turning the key switch to the ON position or by processing the EXTERNAL_DIODE_ON line of the analog interface.
→MODE:RMT?<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 DIOD1: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: μJ^{-1}

Example:
→PENER:CALF?<CR>
←0.5234µJ^-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>

POW:CALF??

This command reads the calibration factor which is used to convert the laser power ADC counts (0 – 1023) to the displayed milliwatt values. The calibration factor is set at the factory.
Unit: mW/cnt

Example:
→POW:CALF?<CR>
←0.044mW/cnt<CR><LF>

POW:REFVOLT:CNTS <n>
POW:REFVOLT:CNTS?

This command modifies the reference voltage of the laser power ADC. It may be used to re-calibrate the displayed power to match the values read at the user's power meter. Higher reference voltage counts result in lower power values.
Range <n>: 200 – 1023
Unit: cnts

Example:
→POW:REFVOLT:CNTS 456<CR>
←<CR><LF>

→POW:REFVOLT:CNTS?<CR>
←456cnts<CR><LF>

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 disables internal pulse triggering and allows external triggering.
Unit: Hz

Table B-3: lists the PRF range for the Explorer models.

Examples:
→QSW:PRF 50000<CR> (Set the pulse frequency to 50000 Hz.)
←<CR><LF>

→QSW:PRF?<CR>
←50000Hz<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
Table B-3: lists the maximum pulse repetition frequencies for the Explorer models.

Examples:
→QSW:PRF:MAX?<CR>
←60000Hz<CR><LF>

QSW:PRF:MIN?

This command reads the minimum pulse repetition frequency.
Unit: Hz
Table B-3: lists the minimum pulse repetition frequencies for the Explorer models.

Example:
→ QSW:PRF:MIN?<CR>
← 20000Hz<CR><LF

READ:DIOD1:CURR?

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

Example:
→READ:DIOD1:CURR?<CR>
←4.56A1<CR><LF> (The diode laser current is 4.56 amps.)

READ:DIOD1: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.
Unit: HrsD1

Example:
→READ:DIOD1:HOUR?<CR>
←234.8HrsD1<CR><LF> (The diode laser has been operated for 234.8 hours.)

READ:DIOD1:TEMP?

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

Example:
→READ:DIOD1: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: degC

Example:
→READ:HEAD:BAS:TEMP? <CR>
←34.5degC<CR><LF>

READ:HEAD:HOUR?

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:HOUR?<CR>
←456.2HrsHd<CR><LF> (The laser head has been supplied with power for 456.2 hours.)

READ:PCUR?

This command reads the actual diode laser current in % of the diode current limit.
Unit: %1

Example:
→READ:PCUR?<CR>
←67.6%1<CR><LF>

READ:PENER?

This command reads the actual pulse energy in µJ.
Unit: µJ

Example:
→READ:PENER?<CR>
←21µJ <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 µJ may be calculated by multiplying by 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:POW?

This command reads the actual laser power, in mW (EXPL-xxx-yyy-P models only).
Unit: mW

Example:
→ READ:POW?<CR>
← 21mW<CR><LF>

READ:PSUPPLY:HOUR?

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:HOUR?<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 or megacounts (depending on *Explorer* model).
Unit: kcnts or mcnts

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-6:).

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>
←8<CR><LF> (System is in SLEEP 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.)

STAT:COND:SYST:DIOD1?

This command reads diode laser status (refer to Table C-2).

Example:
→STAT:COND:SYST:DIOD1?<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: Ranges for Automatic Energy/Power Adjustment

Explorer Model	Min. Pulse Repetition Frequency [Hz]	Max. Pulse Repetition Frequency [Hz]	Min. Pulse Energy (CONT:PENER)* [µJ]	Max. Pulse Energy (CONT:PENER)* [µJ]	Min. Average Power (CONT:POW)* [mW]	Max. Average Power (CONT:POW)* [mW]	Voltage at Analog Port Pin 1 / Output Power
EXPL-355-300-E	20000	60000	1	20	-	-	10 µJ/V
EXPL-355-300-P	20000	150000	-	-	20	500	150 mW/V
EXPL--532-1W-E	20000	60000	1	80	-	-	20 µJ/V
EXPL-532-2W-E	20000	60000	1	80	-	-	20 µJ/V
EXPL-532-1W-P	20000	150000	-	-	20	1500	500 mW/V
EXPL-532-2W-P	20000	150000	-	-	20	2500	1000 mW/V
EXPL-532-200-E	Single-Shot	60000	1	500	-	-	100 µJ/V

* The minimum and maximum pulse energy or average power in this table are the software limitation values. Depending on the laser model and on the current laser configuration (pulse repetition frequency for example), these limits may not be achievable.

Table B-4: Status / Error Reporting Commands

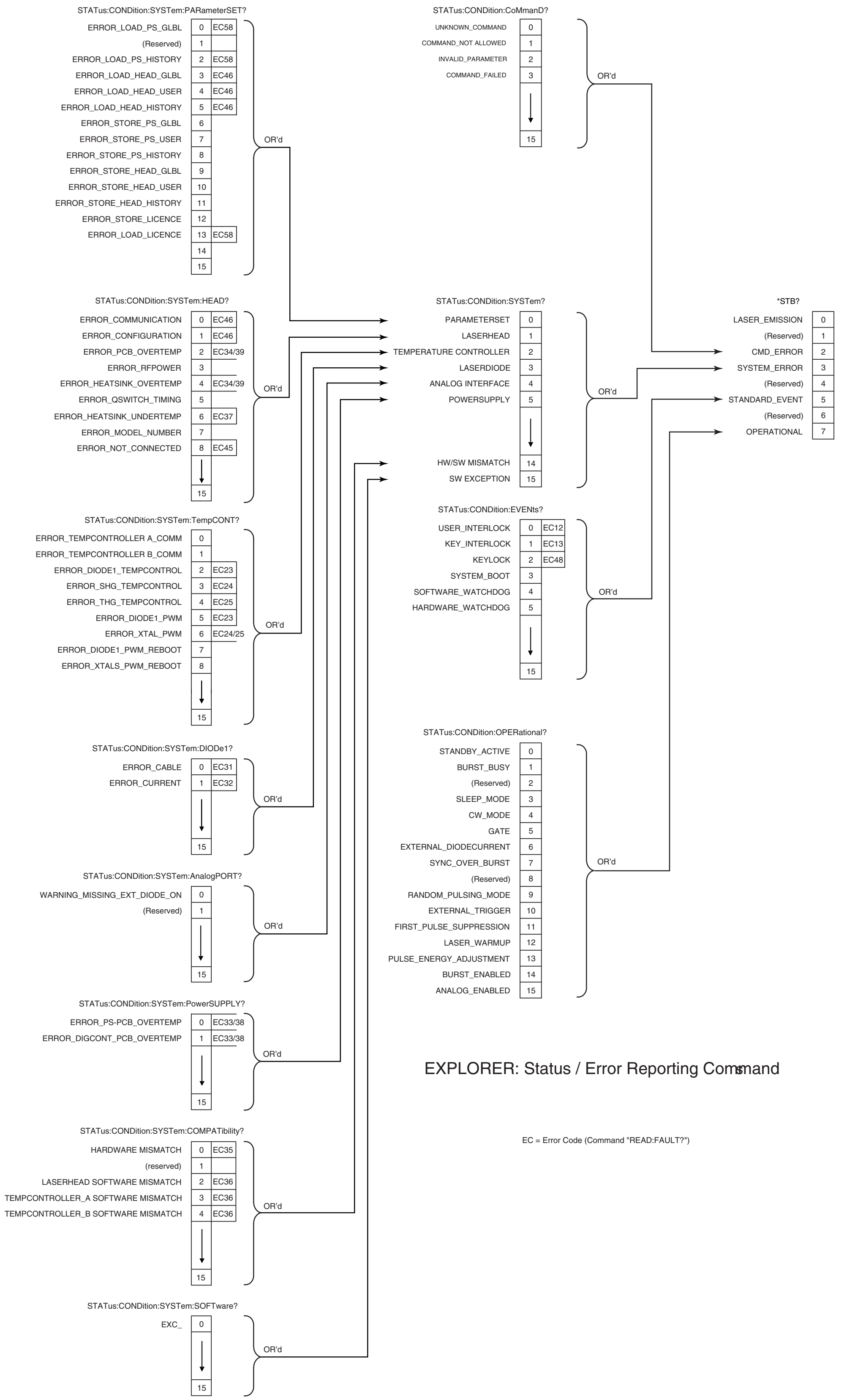

Table B-5: Analog Port Polarity Configuration Bits

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 $\rightarrow 2^2$).

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 + bit 3 $\rightarrow 2^2 + 2^3 = 4 + 8 = 12$).

Table B-6: Analog Port Signal 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-7: 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.”

Parameter Description	Command to Modify Parameter
SHG temperature	CONT:SHG:TEMP <n>
THG temperature	CONT:THG:TEMP <n>
Diode temperature	CONT:DIOD1:TEMP <f>
Diode current	DIOD1:CURR <f> or PCUR <f>
Pulse repetition frequency	QSW:PRF <n>
Operating mode for fan (heat sink)	HEAD:FANCON:MODE <n>
Set temperature for fan in control mode	HEAD:FANCON:TEMP <f>
Voltage percent for fan in drive mode	HEAD:FANCON:PVOLT <f>
Analog port signal polarity	CONFIG:APORT:POLAR <n>
Burst counts	BURST:CNTS <n>
First-Pulse-Suppression delay time	FPS:DELAY <n>
Alert time for software watchdog	WDOG <n>
Auto-on mode	MODE:AUTOON <n>
Computer (Remote) mode	MODE:RMT <n>
Sync pulse spanned over burst	BURST:SYNC <n>

Table B-8: Global Parameters

Global parameters are stored if a user set is stored (with the command CONFIG:STOR <n>).

Parameter Description	Command to Modify Parameter
Pulse energy reference voltage counts	PENER:REFVOLT:CNTS <n>*
Average power reference voltage counts	POW:REFVOLT:CNTS <n>*
Baud rate for serial communication	SYST:COMM:SER:BAUD <n>
User parameter set # that is active at system start-up	CONFIG:PARSET:BOOT <n>

*Depends on Explorer model

Table B-9: Serial Commands: Command Access Restrictions

Command	Description	50 kHz Models	100 kHz Models		UV Models	Green Models	Infrared Models	Analog Mode	Laser Switching on	Laser Emission	Laser OFF	Laser Standby	SLEEP Mode	BURST Mode	BURST BUSY	FPS disabled	INTERNAL triggering mode	EXTERNAL triggering mode	External Current Mode	Pulse Energy / Power Setting	Laserhead Not Connected	Hardware Incompatibility	Software Incompatibility
System Identification																							
*IDN?	read system identification string																						
*IDNC?	read complete identification string including diode serial number and PWM temp.controller SW versions																						
Serial Communication : Baudrate																							
SYST:COMM:SER:BAUD <n>	set baudrate for user communication via RS232								X	X			X		X					X		X	X
SYST:COMM:SER:BAUD?	read baudrate for user communication via RS232												X									X	X
Remote (Computer) or Analog Interface Mode																							
MODE:RMT <n>	place system in remote (computer) or analog interface mode								X	X			X		X					X		X	X
MODE:RMT?	read actual remote mode setting												X									X	X
Diode Current																							
DIOD1:CURR <f>	Set diode current												X						X	X		X	X
DIOD1:CURR?	return the last commanded diode current												X						X	X		X	X
READ:DIOD1:CURR?	return the actual diode current												X						X	X		X	X
PCUR <f>	set diode current to <f> % of maximum current												X						X	X		X	X
PCUR?	return the last commanded diode current in % of the maximum current												X						X	X		X	X
READ:PCUR?	return the actual diode current in % of the maximum current												X						X	X		X	X
DIOD1:MAX?	return adjusted diode maximum current												X								X	X	X
DIOD1:STANDBYC?	return adjusted diode standby current												X								X	X	X
Pulse Repetition Frequency																							
QSW:PRF <n>	set pulse repetition frequency, in Hz 0=external trigger mode												X		X					X		X	X
QSW:PRF 0	set external trigger mode												X	X	X					X		X	X
QSW:PRF?	read last commanded pulse repetition frequency												X							X		X	X
READ:QSW:PRF?	read actual pulse repetition frequency (returns 0 Hz in external triggering mode)												X							X		X	X
QSW:PRF:MIN?	return actual lower pulse repetition frequency limit												X								X	X	X
QSW:PRF:MAX?	return actual pulse repetition frequency limit												X								X	X	X
Diode / Xtal Temperatures																							
CONT:SHG:TEMP <n>	set the SHG crystal temperature, in DAC counts						X						X							X	X	X	X
CONT:SHG:TEMP?	read last commanded SHG crystal temperature in DAC counts						X						X								X	X	X
READ:SHG:TEMP?	read actual SHG crystal temperature (control loop), in ADC counts						X						X								X	X	X
CONT:THG:TEMP <n>	set the THG crystal temperature, in DAC counts					X	X						X							X	X	X	X
CONT:THG:TEMP?	read last commanded THG crystal temperature in DAC counts					X	X						X								X	X	X
READ:THG:TEMP?	read actual THG crystal temperature difference (control loop), in ADC counts					X	X						X								X	X	X
DIOD1:TEMP <f>	set the diode temperature (in degrees Celsius)												X							X	X	X	X
DIOD1:TEMP?	read last commanded diode temperature												X								X	X	X
READ:DIOD1:TEMP?	read actual diode temperature (control loop), in deg C)												X								X	X	X
Head Housing Temperature																							
READ:HEAD:BAS:TEMP?	read actual laserhead housing temperature												X								X	X	X
HEAD:BAS:TEMP:MAX?	read laserhead housing temperature limit, in °C (unit:degC)												X								X	X	X

Laserhead Fan Controller																							
HEAD:FANCONT:TEMP?	return actual set temperature for fan control												X								X	X	X
HEAD:FANCONT:TEMP <f>	set temperature for fan control												X							X	X	X	X
HEAD:FANCONT:SPEED?	read the control voltage (frequency) of the fan, in DAC counts (200 - 1000 cnts)												X								X	X	X
HEAD:FANCONT:MODE <n>	set operation mode for fan control: control or drive mode (constant voltage)												X							X	X	X	X
HEAD:FANCONT:MODE?	return operation mode for fan control: control or drive mode (constant voltage)												X								X	X	X
HEAD:FANCONT:PVOLT <f>	set fan control voltage (in drive mode) in % (13V)												X							X	X	X	X
HEAD:FANCONT:PVOLT?	return fan control voltage (in drive mode) in % (13V)												X								X	X	X
Pulse Energy																							
READ:PENER?	read actual output pulse energy, in µJ		X										X							X	X	X	X
PENER:CALF?	return the actual pulse energy calibration factor. In µJ/cnt		X										X								X	X	X
READ:PENER:HIST?	return a list of pulse energies (last 50 pulses), in ADC counts		X										X							X	X	X	X
PENER:REFVOLT:CNTS?	return reference voltage (in counts) for pulseenergy measurement		X										X								X	X	X
PENER:REFVOLT:CNTS <n>	set reference voltage (in counts) for pulse energy measurement		X										X	X	X					X	X	X	X
Output Power																							
READ:POW?	read actual average power, in mW	X											X							X	X	X	X
POW:CALF?	return the power calibration factor in mW/cnt	X											X								X	X	X
POW:REFVOLT:CNTS?	return reference voltage (in counts) for power measurement	X											X								X	X	X
POW:REFVOLT:CNTS <n>	set reference voltage (in counts) for power measurement	X											X	X	X					X	X	X	X
Status / Errors																							
READ:FAULT?	read actual error code																						
READ:FAULT:HIST?	read error code history (FIFO list of 16 entries)																						
READ:FAULT:LIST?	return list of all active error codes (max. 16)																						
*STB?	read status byte																						
STAT:COND:CMD?	read serial command status																						
STAT:COND:SYST?	read system status																						
STAT:COND:EVEN?	read events status																						
STAT:COND:OPER?	read operational condition status																						
STAT:COND:SYST:PARSET?	read parameter set status (load/storage)																						
STAT:COND:SYST:PSUPPLY?	read powersupply status																						
STAT:COND:SYST:HEAD?	read laserhead system condition																				X		
STAT:COND:SYST:DIOD1?	read laserdiode condition																						
STAT:COND:SYST:TCONT?	read temperature controller condition																						
STAT:COND:SYST:APORT?	read analog port condition																						
STAT:COND:SYST:SOFT?	return software exception status																						
STAT:COND:SYST:COMPAT?	return hardware/software compatibility status																						
History: Pulse Counts, Operating Hours																							
READ:HEAD:HOUR?	read laserhead ON time												X							X	X	X	X
READ:PSUPPLY:HOUR?	read power supply ON time												X							X		X	X
READ:QSW:CNTS?	read actual pulse counter												X							X	X	X	X
READ:DIOD1:HOUR?	read diode operating hours												X							X	X	X	X
Auto-On Feature																							
CONT:AUTOON <n>	set AUTO-ON feature on/off								X	X			X		X							X	X
CONT:AUTOON?	read the AUTO-ON setting												X									X	X
Configuration / Parameter Sets																							
CONFIG:PARSET:BOOT <n>	set parameter set # <n> when booting												X									X	X
CONFIG:PARSET:BOOT?	return actual boot parameter set number												X									X	X
CONFIG:PARSET:STOR <n>	store actual parameters as parameter set #<n>								X	X			X		X					X	X	X	X
CONFIG:PARSET:LOAD <n>	load parameter set #<n>								X	X			X		X					X	X	X	X
CONFIG:PARSET:ACT?	return current parameter set number												X									X	X
Laser On / Off / Standby																							
ON	turn the laser diode on at the last commanded current							X	X	X			X		X					X	X	X	X
OFF	turn diode off							X					X									X	X
MODE:STBY <n>	place diode in STANDBY mode							X	X				X	X	X						X	X	X
MODE:STBY?	return (computer) standby mode												X									X	X

First Pulse Suppression																							
FPS:DELAY <n>	set the delay time of first pulse suppression to <n> µsecs												X		X					X		X	X
FPS:DELAY 0	disable first-pulse-suppression mode												X		X					X		X	X
FPS:DELAY?	return delay time of first pulse suppression												X							X		X	X
Burst Mode																							
BURST:CNTS <n>	set number of pulses to be issued on next "burst" command / enables/disables burst mode							X				X	X		X			X		X		X	X
BURST:CNTS?	return number of set pulses in burst mode												X							X		X	X
BURST	perform burst							X			X	X	X		X			X		X	X	X	X
BURST:SYNC <n>	enable/disable SYNC signal over burst												X		X			X		X		X	X
BURST:SYNC?	return SYNC signal over burst setting												X							X		X	X
Analog Interface																							
CONFIG:APORT:POLAR?	return analog port polarity configuration byte												X									X	X
CONFIG:APORT:POLAR <n>	set analog port polarity configuration								X	X			X		X							X	X
STAT:APORT:SIGNAL?	return analog port pin status byte												X									X	X
Software Watchdog																							
WDOG <n>	set the software watchdog alert time <n>=0 disables SW watchdog												X							X		X	X
WDOG?	return the software watchdog alert time (in seconds)												X									X	X
Power-Saving Mode																							
MODE:SLEEP <n>	switch on/off q-switch + TECs								X	X				X	X					X		X	X
MODE:SLEEP?	return sleep status																					X	X
Pulse Energy Setting																							
CONT:PENER <n>,<n>,<n>	start pulse energy setting procedure		X						X		X	X	X		X				X	X	X	X	X
CONT:PENER 0	stop pulse energy setting procedure		X						X		X	X	X		X				X		X	X	X
CONT:PENER?	return the result of the pulse energy setting procedure		X										X							X	X	X	X
Laser Power Setting																							
CONT:POW <n>,<n>,<n>	start power setting procedure	X							X		X	X	X		X				X	X	X	X	X
CONT:POW 0	stop power setting procedure	X							X		X	X	X		X				X		X	X	X
CONT:POW?	return the result of the power setting procedure	X											X							X	X	X	X

X = Command is not allowed (a ”?” will be returned)

Appendix C Operating Status Codes

This appendix contains the following tables:

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
Serial Commands Register (Query STAT:COND:CMD?)			
0	UNKNOWN_CMD	Unknown command	Use allowed command from list.
1	CMD_NOT_ALLOWED	Command is not allowed, e.g., *BURST* when Burst mode is not activated.	Prepare system to accept the command.
2	INVALID_PAR	Command was sent using invalid parameter(s): e.g., *DIOD1:CURRENT 10.3* 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.
System Condition Register (Query STAT:COND:SYST?)			
0	PAR_SET	There is a problem with the configuration set(s) (communication error, invalid checksums).	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
15	SW_EXCEPTION	An internal software exception status was activated during the execution of the controller software. The laser remains fully operational.	Contact Spectra-Physics service
System Events Condition Register (Query STAT:COND:EVEN?)			
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.

Table C-2: Operating Status and Error Bits (Continued)

Bit Active	Description	Condition	Action Required
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).
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
	System Operational Condition Register (Query STAT:COND:OPER?)		
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	N/A		
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 *MODE:SLEEP 0* 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 to pin 2 of the ANALOG port 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	N/A		
9	N/A		
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 (Continued)

Bit Active	Description	Condition	Action Required
12	LASER_WARMUP	Laser system is warming up	No action is required. If an automatic pulse energy adjustment is to be performed, it is recommended to wait until this bit is cleared (typically 10 minutes after a cold start or 2 minutes after a warm start).
13	PULSE_ENERGY_SETTING	An automatic pulse energy adjustment is taking place.	No action is required.
14	BURST_ENABLED	Burst mode is enabled, i.e., burst counts is set to <n> counts	To perform a burst, enter the BURST command. To disable the burst mode, set the burst counts to 0.
15	ANALOG_ENABLED	The Explorer laser system is in analog mode.	The laser may be switched on and off applying appropriate electric signals to the analog port pins. To disable the analog mode, enter the command MODE:RMT 0.
	System Condition "Parameter Set" Register (Query STAT:COND:SYST:PARSET?)		
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

Table C-2: Operating Status and Error Bits (Continued)

Bit Active	Description	Condition	Action Required
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
	System Condition "HEAD" Register (Query STAT:COND:SYST:HEAD?)		
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 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
3	ERROR_QSWITCH_RF_POWE R	The Q-switch does not work properly.	Contact Spectra-Physics service
4	ERROR_HEATSINK_ OVERTEMPERATURE	The laser 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
6	HEATSINK_UNDERTEMPER ATURE	The heatsink temperature is below the minimum of 18°C (typical). The laser system remains fully operational.	No action is required.

Table C-2: Operating Status and Error Bits (Continued)

Bit Active	Description	Condition	Action Required
7	ERROR_INVALID_MODEL	The internal model setting does not match the installed software.	Contact Spectra-Physics service
8	ERROR_LASERHEAD_ NOT_CONNECTED	The laser head was not detected by the software.	Turn the laser system off. Check the cable connections between the power supply and the laser head. Turn the laser system on again.
	System Condition "POWER SUPPLY" Register (Query STAT:COND:SYST:PSUPPLY?)		
0	ERROR_PS_PCB_OVERTEMP	The laser turned off because the maximum temperature of the main PCB was exceeded.	Contact Spectra-Physics service
1	ERROR_DIGCONT_PCB_ OVERTEMP	The laser turned off because the maximum temperature of the digital controller PCB was exceeded.	Contact Spectra-Physics service
	System Condition "TEMPERATURE CONTROLLER" Register (Query STAT:COND:SYST:TCONT?)		
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
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_REBOO T	A crystal temperature controller reboot procedure took place.	If the problem persists, contact Spectra-Physics service.

Table C-2: Operating Status and Error Bits (Continued)

Bit Active	Description	Condition	Action Required
System Condition "ANALOG PORT" Register (Query STAT:COND:SYST:APORT?)			
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.
System Condition "DIODE" Register (Query STAT:COND:SYST:DIOD1?)			
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
System Condition "COMPATIBILITY" Register (Query STAT:COND:SYST:COMPAT?)			
0	HARDWARE_MISMATCH	The PCB versions of power supply and laser head do not match	Contact Spectra-Physics service
1	N/A		
2	LASERHEAD_SOFTWARE_MISMATCH	The power supply software does not match the laser head software version	Contact Spectra-Physics service
3	TEMPCONTROLLER_A_SOFTWARE_MISMATCH	The power supply software does not match the software version of the temperature controller A	Contact Spectra-Physics service
4	TEMPCONTROLLER_A_SOFTWARE_MISMATCH	The power supply software does not match the software version of the temperature controller B	Contact Spectra-Physics service
System Condition "SOFTWARE EXCEPTION" Register (Query STAT:COND:SYST:SOFT?)			
0	EXC_	An internal software exception status was activated during the execution of the controller software. The laser remains fully operational.	Contact Spectra-Physics service

Table C-3: Fault Codes

Code	Description
Code	**Description**
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
45	Laser head not connected
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[1]

Code	Description
37	Warning undertemp heatsink
38	Warning overtemp power supply
39	Warning overtemp laser head

[1] *These are notifications; the laser is fully functional.*

Table C-5: Laser Emission Shutdown Conditions

Laser Emission Shutdown Condition	Cause	Indication
Diode temperature error (#23)	Diode temperature not stabilized (significant offset from set temperature) or temperature controller not working properly.	Error LED is lit. Fault list contains error #23. (READ:FAULT:LIST?)
Diode cable error (#31)	Diode cable not connected or connection faulty.	Error LED is lit. Fault list contains error #31. (READ:FAULT:LIST?)
Diode current error (#32)	Diode current can not be adjusted by hardware control loop.	Error LED is lit. Fault list contains error #32. (READ:FAULT:LIST?)
SHG xtal temperature error (#24)	SHG crystal temperature not stabilized (significant offset from set temperature) or temperature controller not working properly.	Error LED is lit. Fault list contains error #24. (READ:FAULT:LIST?)
THG xtal temperature error (#25)	THG crystal temperature not stabilized (significant offset from set temperature) or temperature controller not working properly.	Error LED is lit. Fault list contains error #25. (READ:FAULT:LIST?)
Power supply over-temperature (#33)	Either the main PCB temperature or the digital controller PCB temperature in the power supply housing exceeded the safety-shutdown temperature limit.	Error LED is lit. Fault list contains error #33. (READ:FAULT:LIST?)
Laser head over-temperature (#34)	Either the heatsink temperature or the controller PCB temperature in the laser head exceeded the safety-shutdown temperature limit.	Error LED is lit. Fault list contains error #34. (READ:FAULT:LIST?)
Software watchdog triggered	The software watchdog is activated. No serial command was sent to the Explorer within the adjusted alert time.	Bit #4 of the event status byte is set. (STAT:COND:EVEN?).
Hardware watchdog triggered	Unexpected behavior of the control software (e.g., infinite loop).	After start-up, bit #5 of the event status byte is set. (STAT:COND:EVEN?)
User interlock activated (#12)	The user interlock was triggered by an external wiring loop or by removing the analog plug.	Error LED is lit. Fault list contains error #12. (READ:FAULT:LIST?)
Keyswitch interlock activated (#13)	The keyswitch was turned off.	Error LED is lit. Fault list contains error #13. (READ:FAULT:LIST?)
Analog mode: EXT_DIODE_ON signal changed	The level of the EXT_DIODE_ON signal changed from LOW to HIGH or from HIGH to LOW (depending on the analog port polarity configuration).	Bit #0 of the analog interface status byte is set. (STAT:COND:SYST:APORT?)

Appendix D A Brief Review of Laser Theory

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.,

$$h\nu = E_2 - E_1 \qquad [1]$$

where h is Planck's constant, and ν is the frequency of the photon.

"Light" will be used to describe the portion of the electromagnetic spectrum from far infrared to ultraviolet.

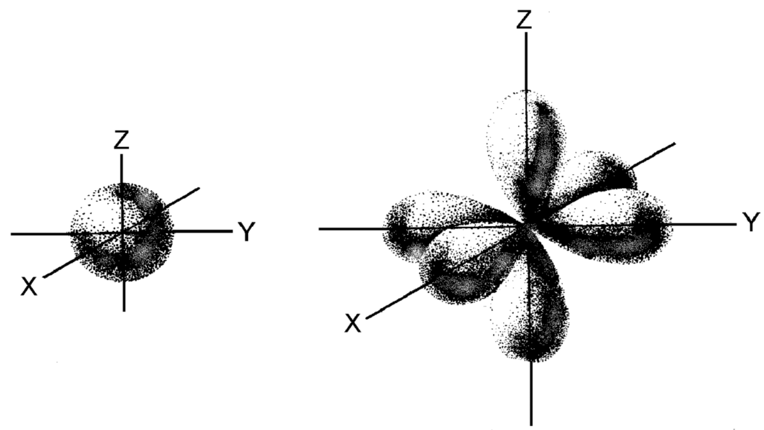

Figure D-1: Electrons occupy distinct orbitals that are defined as the probability of finding an electron at a given position. The shape of the orbital is determined by the radial and angular dependence of this probability.

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

$$\nu = \frac{E_2 - E_1}{h} \qquad [2]$$

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 ν, 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 ν 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 ν 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 ν_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 ν_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 ν_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 ν_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.

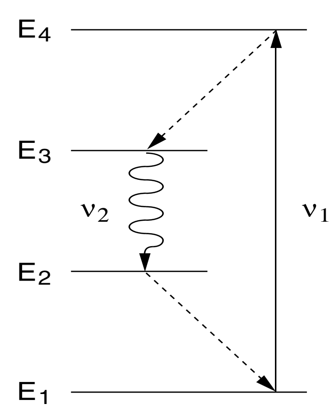

Figure D-2: Typical Four-level Transition Scheme

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).

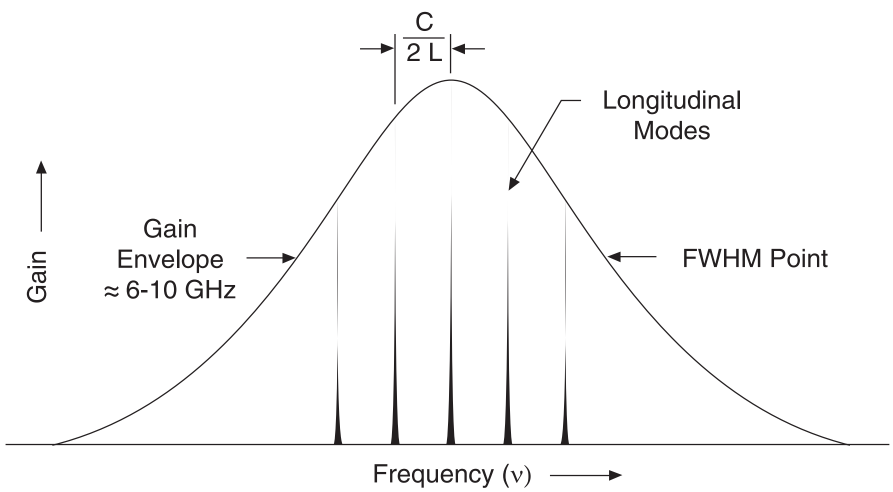

Figure D-3: Frequency Distribution of Longitudinal Modes for a Single Line

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

$$\nu_m = \frac{mc}{2L} \qquad [3]$$

will oscillate, where ν_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

$$\Delta\nu = \frac{c}{2L} \qquad [4]$$

Nd^{3+} 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^{3+} ions doped in a yttrium\crystalline matrix ($Nd:YVO_4$), commonly known as Vanadate.

The properties of neodymium-doped crystals, such as Vanadate, are the most widely studied of all solid-state laser media. The four-level Nd^{3+} 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 $^4F_{3/2}$ level, the upper level of the lasing transition. They remain for a comparatively long time until stimulated to emit a photon.

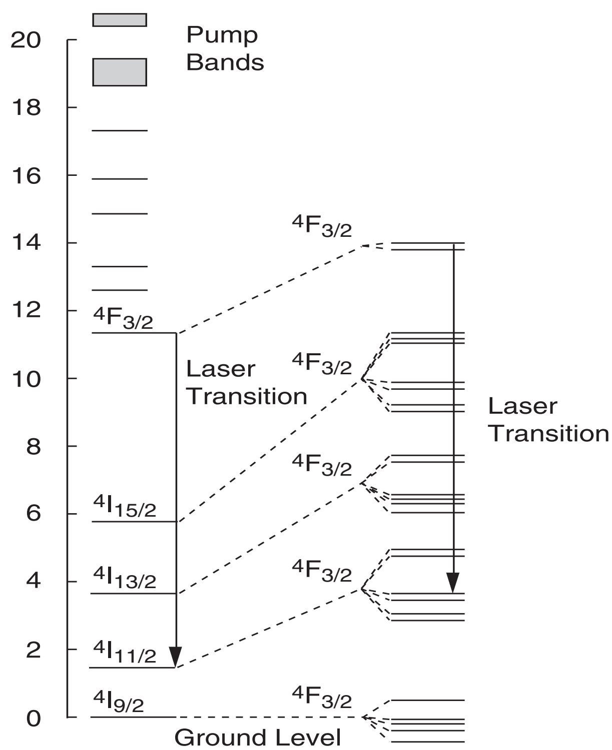

Figure D-4: Energy Level Scheme for the Nd^{3+} Ion

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.

Vanadate possesses several benefits for use in a high repetition rate, solid state laser. Although it has a comparatively short lifetime (only about 100 µs), it has a very low threshold for lasing due to its very large absorption cross section for the diode pump wavelength. It has rapid optical response which enables high frequency Q-switching. Vanadate's natural birefringence avoids the depolarization problems of isotropic crystals like Nd:YAG which can cause difficulties for harmonic generation.

Vanadate accepts high doping of neodymium, which is an important consideration for end-pumping by a diode laser source.

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^{3+} 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.

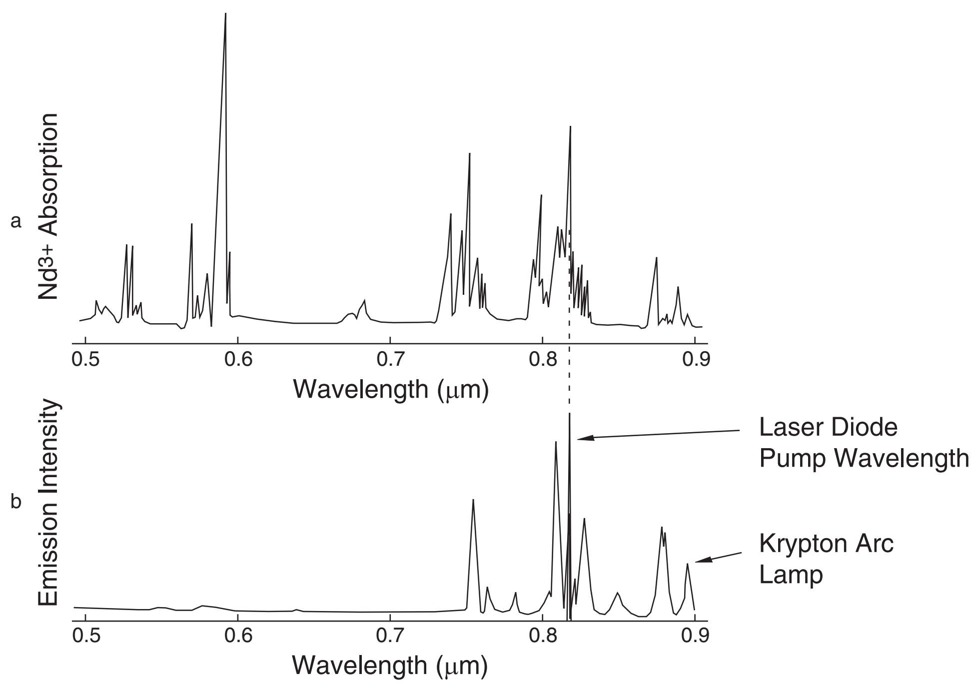

Figure D-5: Nd^{3+} absorption spectra compared to emission of a Krypton Arc Lamp (a) and a Diode Laser Pump (b).

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_{00} 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.

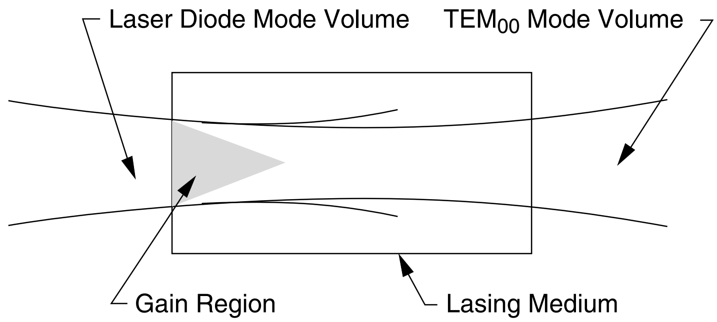

Figure D-6: Mode Matching

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 as "frequency conversion" or "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 techniques 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 than 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, which is 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 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. A piezo-electric transducer is used to impress an ultrasonic wave on the AOM. The photo-elastic 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 of 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 in the crystal 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. Since the internal beam is no longer deflected and is, instead, amplified by the high gain now available in the laser rod, 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.

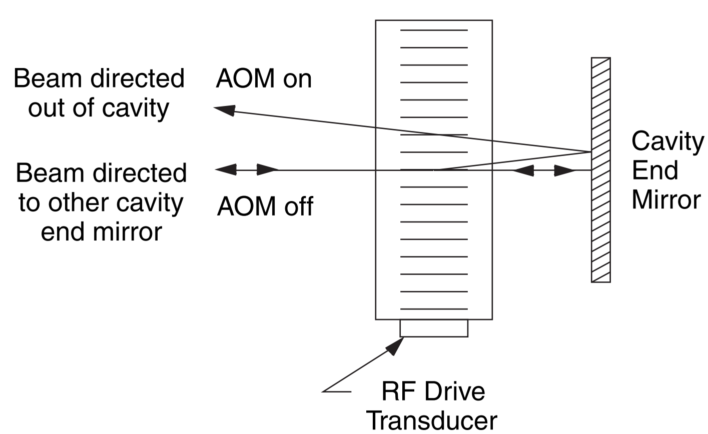

Figure D-7: An Intracavity Acousto-Optic Modulator

Notes

Report Form for Problems and Solutions

We have provided this form to encourage you to tell us about any difficulties you have experienced in either using your Spectra-Physics instrument or its manual—problems that did not require a formal call or letter to our service or marketing departments, but that you feel should be remedied. We are always interested in improving our products and manuals and we appreciate all suggestions.

Send all instrument related questions to:

Spectra Physics, a Newport Corporation Brand
Service Manager
3635 Peterson Way
Santa Clara, CA 95054
FAX: (408) 980-3584

Send all manual related questions to:

Spectra Physics, a Newport Corporation Brand
Senior Director Product Marketing
3635 Peterson Way
Santa Clara, CA 95054
FAX: (408) 980-7101

Thank you.

From:

Name ______________________________

Company or Institution ______________________________

Department ______________________________

Address ______________________________

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Instrument Model Number ______________ Serial Number ______________

Problem: ______________________________

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Suggested Solution(s): ______________________________

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