Millennia Pro 2*s*

Diode-Pumped, CW Visible Laser

User's Manual

Spectra-Physics
Lasers & Photonics

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Preface

This manual contains information required to safely install, operate, maintain, and service the *Millennia Pro 2s* diode-pumped, continuous-wave, visible laser. The system comprises three elements: the *Millennia Pro 2s* laser head, the *Model J20i* power supply and the *Millennia* controller.

The "Introduction" contains a brief description of the *Millennia Pro 2s* laser, its power supply and the controller.

Following that section is an important chapter on safety. The *Millennia Pro 2s* is a Class IV laser and, as such, emits laser radiation that can permanently damage eyes and skin. This section contains information about these hazards and offers suggestions on how to safeguard against them. To minimize the risk of injury or expensive repairs, be sure to read this chapter—then carefully follow these instructions.

"Laser Description" contains a short section on laser theory regarding the Nd:YVO_4 laser crystal and the second harmonic generation technique used in the *Millennia Pro 2s*. It is followed by a more detailed description of the *Millennia Pro 2s* laser system. The chapter concludes with system specifications.

The next few chapters describe the *Millennia Pro 2s* controls, then help you prepare for installing the system and guide you through its operation.

"Service and Repair" is intended to help you guide your Spectra-Physics field service engineer to the source of any problems. *Do not attempt repairs yourself while the unit is still under warranty*; instead, report all problems to Spectra-Physics for warranty repair. This chapter includes a replacement parts list.

Should you experience any problems or you are in need of technical information or support, please contact Spectra-Physics. Chapter 8, "Customer Service," contains a list of world-wide Spectra-Physics Service Centers you can call if you need help.

This product has been tested and found to conform to Directive 73/23/EEC governing product safety using standards EN 60950: 1997, EN 61010-1: 2001 and EN 60825-1: 1994, and it conforms to Directive 89/336/EEC governing electromagnetic compatibility using standard EN 61326-1 w/ A1: 1997 as listed in the official *Journal of the European Communities*. Refer to the "CE Declaration of Conformity" statements in Chapter 2.

This product conforms to the requirements of 21 CFR 1040.10 CDRH and are compliant to Underwriters Laboratory UL1950 and are listed as ULR for recognized components. This equipment has been designed and tested to comply with the limits for a Class A digital device pursuant to Part 15 of the FCC Rules.

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, please let us know. The last page is a form to aid in bringing such problems to our attention.

Thank you for your purchase of Spectra-Physics instruments.

Environmental Specifications

CE Electrical Equipment Requirements

Refer to specification EN-309, "Plug, Outlet and Socket Couplers for Industrial Uses," listed in the official *Journal of the European Communities,* for information regarding the equipment needed in order to provide the electrical service listed under "Service Requirements" at the end of Chapter 3.

Environmental Specifications

The environmental conditions under which the laser system will function are listed below:

Indoor use

Altitude:	up to 3000 m
Temperatures:	18°C to 35°C
Maximum relative humidity:	80% non-condensing for temperatures up to 35°C.
Mains supply voltage:	do not exceed ±10% of the nominal voltage
Insulation category:	II
Pollution degree:	2

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.

CDRH and UL Regulations

This product conforms to the requirements of 21 CFR 1040.10 CDRH. It is designed to meet Underwriters Laboratory UL1950 and uses a power supply that is a UL recognized (ULR) component.

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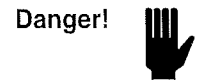
Warning Conventions

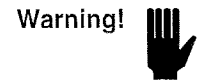
The following warnings are used throughout this manual to draw your attention to situations or procedures that require extra attention. They warn of hazards to your health, damage to equipment, sensitive procedures, and exceptional circumstances. All messages are set apart by a thin line above and below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

Laser radiation is present.

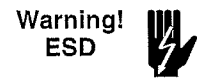


Condition or action may present a hazard to personal safety.

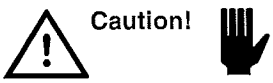
Condition or action may present an electrical hazard to personal safety.



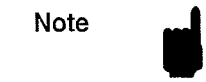
Condition or action may cause damage to equipment.



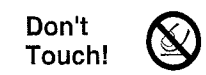
Action may cause electrostatic discharge and cause damage to equipment.



Condition or action may cause poor performance or error.



Text describes exceptional circumstances or makes a special reference.



Do not touch.

Appropriate laser safety eyewear should be worn during this operation.

Refer to the manual before operating or using this device.

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
inductance	henry	H
magnetic flux	weber	Wb
magnetic flux density	tesla	T
luminous intensity	candela	cd
temperature	celcius	C
pressure	pascal	Pa
capacitance	farad	F
angle	radian	rad

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

Unpacking and Inspection

Unpacking Your Laser

Your *Millennia® Pro 2s* 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.

Carefully inspect your laser system as you unpack it. If any damage is evident, such as dents or scratches on the covers, etc., immediately notify the carrier and your Spectra-Physics sales representative.

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

System Components

The following components comprise the *Millennia Pro 2s* laser system:

- *Millennia Pro 2s* laser head
- *Model J20i* power supply
- *Millennia* controller

Verify that all three components are present. The laser head, power supply, and controller are shipped in one container.

Accessories

Included with the laser system is this manual, a packing slip listing all the parts shipped, accessories and an accessory kit. The following accessories are shipped standard with the system:

- 1 US or European power cord (2 m)
- table clamp kit: 3 clamps, 3 pairs of nested spherical washers, 3 mounting screws
- 2 keys for the power supply
- a remote interlock jumper plug (for RS-232 only operation)
- a laser head interlock jumper plug
- an interlock jumper plug
- guses

Chapter 1 Introduction

The Millennia Pro 2s Advantage

The *Millennia® Pro 2s* is a high-power, visible CW laser that provides 2 W of green 532 nm output, and it represents the next generation of diode-pumped, all solid state technology. The design features a rugged, industrial laser head for simple, hands-off operation, and it delivers exceptional power stability and beam-pointing performance.

The *Millennia Pro 2s* is based upon the innovative technology developed for the *Millennia s* Series®, and is pumped by a high-power, long-lifetime ProLite® series diode laser. Since the pump diode is the only consumable in a solid-state laser system, the ProLite design directly and significantly reduces the long-term cost of ownership.

The ProLite® diode laser is packaged in an industry-leading FC*bar*™ fiber-coupled diode module that is field-replaceable, which minimizes any downtime. The module is mechanically indexed for reproducible beam position and consistent installation.

The diode module is located in the *Model J20,* the *Millennia Pro 2s* power supply. The all solid-state design of the *Model J20i* includes a thermoelectric cooler (TEC) for pump diode thermal management. The result is a compact, rack-mountable unit that operates from a standard 110 or 220 Vac single-phase outlet.

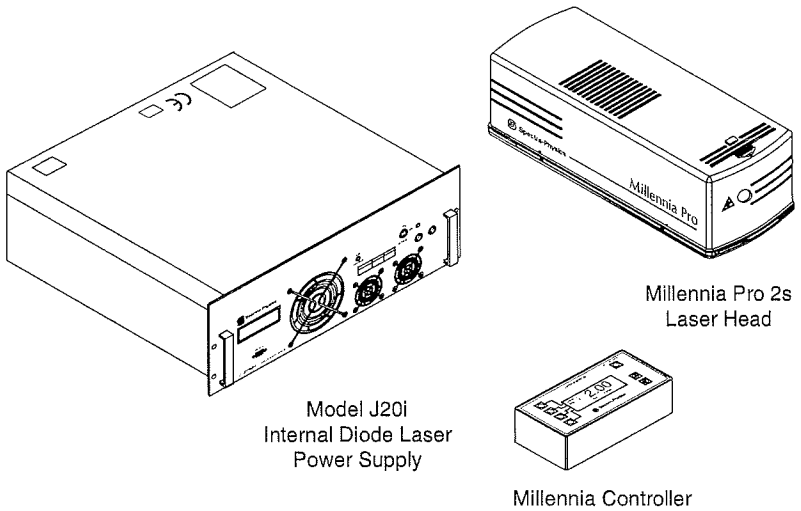


Figure 1-1: The *Millennia Pro 2s* System

The Laser System

The *Millennia Pro 2s* system comprises three basic components:

- *Millennia Pro 2s* laser head
- *Model J20i* power supply
- *Millennia* controller

Laser Head

The *Millennia Pro 2s* laser head houses a sealed laser module and a shutter. The sealed module contains the optical resonator, the Nd:YVO_4 gain medium, the diode laser fiber delivery and telescope focusing system, the lithium triborate (LBO) doubling crystal, and the output beam telescope system. The shutter provides a safe, mechanical means to block the output beam. It is opened and closed via electronic command.

The *Millennia Pro 2s* employs an X-Cavity design to minimize the laser head footprint. Inside the X-Cavity, the Nd:YVO_4 gain medium is end-pumped by laser light from the fiber-coupled FC*bar*™ module in the *Model J20i* power supply. Fiber-coupling transforms the astigmatic light from a diode module into a round beam of exceptional brightness, suitable for an efficient end-pumping geometry. It also allows the diode module to be located in the power supply, thereby removing the heat load from the laser head and facilitating replacement without the need for realigning the cavity.

In the frequency-doubling part of the cavity, the beam is focused into the non-critically phase-matched, temperature-tuned, LBO crystal, which generates the green output beam at 532 nm wavelength. The doubling crystal is housed in an oven to maintain it at an optimum temperature for stable output at that wavelength.

The cavity end mirror in the doubling section has dual infrared and green high-reflective coatings, so that frequency-doubled light is generated in both passes through the crystal. The green beam exits through a dichroic output coupler.

The *Millennia Pro 2s* utilizes an enhanced version of the Spectra-Physics patented quiet, multiaxial mode-doubling (QMAD) intracavity doubling technology to provide ultra-low optical noise of less than 0.04% rms—and it achieves this in a very short cavity length. This revolutionary breakthrough has enabled Spectra-Physics to develop the smallest high power, diode-pumped CW green lasers available today.

Model J20i Power Supply

The *Model J20i* power supply houses the fiber-coupled, FC*bar* diode module that pumps the *Millennia Pro 2s* laser head. The diode module is operated at less than its rated power in order to maintain ideal conditions for the diode laser and ensure long lifetime. The power supply also contains the control logic and power circuitry for the system, as well as the TEC for cooling the diode module. The power supply is air cooled and requires no water or external cooling connections. For electrical power, it simply requires a standard 110 or 220 Vac 10 A power source.

The power supply is small and rack-mountable and measures about 48 x 18 x 41 cm (about 19 x 7 x 16 in.) and weighs about 11 kg (25 lb).

A power/control cable and fiber bundle are placed inside the umbilical that connects the laser head to the power supply.

Controller

Local control is provided by the *Millennia Pro 2s* controller that connects to the front of the power supply via an 8-foot cable.

A simple, menu-driven control program using "soft" keys and clear, large characters on a back-lit display provides easy control and monitoring of the system. The intuitive, layered menu structure provides controls for operating the laser, along with monitoring and diagnostic information.

For users that prefer to operate the laser remotely, either directly or via a computer program, a standard RS-232 serial port is provided on the power supply for a computer or terminal connection.

Patents

The *Millennia Pro 2s* system is manufactured under the following patents:

4,653,056	4,761,786	4,942,582
4,656,635	4,785,459	5,080,706
4,665,529	4,837,771	5,127,068
4,701,929	4,872,177	5,410,559
4,723,257	4,894,839	5,412,683
4,739,507	4,908,832	5,436,990
4.756.003	4,913,533	5,446,749

Chapter 2 Laser Safety

Warning!

This user information is in compliance with section 1040.10 of the CDRH Laser Products Performance Standards from the *Health and Safety Act of 1968*. The use of controls or adjustments, or the performance of procedures other than those specified herein, may result in hazardous radiation exposure.

Eyewear Required

The Spectra-Physics *Millennia® Pro 2s* laser is a *Class IV—High Power Laser* whose beam is, by definition, a safety and fire hazard. Take precautions to prevent accidental exposure to both direct and reflected beams. Diffuse as well as specular beam reflections can cause severe eye or skin damage.

This safety section should be reviewed thoroughly prior to operating the *Millennia Pro 2s* laser system, and the safety precautions listed herein should be followed carefully.

General Hazards

Hazards associated with the use of diode-pumped lasers generally fall into the categories listed below. At all times while working with these lasers, please be aware of these potential hazards and act accordingly. You are responsible for your health and the health of those working around you.

- Exposure to laser radiation can result in damage to the eyes or skin.
- Exposure to chemical hazards, such as particulate matter or gaseous substances, can be health hazards when they are released as a result of laser material processing or as by-products of the lasing process itself. When these lasers are used to pump dye laser systems, be aware that the dyes used can be extremely hazardous to your health if inhaled or, in some cases, even touched.
- Exposure to high-voltage electrical circuits present in the laser power supply and associated circuits can result in shock or even death.
- Possible health risks are present if pressurized hoses, cylinders, liquids and gasses used in laser systems are damaged or misused.

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 the eye's pupil remains constricted, reducing the possibility of damage.
- To avoid unnecessary radiation exposure, keep the protective cover on the laser head at all times.
- 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 those trained in the principles of laser safety.
- Post prominent warning signs near the laser operating area (Figure 2-1).
- Set up experiments so the laser beam is either above or below eye level.
- Provide enclosures for beam paths whenever possible.
- Set up shields to prevent any unnecessary specular reflections.
- Set up a beam dump to capture the laser beam and prevent accidental exposure (Figure 2-2).

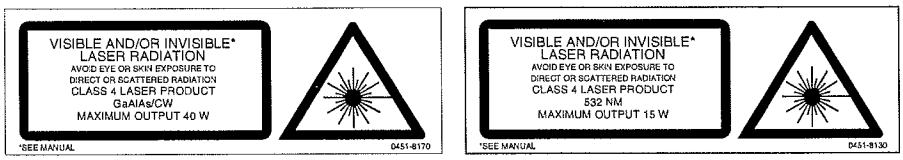


Figure 2-1: These CE and CDRH standard safety warning labels would be appropriate for use as entry warning signs (EN 60825-1, ANSI 4.3.10.1).

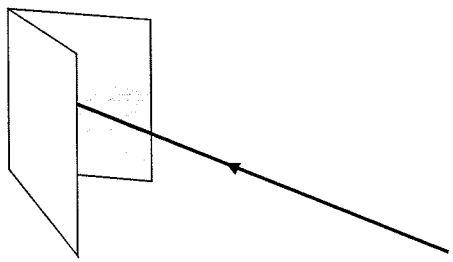


Figure 2-2: Folded Metal Beam Target

Caution! 

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

Danger! 

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

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

Maximum Emission Levels and Protective Eye Wear

It is recommended that laser-safe eyewear be worn at all times when the *Millennia Pro 2s* laser is on. The following are the maximum emission levels possible for this *Millennia Pro 2s* product. Use this information for selecting appropriate laser safety eyewear and implementing appropriate safety procedures. These values do not imply actual system power or specifications.

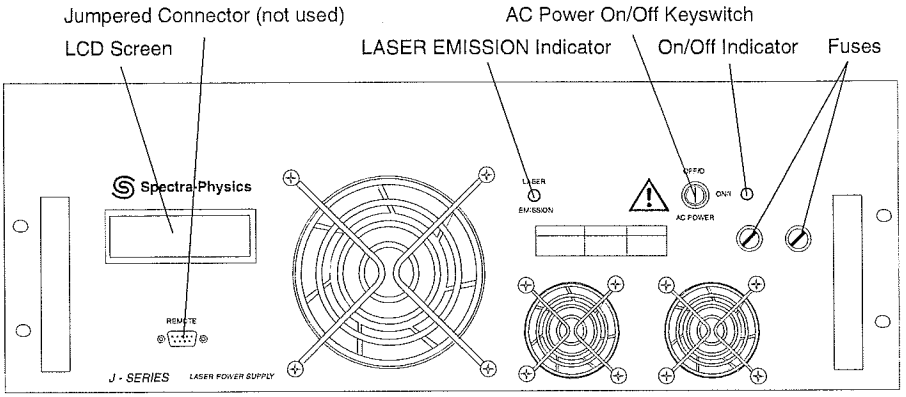
Emission Wavelength	Maximum Power
532 nm – laser output wavelength (second harmonic)	5 W
809 nm – diode laser emission	20 W
1064 nm – fundamental operation wavelength	<< 1 W

During normal operation, the operator will not be exposed directly to hazardous diode laser emission. However, removing the mechanical housing cover will not only invalidate the warranty, but will also expose the operator to hazardous diode laser radiation.

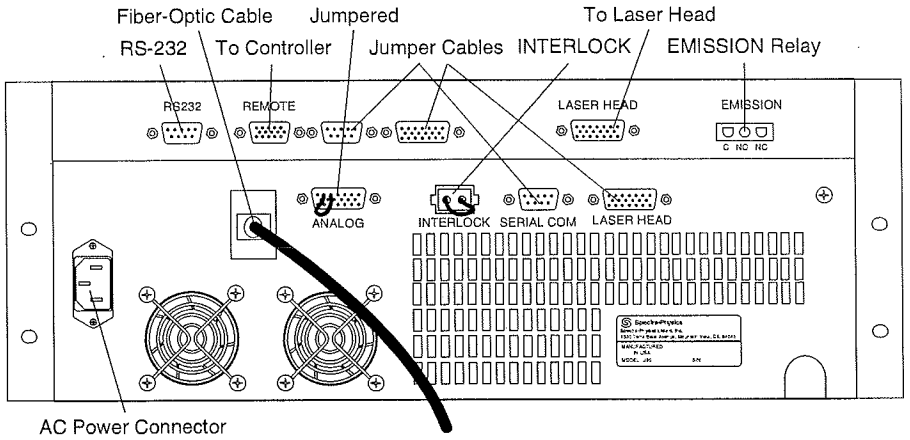
** Any electronic product radiation, except laser radiation, emitted by a laser product as a result of or necessary for the operation of a laser incorporated into that product.*

Safety Devices

Figure 2-3 and Figure 2-4 (next page) show the locations of the safety devices on the power supply and laser head.



Front Panel



Rear Panel

Figure 2-3: The *Model J20i* power supply showing the location of the safety devices.

Interlock Keyswitch

The LASER ENABLE keyswitch provides interlock safety to prevent unauthorized personnel from using the system when the key is turned to the OFF position and the key is removed.

Turning the key to the ON position closes the interlock and energizes the *Model J20i* system control circuitry. It then transfers system control to either the *Millennia* controller or the RS-232 serial interface.

Power Indicator

When on, the yellow POWER light on the power supply indicates that ac power is applied to the system control circuits.

Emission Indicator—Laser Head

When on, the white lamp on the laser head (Figure 2-4) indicates that emission is present or imminent.

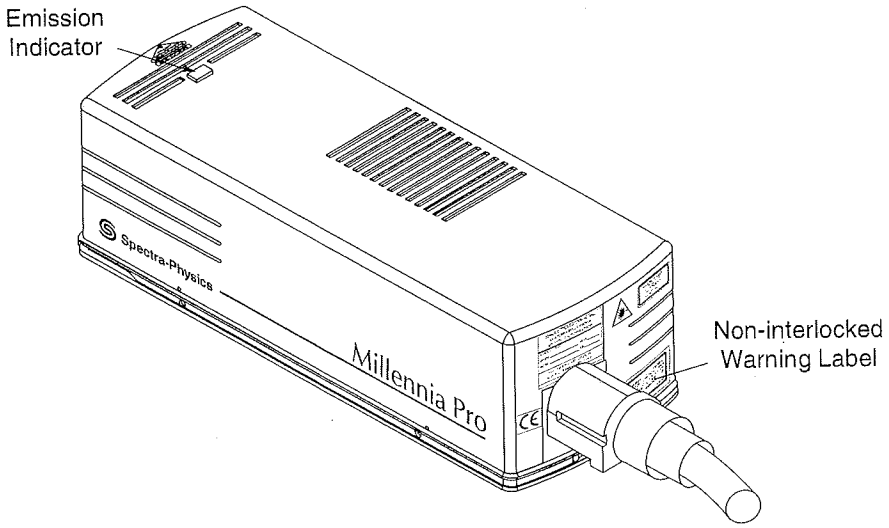


Figure 2-4: *Millennia Pro 2s* **Laser Head**

Emission Indicators—Power Supply

When on, the green EMISSION indicator on the power supply (Figure 2-3) indicates power is being supplied to the diode laser and that emission is present or imminent.

A connector on the back of the power supply (refer to Figure 2-5 and Figure 2-6) provides relay contacts can be used to turn on and off a user-installed emission indicator. When the laser is off, there is closure between pins 3 and 1 and an open between pins 3 and 2. The opposite is true when there is emission or emission is imminent. There is no power supplied by these terminals. This circuit is rated for 250 Vac at 1 A.

These indicators turn on 3 seconds before actual emission occurs.

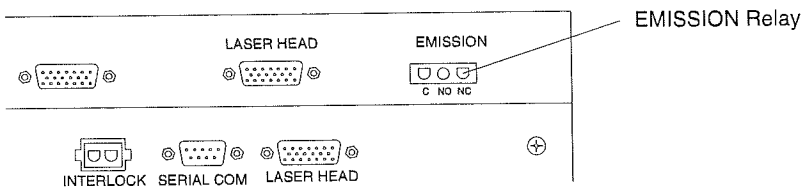


Figure 2-5: EMISSION Indicator Relay

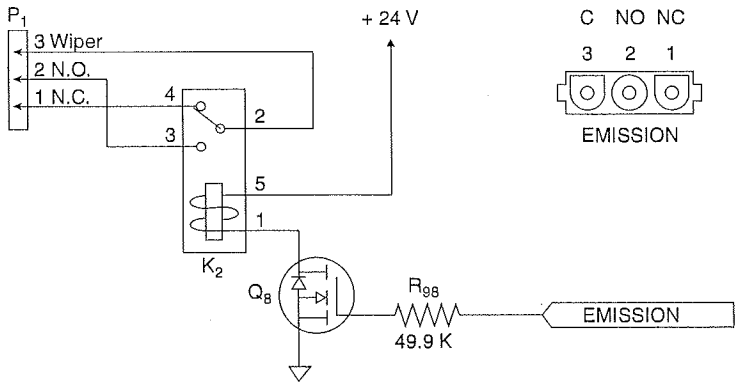


Figure 2-6: The EMISSION Connector Schematic

Shutter

The internal electromechanical laser head shutter is controlled either by the *Millennia* controller connected to the REMOTE connector on the power supply back panel, or by software commands via the RS-232 interface on the back panel. Its interlock fault and fail-safe mode is the closed position.

Safety Interlock

The INTERLOCK connector on the *Model J20i* power supply can be used as a remote safety interlock that can be wired to an external safety switch to turn off the laser in the event the switch is opened. However, to ensure that the laser can turn on even when this interlock is not used, the *Model J20i* is shipped with a shorting jumper plug (Figure 2-7) that defeats the interlock.

Note

To allow the diode laser to turn on, the two INTERLOCK contacts *must* either be wired to a safety switch or be shorted together using the jumper plug provided. The ANALOG jumper should always be installed.

Figure 2-7: INTERLOCK (left) and ANALOG (right) jumper plugs

To use this interlock, remove the jumper plug from the INTERLOCK connector, and either remove the jumper inside or use a similar connector without a jumper to wire to a perimeter safety switch. The switch can be attached to an access door or to other auxiliary safety equipment. Wire the switch as "normally closed" so that when the door or safety device is opened and the switch opens, the power to the diode lasers is immediately turned off, thus preventing unaware personnel from getting hurt.

The LASER HEAD connector is also part of the interlock loop: if the laser head cable is disconnected, the diode pump laser in the power supply is turned off.

ANALOG Interlock Jumper

The ANALOG port is not intended for use on this system. But because the system interlock circuit loops through this connector, a jumper plug (Figure 2-7) is provided to close the interlock circuit. Do not remove the ANALOG jumper plug from this connector. Doing so will prevent the laser from turning on.

Cover Safety Interlock

The laser head and power supply covers are not interlocked. Neither unit should be opened by the user.

Changing the diode laser module in the power supply is restricted to personnel trained by Spectra-Physics. The entire system is to be turned off when a diode laser module is changed, and the covers are to be installed before power is turned on again. The laser head and power supply are not intended to be run with the covers removed. Therefore, there are no cover interlocks. Labels under the power supply cover also warn of high voltages and state that power must be off before the internal covers can be removed.

CDRH Requirements for Operating the *Millennia Pro 2s* Without the Millennia Controller

The *Millennia Pro 2s* laser head and the *Model J20i* power supply comply with all CDRH safety standards when operated with the *Millennia* controller. However, when the laser is operated through the SERIAL COM interface (i.e., without the *Millennia* controller), you must provide the following in order to satisfy CDRH regulations:

- **An emission indicator**—that indicates laser energy is present or can be accessed. It can be a "power-on" lamp, a computer display that flashes a statement to this effect, or an indicator on the control equipment for this purpose.

  It need not be marked as an emission indicator so long as its function is obvious. Its presence is required on any control panel that affects laser output.

- **A safety key**—when the power supply interlock key is not accessible, you must provide a safety key to prevent unauthorized use. The password feature of your personal computer (in the CMOS Setup program) or the Windows* operating system meets this requirement.

* *Windows is a registered trademark of the Microsoft corporation.*

Maintenance Necessary to Keep this Laser Product in Compliance with Center for Devices and Radiological Health (CDRH) Regulations

This laser product complies with Title 21 of the *United States Code of Federal Regulations*, Chapter 1, subchapter J, parts 1040.10 and 1040.11, as applicable. To maintain compliance with these regulations, once a year, or whenever the product has been subjected to adverse environmental conditions (e.g., fire, flood, mechanical shock, spilled solvent, etc.), check to see that all features of the product identified on the CDRH Radiation Control Drawing (found later in this chapter) function properly. Also, make sure that all warning labels remain firmly attached.

1. Verify that removing the INTERLOCK connector on the *Model J20i* power supply (Figure 2-5) prevents laser operation.
2. Verify that the laser can only be turned on when the keyswitch is in the ON position, and that the key can only be removed when the switch is in the off position.
3. Verify that the emission indicator(s) provides a visible signal when the laser emits accessible laser radiation that exceeds the accessible emission limits for Class I.*
4. Verify the time delay between turn-on of the emission indicator(s) and the start of the laser; it must give enough warning to allow action to avoid exposure to laser radiation.
5. Verify that, when the interlock loop is opened, the shutter closes and actually blocks laser radiation emission.

If any of the above items fail to operate as noted and you cannot correct the error, call your Spectra-Physics service representative for assistance.

* *0.39 μW for continuous-wave operation where output is limited to the 400 to 1400 nm range.*

CE/CDRH Radiation Control Drawing

Refer to the CE/CDRH Warning Labels on the next page.

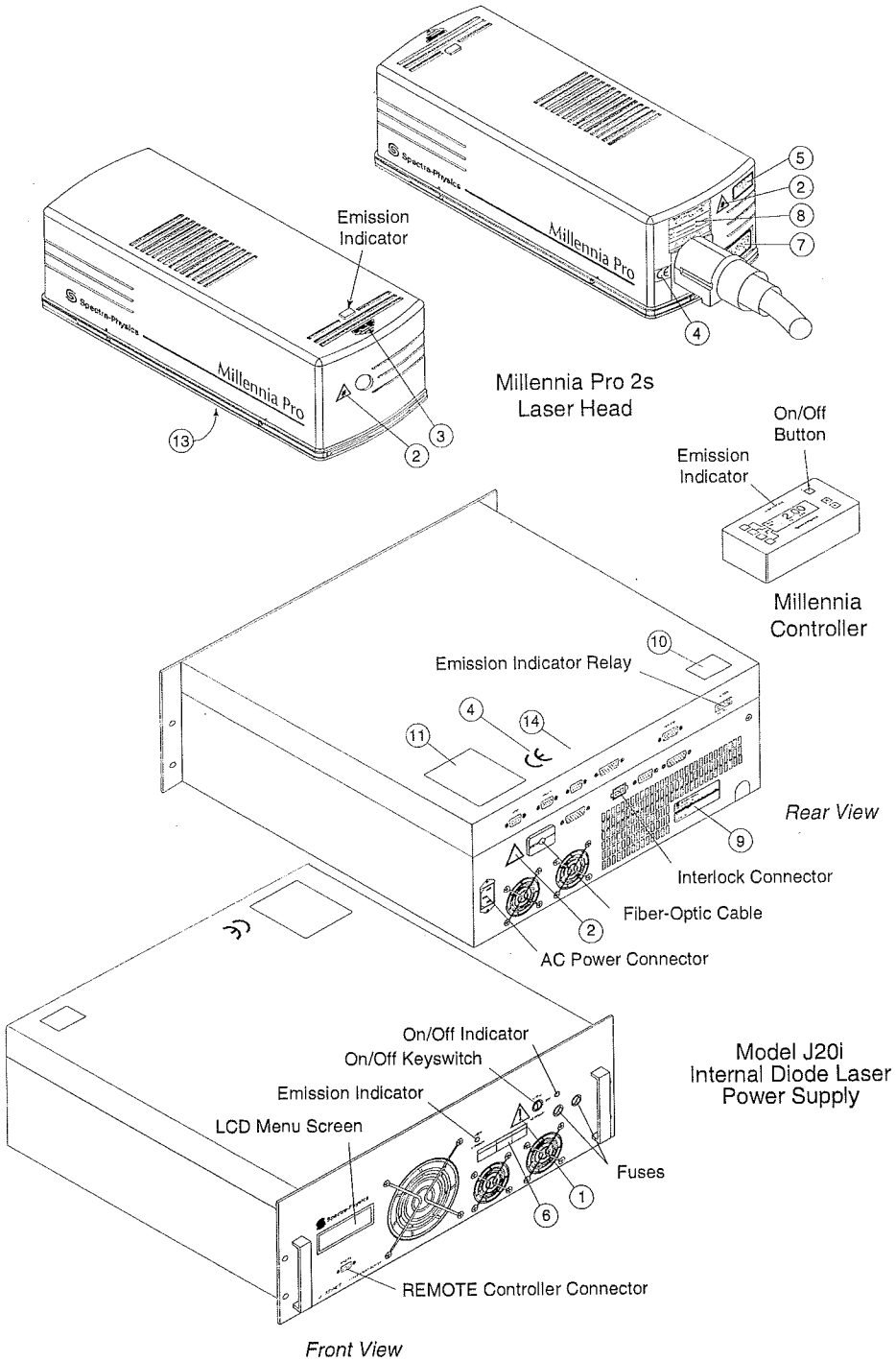


Figure 2-8: CE/CDRH Radiation Control Drawing

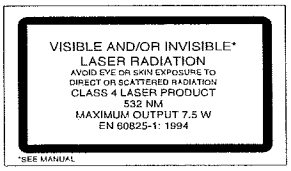
CE/CDRH Warning Labels

CE Caution Label (1)

CE Aperture Label (2)

CDRH Aperture Label (3)

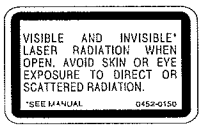
CE Certification Label (4)



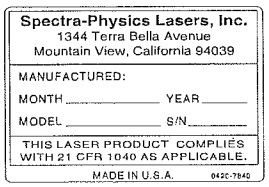
CE Danger Label Laser Radiation (5)

LINE VOLTAGE	FREQUENCY	FUSE F1 F2
100 – 200 V~ 200 – 240 V~	50 – 60 Hz	T 6A 125 V T 3A 250 V

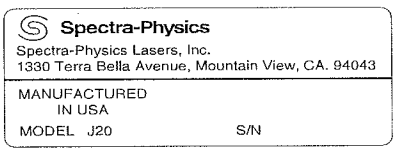
Fuse Label Power Supply (6)



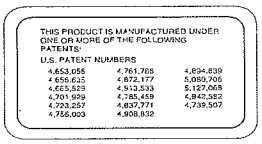
Non-interlocked Housing Label (7)



Laser Head Model/Serial Identification Label (8)



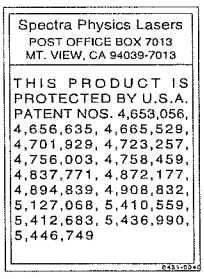
Power SupplyModel/Serial Identification Label (9)



Patent Label Power Supply (10)

CE Warning Label Interlock Defeated (11)

CE Warning Label (12)



Patent Label Laser Head (13)

Registered UL Label (14)

Figure 2-9: CE/CDRH Warning Labels

Label Translations

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

Table 2-1: Label Translations

Label No.	French	German	Spanish	Dutch
Aperture Label (3)	Ouverture Laser - Exposition Dangereuse - Un Rayonnement laser visible et/ou invisible est emis par cette ouverture.	Austritt von sichtbarer und unsichtbarer Laserstrahlung! Bestrahlung vermeiden!	Por esta abertura se emite radiacion laser visible e invisible; evite la exposicion.	Vanuit dit apertuur wordt zichtbare en onzichtbare laserstraling geemiteerd! Vermijd blootstelling!
Danger Laser Radiation (5)	Rayonnement laser visible et/ou invisible*. Exposition dangereuse de l'œil ou de la peau au rayonnement direct ou diffus. Laser de classe 4. 532 nm. Puissance maximum 15 W. *Voir manuel	Sichtbare und/oder unsichtbare Laserstrahlung. Bestrahlung von Auge oder Haut durch direkte oder Streustrahlung vermeiden. Laser Klasse 4; 532 nm; maximale Ausgangsstrahlung: 15 W. *Siehe Bedienungsanleitung.	Radiación láser visible y/o invisible. Evitar la exposición directa ó dispersa sobre la piel o los ojos. Producto láser Clase 4 532 nm, Potencia máxima 15 W. *Ver manual.	Zichtbare en/of onzichtbare* laser straling. Vermijd blootstelling aan ogen of huid door directe of gereflecteerde straling. Klasse 4 laser produkt; 532 nm, maximaal uittredend vermogen 15 W. *Zie handleiding
CE Non-Interlocked Label (7)	Rayonnement Laser Visible et Invisible en Cas D'Ouverture; Exposition Dangereuse de L'œil ou de la Peau au Rayonnement Direct ou Diffus.	Beim Öffnen Austritt von sichtbarer und unsichtbarer Laserstrahlung; Bestrahlung von Auge oder Haut durch direkte oder Streustrahlung vermeiden.	Cuando se abre existe Radiación Laser Visible e Invisible; Evite que los ojos y la piel queden expuestos tanto a la radiación directa como a la dispersa.	Zichtbare en niet zichtbare laser-straling wanneer geoend; vermijd blootsteling aan huid of oog aan disecte straling of weerkaatsingen.
Patent Labels (10, 13)	Ce produit est fabriqué sous l'un ou plusieurs des brevets suivants.	Dieses Produkt wurde unter Verwendung einer oder mehrerer der folgenden US-Patente hergestellt.	Este producto esta fabricado con una o más de las siguientes patentes de los Estados Unidos.	Dit product is gefabriceerd met een of meer van de volgende USA patenten.

CE Declaration of Conformity

We,

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

declare under our sole responsibility that the:

Millennia Pro 2s Diode-Pumped, Solid State Laser System with Model J20i power supply, Millennia controller or compliant, user-supplied, pc-based controller

manufactured after November 3, 2003,

meets the intent of EMC Directive 89/336/EEC: 1989, for electromagnetic compatibility and 73/23/EEC: 1973, for low-voltage directives. Compliance was demonstrated to the following specifications as listed in the official *Journal of the European Communities*:

EMC Directive 89/336/EEC: 1989

EN 61326-1 w/A1: 1997

Low Voltage Directive 73/23/EEC: 1973

EN 61010-1: 2001, Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use

EN 60825-1: 1997, Safety of laser products- Part 1 Equipment classification, requirements, and users guide

EN 60950: 1997, Safety of Information Technology Equipment, including electrical business equipment

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

Bruce Craig
Director of Engineering and Marketing

Spectra-Physics
Lasers & Photonics

Solid-State Lasers
October 27, 2003

Sources for Additional Information

The following are some sources for additional information on laser safety standards, safety equipment, and training.

Laser Safety Standards

Safe Use of Lasers (Z136.1: 1993)
American National Standards Institute (ANSI)
11 West 42nd Street
New York, NY 10036
Tel: (212) 642-4900

Occupational Safety and Health Administration (Publication 8.1-7)
U. S. Department of Labor
200 Constitution Avenue N. W., Room N3647
Washington, DC 20210
Tel: (202) 693-1999

A Guide for Control of Laser Hazards, 4th Edition, Publication #0165
American Conference of Governmental and
Industrial Hygienists (ACGIH)
1330 Kemper Meadow Drive
Cincinnati, OH 45240
Tel: (513) 742-2020
Internet: www.acgih.org/home.htm

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

Compliance Engineering
70 Codman Hill Road
Boxborough, MA 01719
Tel: (978) 635-8580

International Electrotechnical Commission
Journal of the European Communities
EN60825-1 TR3 Ed.1.0—Laser Safety Measurement and Instrumentation
IEC-309—Plug, Outlet and Socket Coupler for Industrial Uses
Tel: +41 22-919-0211
Fax: +41 22-919-0300
Internet: http://ftp.iec.c.h/

Cenelec
European Committee for Electrotechnical Standardization
Central Secretariat
rue de Stassart 35
B-1050 Brussels

Document Center
1504 Industrial Way, Unit 9
Belmont, CA 94002-4044
Tel: (415) 591-7600

Equipment and Training

Laser Safety Guide
Laser Institute of America
12424 Research Parkway, Suite 125
Orlando, FL 32826
Tel: (407) 380-1553

Laser Focus World Buyer's Guide
Laser Focus World
Penwell Publishing
10 Tara Blvd., 5th Floor
Nashua, NH 03062
Tel: (603) 891-0123

Lasers and Optronics Buyer's Guide
Lasers and Optronics
Gordon Publications
301 Gibraltar Drive
P.O. Box 650
Morris Plains, NJ 07950-0650
Tel: (973) 292-5100

Photonics Spectra Buyer's Guide
Photonics Spectra
Laurin Publications
Berkshire Common
PO Box 4949
Pittsfield, MA 01202-4949
Tel: (413) 499-0514

Chapter 3 Laser Description

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 3-1). The energy of an electron is determined by the orbital that it occupies, and the overall 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.*

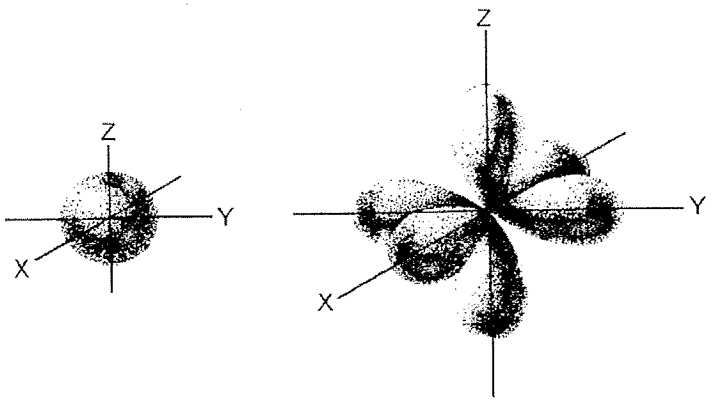


Figure 3-1: Electrons occupy distinct orbitals that are defined by the probability of finding an electron at a given position, the shape of the orbital being determined by the radial and angular dependence of the probability.

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 take advantage of absorption, and both spontaneous and stimulated emission phenomena, using them 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 3-2. 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.

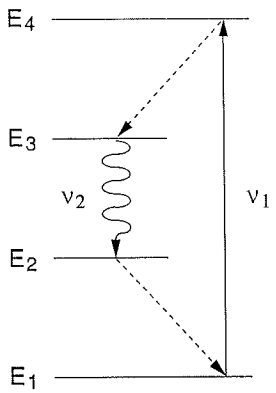


Figure 3-2: A Typical Four-level Transition Scheme

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. Also, the first atom that is pumped contributes to the population inversion in the four-level arrangement, while 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 a resonant 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.

Both cavity mirrors are coated to reflect the wavelength, or wavelengths, of interest while transmitting all others. One of the mirrors, the output coupler, transmits a fraction of the energy stored within the cavity, and the escaping radiation becomes the output beam of the laser.

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.

Linewidth 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 3-3).

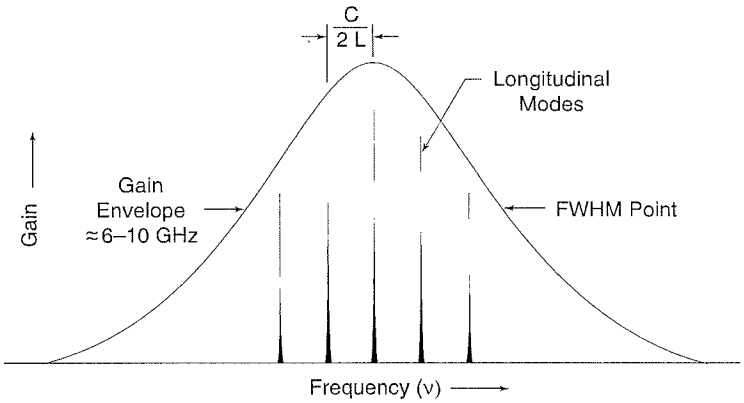


Figure 3-3: Frequency Distribution of Longitudinal Modes for a Single Line

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

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

Nd^{3+} as a Laser Medium

In commercial laser designs, the source of excitation energy for the gain medium is usually optical or electrical. Arc lamps are often employed to pump solid-state lasers, and 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 *Millennia® Pro 2s* uses the output from a diode laser to pump Nd^{3+} ions doped in a yttrium vanadate crystalline matrix (Nd:YVO_4).

The properties of neodymium-doped matrices, such as yttrium aluminum garnet (Nd:YAG) and yttrium lithium fluoride (Nd:YLF), are the most widely studied and best understood of all solid-state laser media. The four-level Nd^{3+} ion scheme is shown in Figure 3-4. The active medium is triply ionized neodymium which has principle absorption bands in the red and near infrared. Excited electrons quickly drop to the $^4F_{3/2}$ level, the upper level of the lasing transition, where they remain for a relatively long time (about 60 µs for Nd:YVO_4).

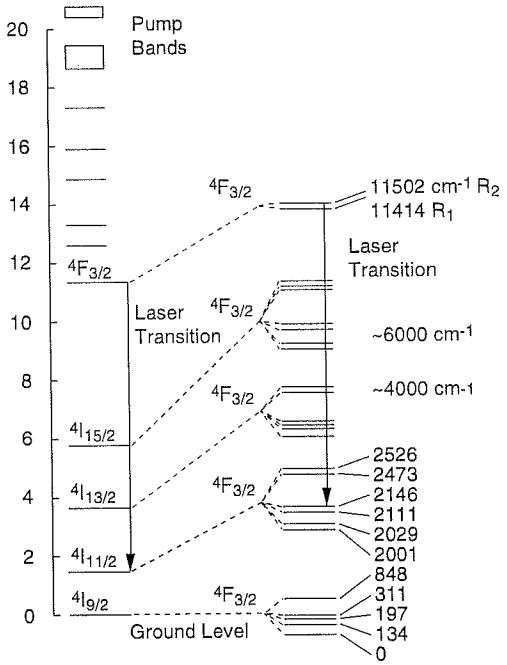


Figure 3-4: Energy Level Scheme for the Nd^{3+} Ion

The most probable lasing transition is to the $^4I_{1/2}$ state, where a photon at 1064 nm is emitted. Because electrons in that state quickly relax to the ground state, its population remains low. Hence, it is easy to build a population inversion. At room temperature the emission cross section of this transition is high, so its lasing threshold is low. While there are competing transitions from the same upper state, most notably at 1319, 1338, and 946 nm, all have lower gain and a higher threshold than the 1064 nm transition. In normal operation, these factors and wavelength-selective optics limit oscillation to 1064 nm.

Diode-Pumped Laser Design

Diode lasers combine very high brightness, high efficiency, monochromaticity and compact size in a near-ideal source for pumping solid-state lasers. Figure 3-5 shows the monochromaticity of the emission spectra of a diode laser compared to a krypton arc lamp and a black body source, and compares that with the absorption spectra of the Nd^{3+} ion. The near-perfect overlap of the diode laser output with the Nd^{3+} absorption band ensures that the pump light is efficiently coupled into the laser medium. It also reduces thermal loading since any pump light *not* coupled into the medium is ultimately removed as heat.

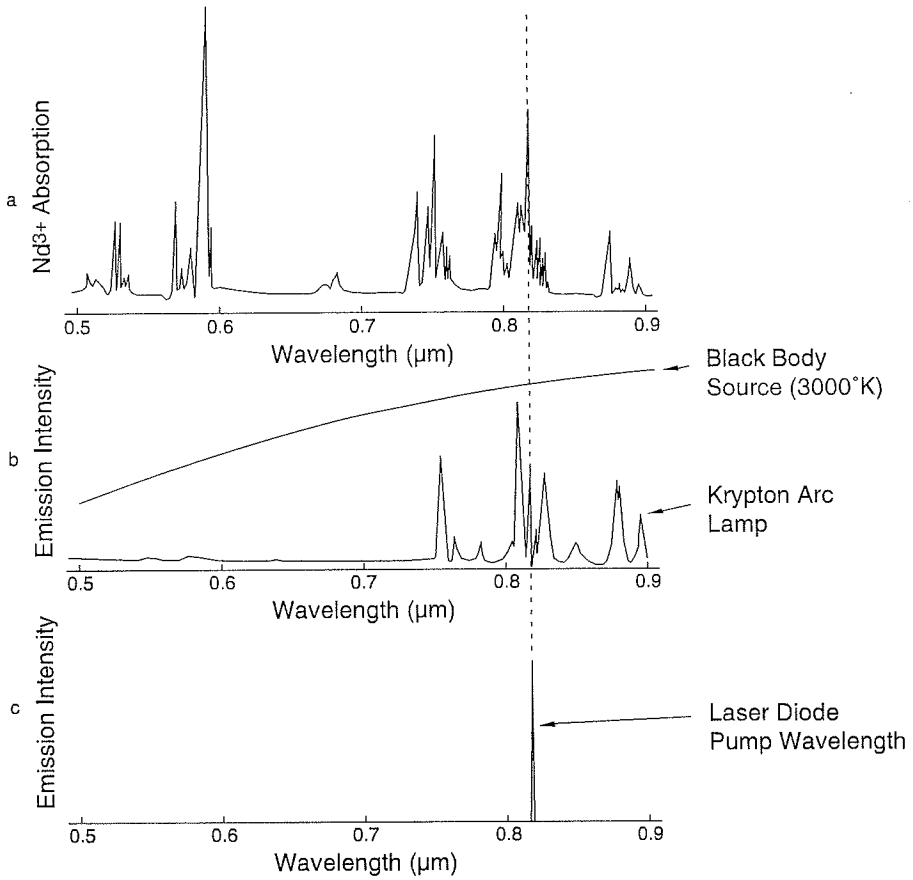


Figure 3-5: Nd^{3+} absorption spectra (a) compared to emission spectra of a black body source and krypton arc lamp (b) and a diode pump laser (c).

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. The maximization of this overlap is often called *mode matching*, and in most applications, TEM_{00} is the laser mode that is most desired (a single spot that is brighter in the middle than on the edge). A longitudinal pumping geometry provides this sort of optimal mode-match.

Longitudinal pumping (along the beam path) 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 radius is chosen to be as small as possible to minimize the solid-state laser threshold. Figure 3-6 shows a schematic of a mode-matching design of this type.

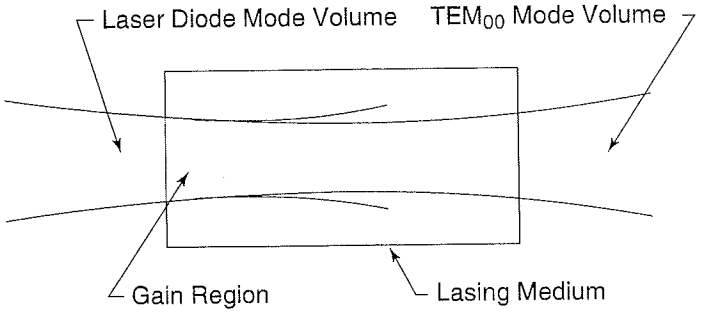


Figure 3-6: Mode Matching

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. However, increasing the TEM_{00} mode volume raises the solid-state laser threshold. This is undesirable when attempting to create an efficient diode laser design.

At Spectra-Physics, diode laser bars are used that are made from a single monolithic piece of semiconductor material that typically contains ten to twenty diode lasers. The bars are ideal as high power pump sources. They have the same high efficiency as discrete diode devices, yet they allow for manufacture of a much simpler and more reliable high-power pump laser design than is possible in a design incorporating an equal number of discrete devices (for the same output power level). However, the active emission area for these new devices is increased from the 200 μm range found in low-power diode lasers, to 1 cm: a "ribbon of light." The use of these bars has, therefore, been limited due to the difficulty of mode matching their outputs.

A number of attempts were made by some manufacturers to couple the output of a diode laser bar into a multimode optical fiber, but the results were discouraging, with coupling efficiencies on the order of 60–70% with a numerical aperture of 0.4. This makes for an expensive, inefficient pump source.

Spectra-Physics developed and patented a vastly more efficient method of fiber coupling the output of the diode laser bar called FC*bar*™. With this method, it is possible to achieve coupling efficiencies in excess of 90% with a numerical aperture of 0.1. With such high coupling efficiency and brightness, high power diode-pumped laser designs are readily achieved.

Frequency Doubling

In the *Millennia Pro 2s*, the high output power from the diode laser is used to end-pump the Nd:YVO_4 lasing medium. The resulting 1064 nm output is converted to visible light through frequency doubling (or second harmonic generation) in a nonlinear crystal. The *Millennia Pro 2s* uses a 90°, noncritically phase-matched, temperature-tuned lithium triborate (LBO) nonlinear crystal as its doubling medium. Although LBO has a lower nonlinear coefficient than other materials, it offers several advantages: (a) noncritical phase matching means colinear fundamental and second harmonic beams, which facilitates alignment, (b) there is no spatial "walk-off" of the fundamental and second harmonic beams, which preserves the high spatial mode quality and favors a long interaction length for higher gain, and (c) the crystal can be easily optimized for maximum conversion efficiency by simply changing its temperature (with no realignment of the laser cavity).

In frequency doubling, the second harmonic power ($P_{2\omega}$) is given by:

$$P_{2\omega} \propto \frac{d_{eff}^2 P_{\omega}^2 l^2 [\phi]}{A} \qquad [5]$$

where d_{eff} is the effective nonlinear coefficient, P_{ω} is the fundamental input power, l is the effective crystal length, $[\phi]$ is a phase-matching factor, and A is the cross-sectional area of the beam in the crystal. Since the second harmonic output is dependent upon the square of the fundamental peak power, very high conversion efficiencies can be achieved by enhancing the intensity of the fundamental wave through intracavity frequency doubling or through the use of an external-cavity resonant-doubler. The former is used in the *Millennia Pro 2s*.

Historically, free-running intracavity-doubled, diode-pumped, solid-state lasers have typically yielded chaotic output with large amplitude fluctuations that render the laser output useless for most scientific applications. This was first identified at Spectra-Physics* over fifteen years ago in a short cavity diode-pumped Nd:YAG laser with a KTP intracavity doubler; it has since become known as the "green problem." Part of the cause of the instability arises from nonlinear coupling of axial modes via sum-frequency mixing in the laser cavity. The problem can be circumvented by forcing oscillation on a single longitudinal mode. However, this adds considerable complexity to the laser, since it requires an actively stabilized ring cavity (and it may also have power limitations). The *Millennia Pro 2s* overcomes this chaotic noise problem with the simple, patented**, QMAD (Quiet Multiaxial Mode Doubling) technology, which makes use of many axial modes (see Figure 3-7).

* *T. Baer. J. Opt. Soc. Am. B3, 1175 (1986).*
** *patent number 5,446,749*

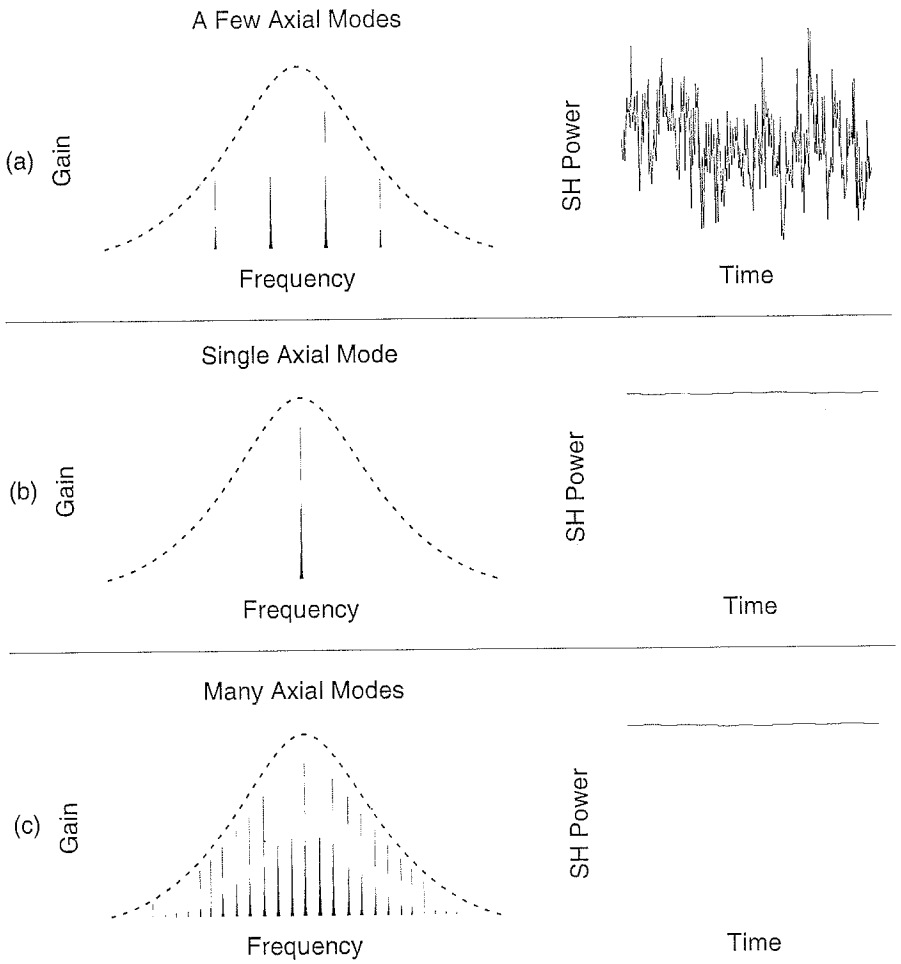


Figure 3-7: The quiet multiaxial mode-doubling (QMAD) solution to the "green problem." (a) The "green problem." Intracavity frequency doubling in a laser with a few axial modes produces large amplitude fluctuations in the second harmonic output resulting from nonlinear coupling of the modes through sum-frequency mixing. (b) The single-frequency solution forces oscillation on a single axial mode to eliminate mode coupling. (c) The QMAD solution produces oscillation on many axial modes, effectively averaging the nonlinear coupling terms to provide highly stable second-harmonic output.

In the *Millennia Pro 2s*, the laser cavity allows oscillation of over 100 longitudinal modes. This facilitates quiet intracavity doubling by reducing the relative power in each axial mode so that no one mode reaches sufficient peak power to induce high nonlinear loss. Effectively, there is an averaging of the nonlinear coupling terms, and the resultant frequency-doubled output exhibits extremely low-amplitude noise (about an order of magnitude lower than that of an ion laser).

The Millennia Pro 2s System

The *Millennia Pro 2s* laser head is designed for maximum reliability with minimum complexity. Operation is so inherently stable and the output so quiet that no adjustments are needed for normal use.

The *Millennia Pro 2s* system comprises three basic components:

- *Millennia Pro 2s* laser head
- *Model J20i* power supply
- *Millennia* Controller

The following sections will be confined to descriptions of the laser head and power supply. The controller is fully described in Chapter 6.

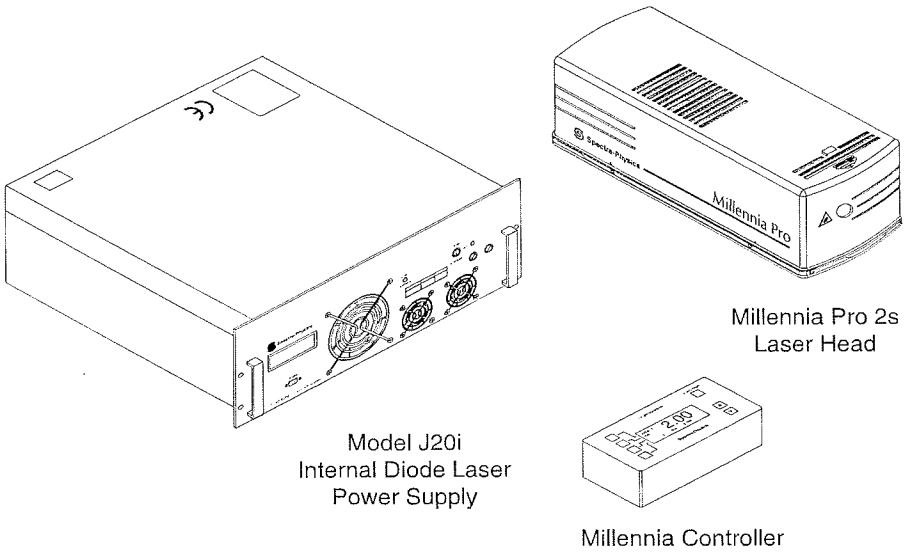


Figure 3-8: The *Millennia Pro 2s* System

The output from a high-power, fiber-coupled diode module (FC*bar)* in the power supply is used to end-pump the laser gain medium (a neodymium yttrium vanadate ($Nd:YVO_4$) crystal) in the laser head. Because the FC*bar* design allows the diode module to be placed in the *Model J20i* power supply, the heat it generates does not adversely affect the laser head. Plus, such placement eliminates the need to realign the cavity if the module needs to be replaced. The infrared laser light generated by the crystal is converted to 532 nm green output by intracavity frequency doubling.

Control of the entire system is available via a simple, menu-driven controller that attaches to the power supply via an 8-foot cable.

The Millennia Pro 2s Laser Head

The $Nd:YVO_4$ laser crystal is the "driving engine" of the *Millennia Pro 2s* laser. The crystal is end-pumped by the the output of the FC*bar* diode module in the power supply and provides a very high, small-signal CW gain. The crystal is capable of producing over 5 W of near diffraction-limited, 1064 nm infrared power with a conversion efficiency greater than 50%.

To produce 532 nm green laser output, the *Millennia Pro 2s* uses a simple, linear, X-Cavity design to double the 1064 nm infrared input power.

As shown in Figure 3-9, the output from the pump module in the power supply is fiber-coupled into the laser head and focused into one end of the Nd:YVO_4 laser crystal. A telescope focuses the pump light through a dichroic fold mirror and into the laser crystal. This mirror is highly transmissive at the diode pump laser wavelength and highly reflective at 1064 nm. The diode laser light is absorbed by the crystal, which then produces output at 1064 nm.

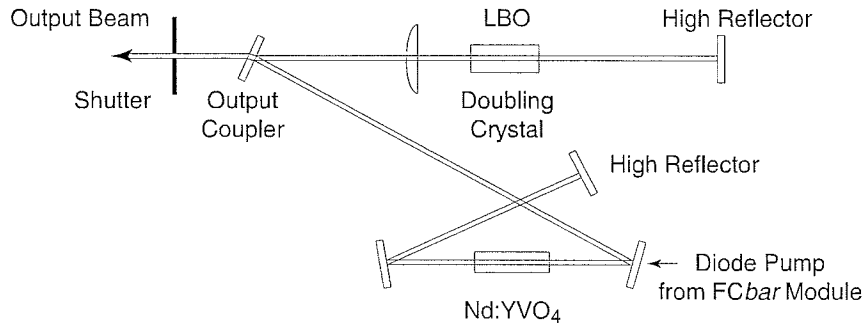


Figure 3-9: Schematic of the *Millennia Pro 2s* Laser Head

A lithium triborate (LBO) crystal placed in the cavity converts the 1024 nm intracavity light to the green 532 nm output wavelength through nonlinear processes.

Frequency Doubling

Frequency-doubling converts the 1064 nm light from the laser crystal to the green 532 nm light that becomes the output of the laser.

For maximum intracavity frequency doubling efficiency, a noncritically phase-matched, temperature-tuned LBO crystal is used. It offers a large acceptance angle, which makes it insensitive to any slight misalignment of the *Millennia Pro 2s* cavity. A compact, low-power, temperature-regulating oven is used to maintain the crystal at the appropriate phase-matching temperature to maintain the 532 nm output power.

QMAD technology allows the *Millennia Pro 2s* to provide greater than 2 Watts of exceptionally stable, low-noise, frequency-doubled light. It provides a stable balance of:

- a very large number of axial modes (typically hundreds)
- small signal gain
- gain saturation
- nonlinear conversion
- long excited-state lifetime and
- cavity lifetime.

The result is a high-power, multiaxial-mode laser that exhibits extremely low noise performance with very high reliability, and a doubled beam that has a smooth intensity distribution and is near diffraction limited.

Beam Delivery

A dichroic output coupler allows the 532 nm light to exit the cavity while reflecting the 1064 nm light back into the cavity. Virtually all the doubled light passes through the dichroic output coupler where the beam is directed out of the laser. The 90° polarization rotator aligns the polarization axis vertically for convenience to match the orientation commonly found in many applications.

A beam splitter and photodiode sample the output and provide feedback to the pump laser driver to provide a constant output in power mode operation. A shutter placed outside the cavity enclosure attenuates the beam until it is commanded to open either by the controller or via remote command.

Unlike other systems that require multiple feedback loops to maintain stable output, the *Millennia Pro 2s* is inherently stable within its operating range. It requires only one simple feedback loop to maintain its exceptional performance and maintain constant output power. The light pick-off is an integral part of the system.

The Model J20i Power Supply

The *Model J20i* power supply provides the diode laser pump light that powers the *Millennia Pro 2s* laser head. It also contains the power circuitry for the system, as well as the thermo-electric cooler for the diode module. The logic control hardware is housed in the top section of the power supply.

The *Model J20i* is available in either 110 Vac or 220 Vac versions, for 10 A 50/60 Hz single phase electric utilities, and it is air cooled.

The FCbar System

The pump source for the *Millennia Pro 2s* laser head consists of a single ProLite diode laser capable of producing 20 W. An integral optical fiber cable transports the output from the module containing the ProLite to the laser head where it is focused into one end of the laser crystal. This patented modular concept is called a "fiber-coupled bar" or FC*bar*.

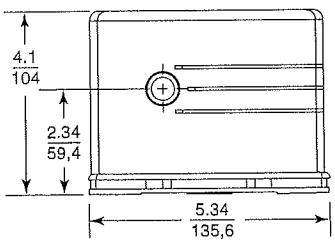
FC*bar* technology enables the high power levels available from the diode module in the power supply to be used to efficiently end-pump the Nd:YVO_4 laser crystal in the laser head. This is done (a) by collimating the output of the module with a cylindrical microlens of high numerical aperture, then (b) by coupling this highly asymmetric light into a fiber bundle that, in turn, delivers a symmetrical beam of exceptional brightness to the crystal. To stabilize the output wavelength of the diode module, the module is mounted directly onto a temperature regulated heatsink.

Because the coupling technology is so efficient, the 20 W diode module is significantly derated to increase its operating lifetime. Typically, 85 to 90 percent of the diode laser light is transmitted by the bundle. Thus, as much as 13 W of usable output is available from the derated diode module at the output of the fiber bundle.

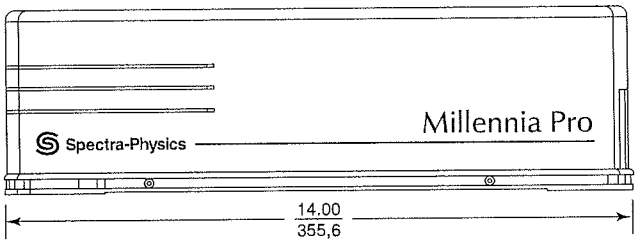
The fiber bundle is then terminated at the laser head with an industry standard fiber-optic connector that provides a precise and repeatable attach-

ment of the bundle to the laser head. This allows the FC*bar* module to be replaced in the field without requiring re-alignment of the *Millennia* laser cavity.

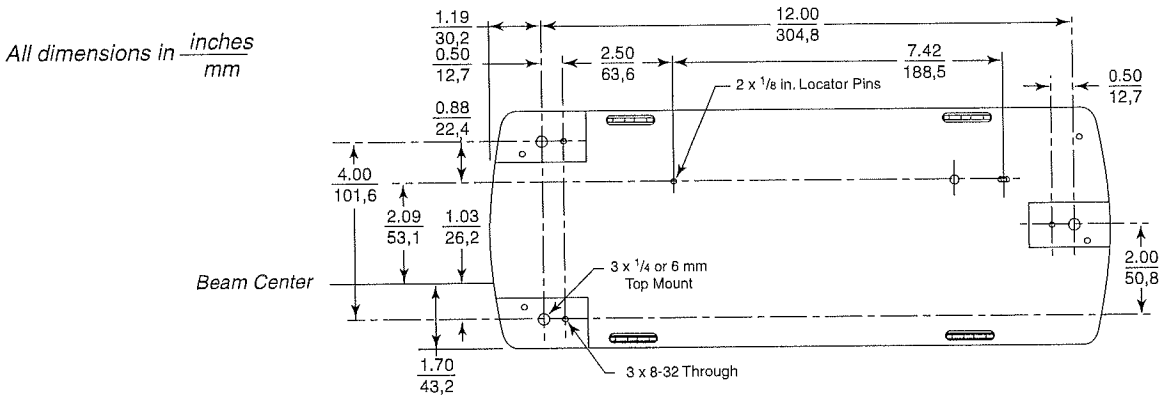
Outline Drawings



Millennia Pro 2s Output End View

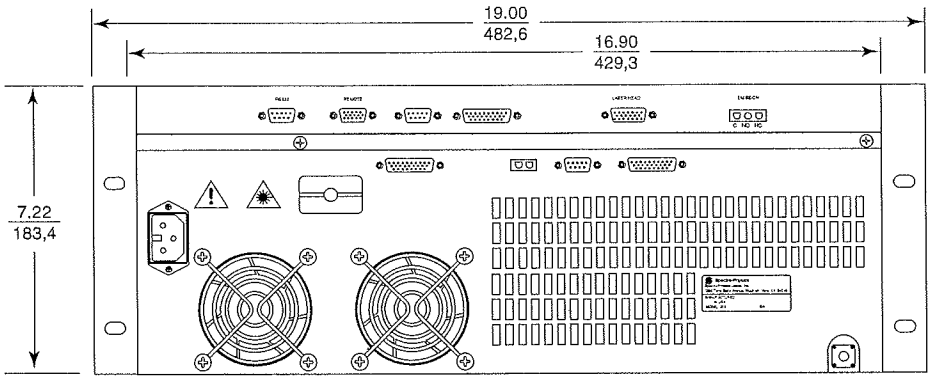


Millennia Pro 2s Side View

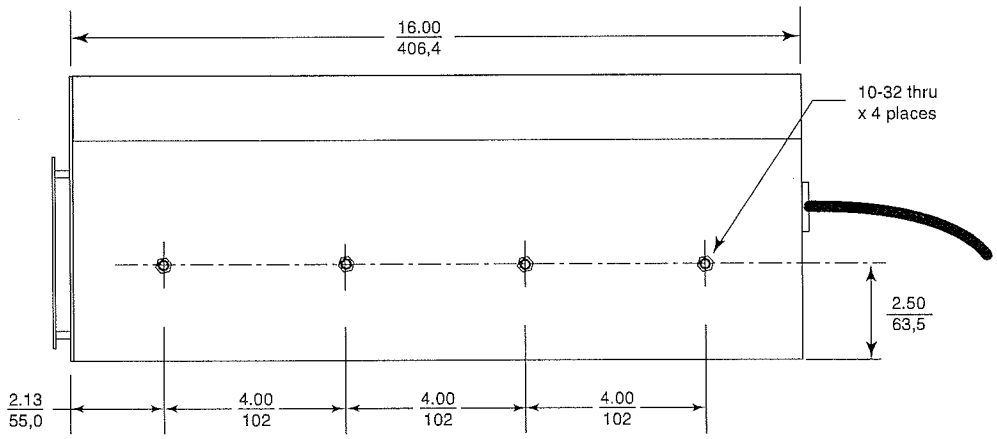


Millennia Pro 2s Bottom View

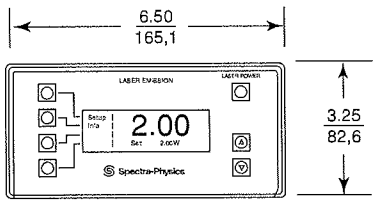
Figure 3-10: Outline Drawing, *Millennia Pro 2s*



Back Panel, Model J20i Power Supply



Side View, Model J20i Power Supply



All dimensions in inches / mm

Millennia Controller Top View

Millennia Controller Side View

Figure 3-11: Outline Drawing, *Model J20i*

Specifications

Table 3-1: *Millennia Pro 2s* Laser Output Characteristics[1]

Power	> 2 W
Wavelength	532 nm
Spatial Mode[2]	TEM_{00}
Beam diameter at $1/e^2$ points[3]	2.3 mm ±10%
Beam divergence, full angle	< 0.5 mrad
Polarization	> 100:1, vertical
Power Stability[4]	±1%
Beam Pointing Stability[5]	< 5 µrad/°C
Noise[6]	< 0.04% rms
Boresight Tolerance	
Nearfield	±0.25 mm
Farfield	< 3 mrad

[1] *Specifications subject to change without notice.*
[2] *M^2 < 1.1; Beam ellipticity < 10%.*
[3] *Measured at the exit port.*
[4] *Measured over a 2-hour period after a 30-minute warm-up, from standby mode*
[5] *Measured as far-field x and y positions, after a 30-minute warm-up, from standby mode.*
[6] *Measured over a 10 Hz to 0.1 GHz bandwidth at the specified output power*

Table 3-2: Power Requirements

Power Supply	110 Vac ±10% at < 10 A, 50/60 Hz 220 Vac ±10% at < 6 A, 50/60 Hz

Table 3-3: Fuse Requirements (Power Supply)

Fuses (3AG, Type T, Fast Blow)	F_1 / F_2
100 – 200 Vac	6 A 125 V
200 – 240 Vac	3 A 250 V

Table 3-4: Dimensions

Laser Head	
Size (H x W x L)	10.4 x 13.5 x 35.0 cm (4.1 x 5.3 x 14.0 in.)
Weight	10 kg (22 lb)
Umbilical Length	4 m (13 ft)
Controller Cable Length	2.5 m (8 ft)
Power Supply	
Size (H x W x L)	18.3 x 48.3 x 40.6 cm (7.2 x 19 x 16 in.)
Weight	11 kg (25 lb)
Power Cable Length	2.44 m (8 ft)

Chapter 4 Controls, Indicators and Connections

Introduction

This chapter defines the user controls, indicators and connections of the *Millennia Pro 2s* laser system and is sub-divided into three sections: the *Millennia Pro 2s* laser head, the *Millennia* controller and the *Model J20i* power supply.

The Millennia Pro 2s Laser Head

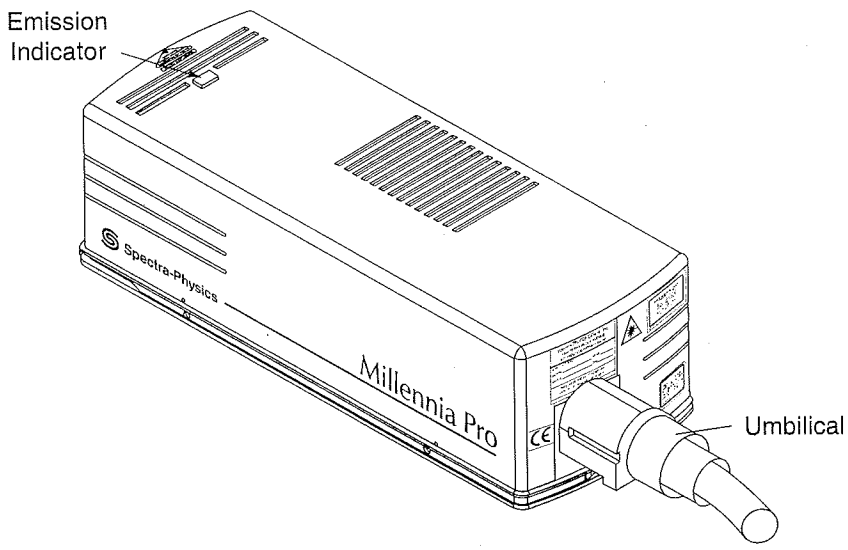


Figure 4-1: The *Millennia Pro 2s* laser head

Internal Controls

There are no user-serviceable parts or adjustments to be made inside the laser head.

Indicators

Emission indicator light—warns of present or imminent laser radiation. This white-light CDRH indicator is located on top of the laser near the output bezel. A built-in delay between lamp turn-on and actual emission allows for evasive action in the event the system was started by mistake and the shutter is open.

Connections

Umbilical connector—provides pump laser energy to the laser head from the laser diode module in the power supply. *This umbilical is permanently attached to both the laser head and power supply: do not try to remove it.* To move the laser system, set the laser head and the controller on top of the power supply and carry or cart the system to its new location.

Control cable—provides control signals to and from the power supply.

Millennia Controller

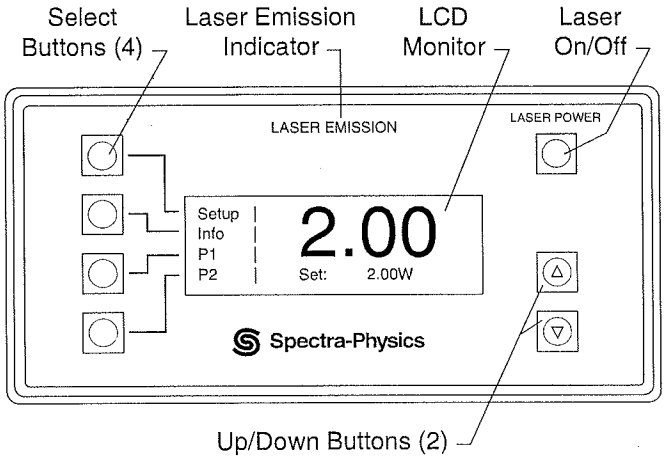


Figure 4-2: The *Millennia* Controller

Controls

Seven buttons on the controller operate the *Millennia Pro 2s* laser.

Select buttons (4)—located to the left of the LCD screen are used to select one of four possible actions shown on the left side of the screen. For example, pressing the top left button brings up the Setup menu. When the up/down arrows are shown on the screen, pressing the associated button scrolls the text.

LASER POWER button—performs 3 functions: (a) it begins the laser warm-up cycle, (b) turns on the laser and (c) turns off the laser. (Note: the LASER ENABLE interlock keyswitch on the power supply must be set to ON in order for the laser to turn on).

Press the button once to begin the warm-up cycle. Then, when the cycle completes, press and hold it in about 3 seconds to turn on the laser. The emission indicator on the laser head turns on while the button is held in, LASER EMISSION on the controller panel flashes, and the power supply EMISSION circuit closes to indicate emission is imminent (following a CDRH delay of about 6 seconds).

When emission actually occurs, the LASER EMISSION indicator on the controller stops flashing and stays on.

Up/down buttons—in the lower right corner of the panel increase or decrease the value displayed on the screen, or allow the operator to select from a list a parameter to be changed or displayed.

Shutter—blocks the output beam when output is not requested. The shutter is controlled manually via the Setup menu on the controller or via the RS-232 interface using software (see Chapter 6).

Indicators

LCD monitor—provides feedback and control of the laser, depending on which menu is displayed. Large digits always display *actual output power.* Below the output power display and shown in smaller text is the output power setpoint. "RS-232 Enabled" is shown instead if the system is being operated remotely via the RS-232 serial link.

LASER EMISSION indicator—is off when there is no laser emission, flashes 3 seconds prior to emission, then stays on when emission is present.

Connections

There are no connectors on the controller. The 3 m control cable is permanently attached; do not try to remove it. This cable plugs into the 15-pin REMOTE connector on the back of the power supply.

Model J20i Power Supply

Front Panel

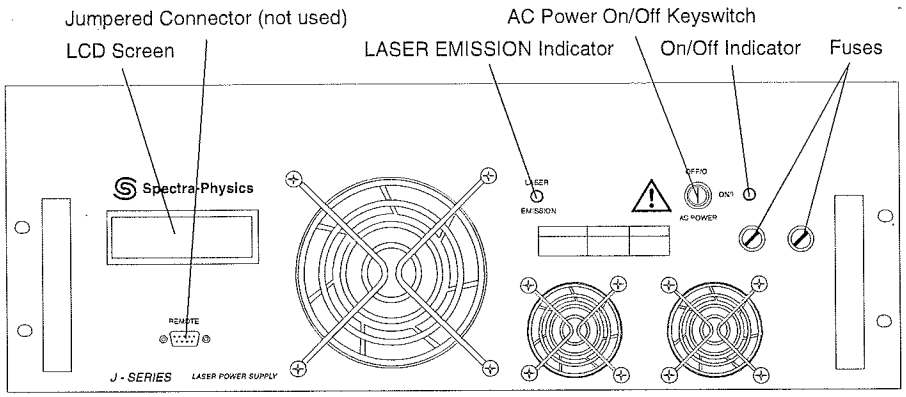


Figure 4-3: The *Model J20i* Power Supply Front Panel

LCD display—displays the status (including status codes) of the power supply during boot-up and normal operation. If a problem occurs, all warnings, including system operation errors, are displayed on this panel as well as the control device.

LASER EMISSION indicator (green)—shows that power is supplied to the diode module and that laser emission is present or imminent.

AC POWER OFF/ON keyswitch—provides power to the laser system when it is turned on and prevents unauthorized use of the laser when it is turned

off and the key is removed. When the key is inserted and turned to the ON position, the power supply performs an internal diagnostic check, and the laser head doubling crystal oven is allowed to warm up. Control then transfers to the *Millennia* controller or to the host system (via the RS-232 link), depending on your configuration.

Note

Because the power supply must be on in order for the doubling oven to remain on, it is recommended that, to permit a short warm-up period, the AC POWER ON/OFF keyswitch be left in the ON position at all times (unless the system is going to be off for an extended period of time) and that the *Millennia* controller or RS-232 serial commands be used to turn the system on and off. If security is an issue, use the key to turn off the system, then remove the key.

ON/OFF indicator (yellow)—turns on immediately when line power is applied to the system and the keyswitch is turned on.

Fuses (F1, F2)—provide protection for various circuits. Replace fuses F1 and F2 according to the table in Chapter 3.

REMOTE connector (9-pin, D-sub)—is not used and a jumper is provided that should never be removed. For system control, use the REMOTE connector on the rear panel when the controller is used or the RS-232 connector when remote control is necessary.

Air intake—allows cooling air to be drawn into the power supply. Heated exhaust air is vented from the rear panel.

Warning!

Provide at least 6 inches of clearance to the power supply front and back panels to allow cool air to enter the front and for the heated exhaust air to exit the rear panel. Damage to components caused by insufficient cooling is not covered by the warranty.

Rear Panel

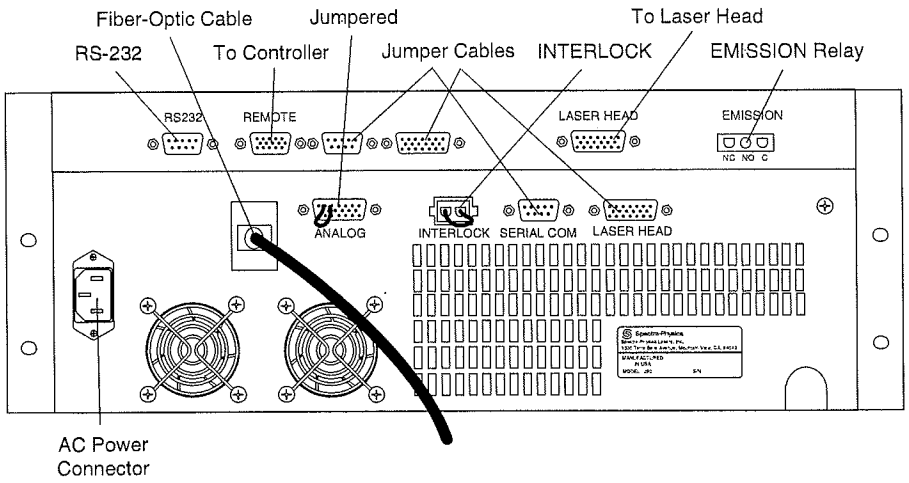


Figure 4-4: The *Model J20i* Power Supply Rear Panel

The following are described as you view the power supply control panel from left to right, top to bottom.

Top Row

RS-232 serial port connector (9-pin, D-sub)—provides a standard serial port attachment for a host system to operate the system remotely. Only three of the pins are used. Controlling the system via serial commands using this port is described in Chapter 6, "Operation."

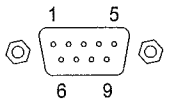


Figure 4-5: The 9-Pin SERIAL COM Port

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

	Computer or Terminal			*Model J20i*	
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	

REMOTE connector (15-pin, D-sub)—provides attachment for the *Millennia* controller.

Jumpered connector (9-pin, D-sub)—should be permanently attached to the SERIAL COM connector below it in the second row. Do not disconnect the connector attached to it.

Jumpered connector (27-pin, D-sub)—should be permanently attached to the LASER HEAD connector below it in the second row. Do not disconnect the connector attached to it.

LASER HEAD connector (27-pin D-sub)—provides attachment for the control cable to the laser head.

EMISSION connector (3-pin Molex)—provides access to relay contacts that can be used to turn on and off a user-installed emission indicator. When the laser is off (i.e., there is no emission), there is closure between the NC and C terminals and an open between the NO and C terminals. The opposite is true when the laser is on, i.e., there is emission or emission is imminent. There is no power supplied by these terminals. This circuit is rated for 250 Vac at 1 A.

Pin #	Description
3	Wiper
2	Normally Open
1	Normally Closed

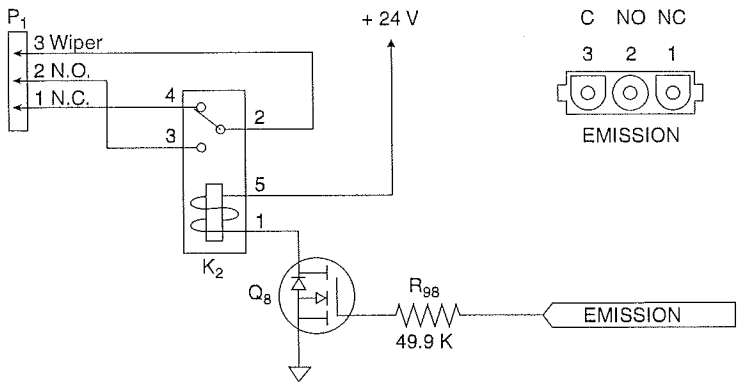


Figure 4-6: *Model J20i* Emission Connector Circuit

Second Row

Fiber-optic cable—pass-through for the armored fiber-optic cable. This cable is permanently attached to the diode module inside the power supply. Do not try to disconnect it. Call Spectra-Physics to set up a service call if the diode module needs replacement.

ANALOG connector (26-pin, D-sub)—provides attachment for a jumpered plug that configures the *Model J20i* power supply for use with the *Millennia Pro 2s* laser. *Do not remove the plug: doing so will keep the system from starting, or will shut it off if it is already on.*

INTERLOCK connector (2-pin Molex)—provides attachment for a user-supplied safety switch. These contacts must be shorted together before the laser will operate. A defeating jumper plug is installed at the factory to permit operation without a safety switch. The plug can be replaced with a similar non-shorting plug that is wired to auxiliary safety equipment (such as a door switch) to shut off the laser when actuated (opened). Such a switch must be designed for a low-voltage, low-current signal.

Pin #	Description
1	System Interlock
2	System Interlock Return

Jumpered SERIAL COM connector (9-pin)—should always be attached to the 9-pin connector above it in the top row. Do not disconnect the connector attached to it. Also, do not confuse this connector with the RS-232 connector on the top row that provides attachment for a terminal or computer.

Jumpered LASER HEAD connector (27-pin, D-sub)—should always be attached to the 27-pin connector above it in the top row. Do not disconnect the connecting cable attached to it.

Lower Section

Power cord connector—provides attachment for the IEC-320-C13 power cord provided with the unit. Connect the cord to a power source capable of providing 15/10 A at 110/220 Vac.

Air exhaust—vents heated air from the power supply.

Chapter 5 Installation

Warning!

The installation procedures in this chapter are not intended for the initial installation of your laser. Call your Spectra-Physics service representative to arrange an installation appointment, *which is part of your purchase agreement*. Allow only personnel authorized by Spectra-Physics to install and set up your laser. You will be charged for repair of any damage incurred if you attempt to install the laser yourself, and such action might also void your warranty.

This section provides information for the initial planning and set-up of the *Millennia® Pro 2s* laser system. If the laser has not been set up before, or if you are moving the laser system to a new location, please review this section in detail.

When you received your laser, it was packed with the laser head and power supply already connected. *Do not disconnect the umbilical cable from either end!*

System Installation Considerations

Be sure to follow all safety precautions for laser use while handling or storing the laser. Be sure to install all laser safety devices before using the laser. Refer to the Chapter 2, "Laser Safety," for more information on this topic.

Except for a small screwdriver, all the tools and equipment needed to set up the *Millennia Pro 2s* laser are in the accessory kit.

The laser head is fastened to the mounting surface using the clamps, screws and nested spherical washers provided with the system. The clamps can be used with optical tables with either metric spacing or English hole spacing.

The power supply and laser head together typically produce about 500 W (1.7 kBTU per hour) of waste heat. Provide enough cooling capacity to prevent the room from over-heating.

The fiber-optic bundles in the umbilical have a minimum bend radius of 6 in. (15 cm). Consider both the minimum bend radius and strain relief as you route the umbilical from the power supply to the laser head.

Warning!

Do not twist the umbilical or bend it to a radius of less than 6 in. (15 cm). Doing so can damage the fibers inside. Such damage is not covered by your warranty.

Mounting the Model J20i Power Supply

1. Place the power supply in a convenient location within 4 m of the laser head (the length of the umbilical). The power supply may be installed either as a stand-alone unit, or mounted in a standard 19 in. rack (see sub-section below).
2. Allow 6 in. (15 cm) of clearance to the front and back panels for proper air flow. Prevent heated air exhausted from the back panel from returning to the intakes on the front panel or from blowing into the area where the laser head is mounted.
3. Provide enough room-cooling capacity to counter the heat produced by the system and to prevent room overheating (refer to "Specifications" on page 3-15).
4. Ensure the electrical cables and umbilical are safely routed and are not under any strain or compression. Avoid conditions where the cables can be stepped on by personnel or rolled over by carts. Use caution when moving the power supply to prevent fiber damage.

Mounting the Power Supply in a Standard Rack

Because the laser head and power supply are permanently connected via the umbilical, when an enclosed rack unit is used, two people are required to install the system.

1. Leave the laser head on the cart or nearby surface (distance is limited by the umbilical) and install the power supply in the rack as you would normally. Fasten the power supply to the front panel of the rack using 4 screws.

Caution!

These four screws are only meant to secure the power supply in place, *not to support it.* Provide slides or rails to support the weight of the power supply. Mounting holes are provided on the side of the power supply for attaching slides—see the outline drawings at the end of Chapter 3 for details.

2. Have one person pass the laser head through the rack from the front to the second person behind it.

Warning!

Do not twist the umbilical or bend it to a radius of less than 6 in. (15 cm). Doing so can damage the fibers inside. Such damage is not covered by your warranty.

Mounting the Laser Head

The laser head should be secured to an optical table or other flat mounting surface. Three slots are provided in the bottom edge of the mounting base for this purpose, two near the output bezel and one at the center rear. Three laser head clamps are supplied that can be used on tables with either metric 175 mm hole spacing or English 1 inch spacing.

Note

The holes on the bottom plate of the laser head are for use in mounting other versions of the *Millennia Pro* laser head. Do not use these holes to mount the *Millennia Pro 2s* laser head.

1. To secure the laser head to the table, insert the three laser head clamps into the slots in the mounting base as shown in Figure 5-1.

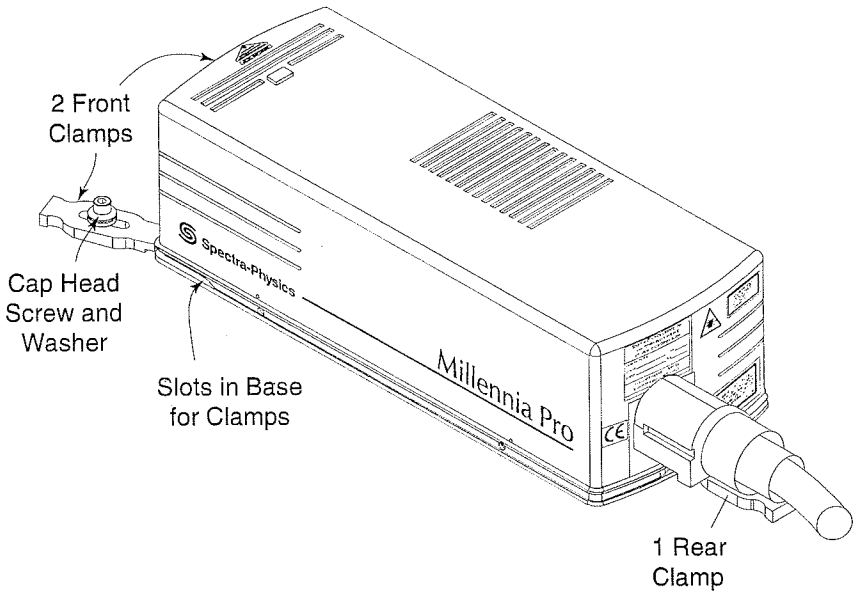


Figure 5-1: Laser Head Mounting Clamps And Base Slots

2. Using table mounting screws along with a single large washer on each screw (also provided), fasten the laser to the table via the desired mounting holes.

Connecting the System

Follow the steps in this section to connect the various components of the *Millennia Pro 2s* laser system. When done, verify each was connected properly to prevent damage to the system.

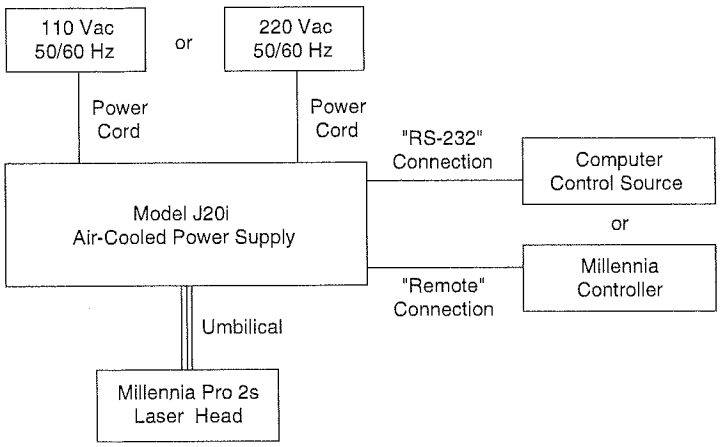


Figure 5-2: The *Millennia Pro 2s* Interconnect Drawing

1. Verify the control cable is attached to the 27-pin D-sub connector located just below the umbilical connection on the laser head and to the LASER HEAD connector on the *top* row of the power supply rear panel (Figure 5-3).

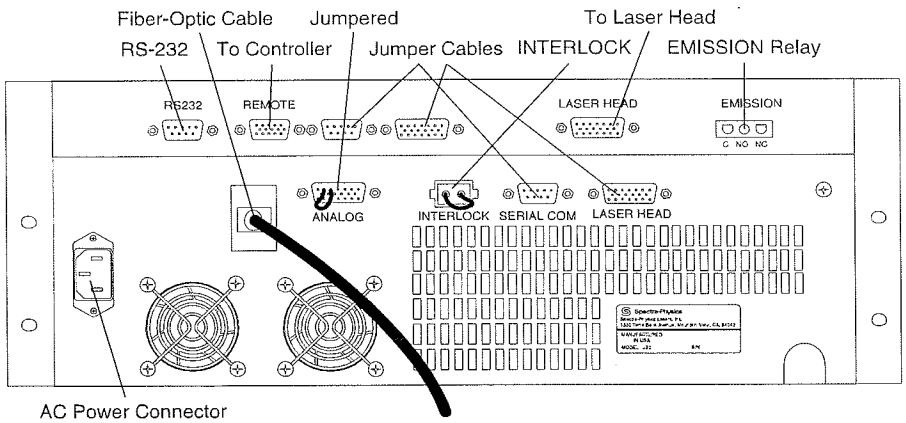


Figure 5-3: The *Model J20i* Power Supply Rear Panel

2. The two pins of the INTERLOCK connector on the rear panel of the *Model J20i* must be either jumpered or connected to an external, *closed* safety switch or the laser will not turn on. All relays or switches used for this purpose should be designed for a 24 Vdc, 100 mA signal that is supplied by the circuit.

   If a safety switch is not used, the 2-pin jumper plug (P/N 0129-2941) must be inserted into the INTERLOCK connector to close the circuit.

3. Verify a jumper plug (P/N 0129-4024) is inserted into the 26-pin ANALOG connector.
4. Attach the control device.
   a. If the system was configured at the factory for control via the RS-232 port *only*, skip to Step c.
   b. Attach the *Millennia* controller cable to the 15-pin REMOTE connector on the *top* row of the power supply *rear* panel. If necessary, remove the jumper plug from the connector and store it in a safe place.

      The *Millennia* controller can be used either to control the system directly or to select serial command control through the RS-232 connection.
   c. If serial commands are going to be used to control the laser system, attach a standard 9-pin serial cable (not provided) between the serial port of your host controller (typically a personal computer) and the RS-232 connection on the power supply rear panel.

      Refer to Chapter 4 for pin descriptions. Also refer to "Controlling the System Using the RS-232 Interface" in Chapter 6, "Operation."

      Verify the REMOTE connector jumper plug is in place on the power supply front panel (see Figure 5-4).

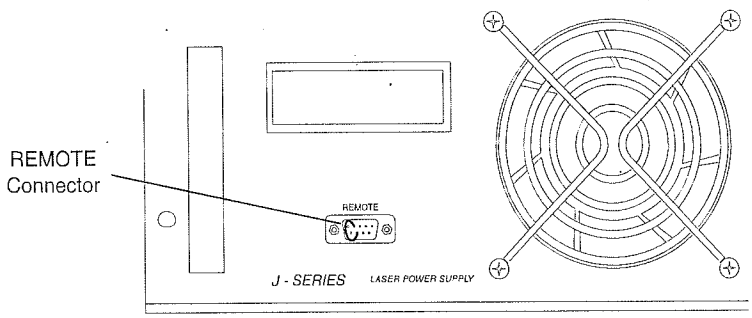


Figure 5-4: Jumpered REMOTE Connector on *Model J20i* Front Panel

5. If an emission indicator lamp other than the one on the laser head or the power supply front panel is required, use the EMISSION relay connector (Figure 5-5) on the rear panel of the power supply to turn on and off a lamp.

   To use the EMISSION relay, attach a wire to pin 3 and pin 2 of the connector. When the laser is off (i.e., when there is no emission), there is closure between pins 3 and 1 and an open between pins 3 and 2. The opposite is true when there is emission or emission is imminent.

   No power is supplied by these terminals. This circuit is rated for 250 Vac at 1 A.

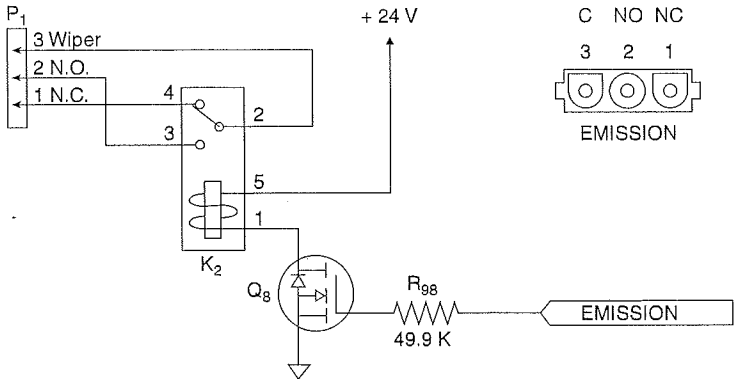


Figure 5-5: The EMISSION Connector Schematic

6. Verify the jumper cables joining the connectors on the top row to the SERIAL COM and LASER HEAD connectors below are in place.
7. Attach the provided IEC power cord to the power connector on the power supply and fasten it to the receptacle using the retaining screws so that it does not pull out. Plug the other end into a facility power outlet that can supply either 110 Vac at 10 A or 220 Vac at 6 A, single phase, 50 or 60 Hz.

   A Schuko type plug is provided for use in European countries. If you received a plug inappropriate for your area, call your Spectra-Physics regional distribution center to obtain one (refer to Chapter 8, "Customer Service," for phone numbers).
8. Verify the correct fuses are in place for the power supply. Refer to the "Specifications" table at the end of Chapter 3.

Alignment

There is no alignment procedure for the *Millennia Pro 2s* laser system: there are no knobs to adjust or optics to change. Just point it in the appropriate direction. Refer to the outline drawings at the end of Chapter 3 for dimensions.

When ready to turn on the laser, refer to Chapter 6, "Operation."

Chapter 6 Operation

The Spectra-Physics *Millennia® Pro 2s* laser is a *Class IV—High Power Laser* whose beam is, by definition, a safety and fire hazard. Take precautions to prevent accidental exposure to both direct and reflected beams. Diffuse as well as specular beam reflections can cause severe eye or skin damage.

Please read this entire chapter and Chapter 2 on laser safety before using your laser for the first time. This chapter contains information for operating the laser system locally using the controller provided or remotely using a computer and the system commands explained later in this chapter.

Once the *Millennia Pro 2s* has been installed, we strongly suggest the ac power keyswitch on the power supply be left in the "on" position at all times. Doing so drastically reduces warm-up time by keeping the SHG doubling crystal oven on, and it will help protect the crystal, especially in humid environments, by keeping it dry.

Using the Millennia Controller

The controller provided with the system is a convenient device for operating the *Millennia Pro 2s* laser locally (Figure 6-1).

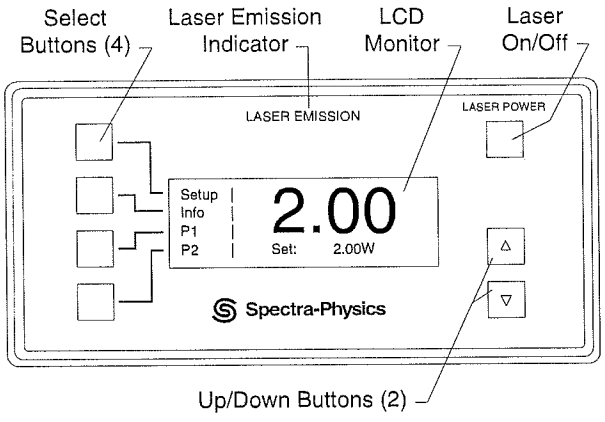


Figure 6-1: The *Millennia* Controller

Use the four buttons on the left side of the panel to select one of the four possible options shown on the left side of the screen. For example, press the top left button to go to the Setup menu or the next button down to go to the Info menu, etc. Not all menus use all of the buttons.

The LASER POWER button turns the laser on and off.

The up/down buttons in the lower right corner either increase or decrease the value displayed on the screen (such as the power setpoint), or allow the selection or change of a parameter from a list on the display.

What is shown on the LCD screen depends on the menu selected. The large digits always display *actual output power*, and below that in smaller text is either the output power setpoint (when Power mode is selected) or the percentage of maximum current (when Current mode is selected). "RS-232 Enabled" is displayed if the system was selected for remote operation via the serial link.

In general:

- Use the Main menu to monitor output power and to set the power or current setpoint (the desired output).
- Use the Setup menu to open and close the shutter, to select power or Current mode, to run the SHG crystal optimization routine and to select local or RS-232 remote control of the system. RS-232 commands are listed at the end of this chapter. The Setup menu also lets you activate or deactivate standby mode and to set its delay time before activation. Main menu power setpoints P1 and P2 are also set from here.
- Use the Info menu to view the diode pump laser drive current, the diode pump laser temperature, the temperature status of the SHG doubling crystal, and the revision level of the *Millennia Pro 2s* software. Also included is a history (HST) line that shows the last three system error codes.

Refer to the following sections for more information on each menu.

The Menu System

Four menus, Main, Setup, Standby, and Information, are used to control and monitor the system. Sample menu displays are shown in Figure 6-2.

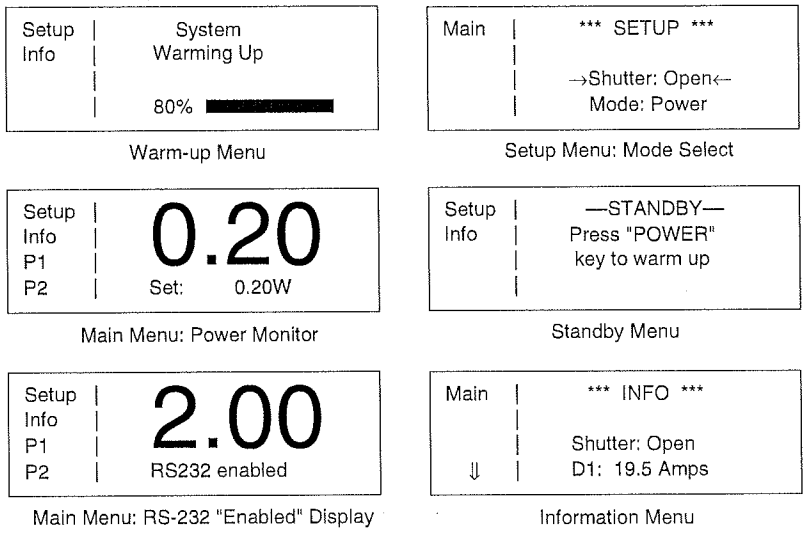


Figure 6-2: *Millennia Pro 2s* Menus

The upper left-hand frame shows the warm-up menu that is displayed soon after the system is powered up from a cold start (i.e., the power supply was turned off the last time it was used). It allows the operator to monitor the warm-up process, which takes about 30 minutes. If the system is being controlled remotely using the serial (RS-232) interface, a query command allows the operator this same monitoring capability (refer to the "Queries" section later in this chapter).

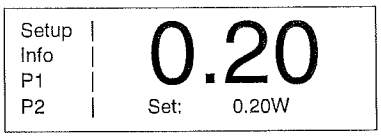
The Standby menu is displayed anytime the power supply is left on but there has been no laser emission for a time greater than the STANDBY delay time setting.

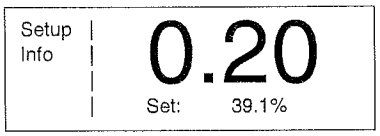
The four menus are described in the following sections.

The Main Menu

When the system is ready for operation following the warm-up sequence, the Main menu is displayed. From here, output power and system performance can be monitored. The large numbers indicate actual output power; the smaller numbers below it indicate either the desired output power (the power setpoint when the system is set for Power mode), the desired diode laser drive current (the current setpoint, as a percentage of maximum current, when the system is set for Current mode), or RS-232 ENABLED when the system is set for remote operation via the serial link.

In the next figure, the screen on the left shows the Power mode display; the screen on the right shows the system in Current mode. When the system is tracking correctly in Power mode, actual output power and setpoint are the same (within ±0.01 W).





To change the power or current setpoint, either press one of the preset power setpoint keys, P1 or P2, to move directly to a preset power (set in the Setup menu), or use the up/down buttons to set a new value. Note that when the buttons are held down, the setpoint numerical update pauses from time to time. This is normal. To change from power to Current mode, or vice versa, use the Setup menu.

If an error occurs, ERROR flashes in the lower left corner of the Main menu. Press the lower left button to display the error source. (Status codes and their definitions are listed in Appendix A.) When the problem is corrected, the ERROR message turns off. If the error code is generated by the power supply, it is logged on the history (HST) line in the Info menu.

Menus available from the Main menu are:

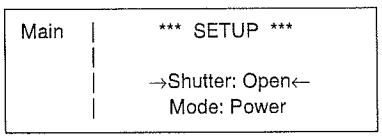
- Setup
- Info

The Setup Menu

Use the Setup menu to:

- open and close the shutter,
- run the SHG optimization routine,
- select LOCAL control (the *Millennia* controller) or a remote control source (connected to the RS-232 port),
- activate or deactivate Standby mode,
- set the Standby mode delay time before activation, and
- set the Main menu preset power values for P1 and P2.

Access this menu from the Main menu.



Use the two lower left buttons to scroll the menu up and down; the "selected" item is the one between the horizontal arrows (SHUTTER: OPEN in the example screen above). The value for the selected item is changed by using the up/down buttons to the right of the screen. The selections and/or changes are activated upon return to the Main menu. Selections include:

- Shutter: Open, Closed
- Mode: Power, Current, SHG Opt, RS-232
- Stdby: 15 min, 30 min, 1 hour, 4 hours, Never
- P1 Set: any value between 0.2 and 2.0 W
- P2 Set: any value between 0.2 and 2.0 W

The shutter, when closed, mechanically blocks the output beam. For emission to occur, the laser diode must be turned on and the shutter opened.

Power mode is used to maintain constant output power and is the "normal" mode setting. Current mode is used to maintain constant diode laser current while measuring laser output power. Current mode is primarily used for diagnostic purposes.

"SHG Opt." (SHG optimization) is an automatic routine that optimizes the temperature of the LBO doubling crystal after installation to provide optimum conversion efficiency. Optimizing conversion efficiency minimizes the pump diode laser current required to reach the specified maximum 532 nm output power. The SHG optimization routine should be run immediately following installation and should not need to be run subsequently except when the laser ambient environment has changed significantly. It takes about 15 minutes for the routine to run.

When "RS-232" control is selected, "RS-232 Enabled" is displayed on the Main menu as shown below, and control is transferred to the host system.

The baud rate can be changed to match the speed of the host system. This setting, along with the software commands for serial control, are explained later in this chapter under "The RS-232 Serial Port." The default RS-232 settings are: 9600 baud, 8 data bits, no parity, 1 stop bit.

Standby (Stdby) mode, when active, causes an automatic system power down mode whenever the power supply is left on but no laser emission has occurred for a time greater than the Stdby delay time setting. When security and safety are not paramount, this is the preferred "off" mode when the laser is used on a day-to-day basis. (Standby mode can be turned off by setting the delay time to "Never.")

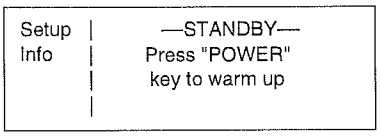
P1 SET and P2 SET allow the operator to preset two power levels that can be selected from the Main menu during operation by simply pressing one of the two lower left buttons on that screen. Refer to the "Main menu."

Pressing the Main button from the Setup menu activates the values just selected and then displays the Main menu.

The Standby Menu

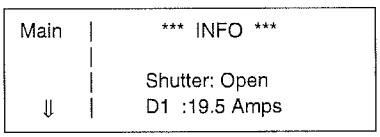
When "Stdby" is activated in the Setup menu, the Standby menu is automatically displayed whenever the *Model J20i* power supply is left on but no emission has occurred for more than the delay time set for Stdby (refer to the "Setup menu"). This is the recommended, overnight "off" position. Refer to "Turning on the Laser, Warm Start" later in this chapter.

This display is not shown when the system is started cold, i.e., when the power supply has been turned off. Nor can it be accessed from any other menu.



The Info Menu

The Info (information) menu provides status information on the shutter, i.e., whether it is open or closed, provides diagnostic information on the diode lasers and the SHG doubling crystal, and displays a history (HST) line that lists the three most recent system error codes for diagnostic purposes. The codes and their definitions are listed in Appendix A. Note that only the power supply codes, 0 through 126, are displayed on the controller. The other system error/status codes are displayed on the power supply. The Info menu is accessed from the Main menu.



Use the select buttons (not the up/down buttons) to scroll the screen (note the down arrow in the picture above). Two lines are displayed at a time as follows, from top to bottom:

- The status of the shutter (open/closed).
- The drive current for diode laser D_1.

Note

It is normal to require greater than 60% of full current before reaching the threshold for green output power.

- The temperature of the diode laser.
- The status of the SHG doubling crystal temperature (it is STABLE when the proper temperature is reached).
- The status code history (HST) line.
- The revision level of the *Millennia Pro 2s* software. Have this revision number available whenever calling for service.

Pressing the Main button displays the Main menu.

System Start-up/Shut Down

There are two turn-on sequences, one for a cold start when the *Model J20i* power supply was turned off the last time it was used, and one for a warm start when the system is in Standby mode (when the laser is off but the power supply was left on). Each sequence is described below.

Note

When Standby mode is activated, the system automatically powers down after the preset delay time, and the Standby menu is displayed. To restart the unit, follow the procedure for a warm start turn-on.

Turning On the Laser, Cold Start

1. Verify all connectors are plugged into the power supply (they should never be disconnected—if they were, refer to Chapter 5, "Installation," for instructions on reconnecting them).
2. Turn on the power supply using the keyswitch.

Power Supply Start-up

As the system starts up, the following message sequence is displayed on the power supply LCD screen:

"Spectra-Physics" followed by the software version number.

"System Initializing"

"Bypass delay time"

"Laser Diodes Off"

"Status – Wait"

"Cooling System Test"

"Diode Safety Check"

"Adjusting Temperature"

This message remains on the screen until the diode lasers are at operating temperature. The Warm-up menu is now displayed on the controller.

"Boot Complete, Laser Diodes Off, Power Mode Ready"

This final message from the power supply indicates it is ready for use.

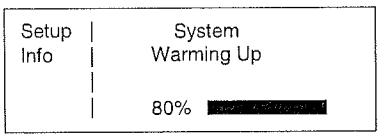
Controller Start-up

The following message sequence is displayed on the controller as the system turns on:

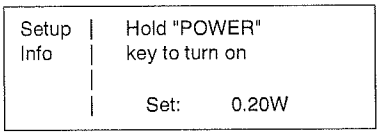
"Spectra-Physics"

"Welcome to the new Millennia"

After the welcome message, the system begins the warm-up cycle, which can take up to 30 minutes. A time bar is displayed (0 to 100%) to indicate progress:

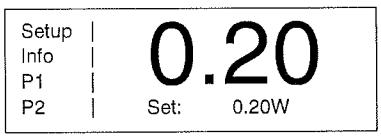


3. When the system has warmed up, the following screen is displayed:



Press and hold in the LASER POWER button until the laser starts. When the button is pressed, the LASER EMISSION light flashes for a few seconds and the emission indicator on the laser head turns on to indicate emission is imminent. Then, when the diode laser turns on and laser emission occurs, the LASER EMISSION light stops flashing and remains on, and radiation is available when the shutter is opened.

At this point, the Main menu is displayed and output power ramps up to 0.20 W. "0.20 W" is displayed if the laser was set to Power mode when it was last used, or an equivalent current value is displayed if the laser was set to Current mode. Power mode is shown in the Main menu below.

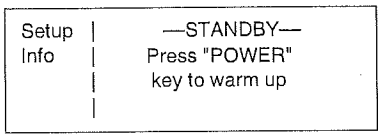


4. Use the Setup menu to open the shutter and, if desired, to change the laser mode.
5. From the Main menu, set laser output power using the up/down buttons or by pressing the P1 or P2 button. Actual output power will follow the setpoint value.

This completes the system cold start procedure. The system is now ready for use.

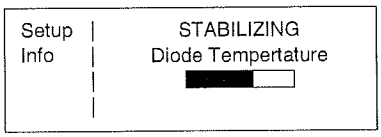
Turning On the Laser, Warm Start

This procedure assumes the unit was left in Standby mode after it was last used. When this is the case, the following Standby prompt is displayed.

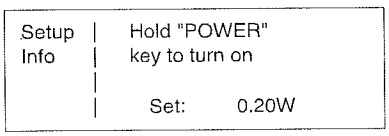


1. Press the LASER POWER button to begin the short warm-up cycle.

   The following prompt is displayed for about 2 minutes while the diode module temperature stabilizes:

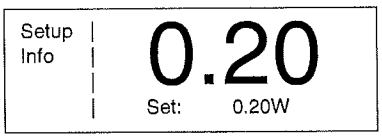


2. When the system has warmed up, the following screen is displayed:



   Press and hold in the LASER POWER button until the laser starts. When the button is pressed, the LASER EMISSION light flashes for a few seconds and the emission indicator on the laser head turns on to indicate emission is imminent. Then, when the diode laser turns on and laser emission occurs, the LASER EMISSION light stops flashing and remains on, and radiation is available if the shutter is open. (The shutter will be in the same position it was in when it went to Standby.)

   At this point, the Main menu is displayed and output power ramps up to the previously set power level. "0.20 W" is displayed if the laser was set to Power mode when it was last used, or an equivalent current value is displayed if the laser was set to Current mode. Power mode is shown in the Main menu below.



3. Use the Setup menu to open the shutter and to change the laser mode.
4. From the Main menu, set laser output power using the up/down buttons or by pressing the P1 or P2 button. Actual output power will follow the setpoint value.

This completes the system warm start procedure. The system is now ready for use.

Turning Off the Laser

Note

We suggest the *Millennia Pro 2s* be set to turn the laser off in Standby mode when not in use; leave the *Model J20i* keyswitch in the "on" position at all times. This reduces warm-up time and keeps the SHG crystal dry and at optimum operating temperature.

To turn off the laser:

1. Close the shutter via the Setup menu.
2. Press the LASER POWER button to turn off the laser.
3. Leave the power switch on the power supply in the "on" position.

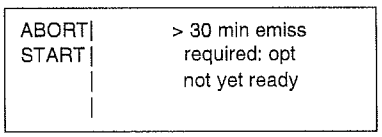
   This completes the normal turn-off procedure. If Standby mode has been activated (and it should be), the system will go to power-down Standby mode automatically after the preset delay time. This is the preferred "off" mode for day-to-day operation. If the laser is not to be used for an extended period of time, turn off the power supply completely.

Setting the SHG Crystal Temperature

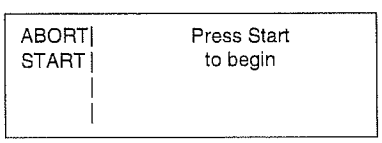
Automatic SHG Optimization

"SHG Opt." (SHG optimization) is an automatic routine that optimizes the temperature of the LBO doubling crystal after installation to provide optimum conversion efficiency. Optimizing conversion efficiency minimizes the pump diode laser current required to reach the specified maximum 532 nm output power. The SHG optimization routine should be run immediately following installation and should not need to be run subsequently except when the laser ambient environment has changed significantly.

This routine takes about 15 minutes to run. However, the system must have been on for at least 30 minutes prior to this to ensure it has reached its long-term equilibrium state. (It is recommended that the laser be run at maximum power for 1 hour before running this routine.) If the system has been on for less than 30 minutes and the operator tries to start this routine, the following screen is displayed:

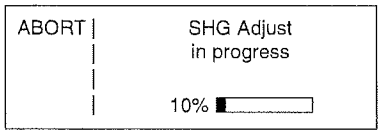


If the time requirements are met, the following is displayed:



To start the routine:

1. Select the Setup menu, then select the SGH Opt mode and press the Main menu button to invoke the routine (all modes and settings are invoked upon leaving the Setup menu). The screen above will appear.
2. Press the "Start" button. The shutter will close and a screen similar to the one below will be displayed:



   If the procedure must be aborted, press the "Abort" button at any time to return to the Setup menu. System mode and power level will return to the settings that were in effect prior to invoking the SHG Opt. routine.
3. At the end of the process, the Main menu is displayed and the laser is placed in Power mode at maximum power with the shutter closed. If the routine was unable to achieve its power target, the unit will return to the mode and power level that were in effect at the time the routine was invoked.

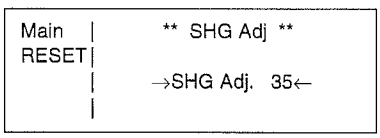
Manual SHG Optimization

We strongly recommend that the temperature of the SHG doubling crystal not be changed manually. Instead, use the automatic routine (see above) whenever possible. There are, however, a few rare instances where manual optimization might be appropriate.

To change the SHG crystal temperature in those rare cases:

1. Select the Setup menu.
2. Place the system in Current mode and set it for the desired output power.
3. Press the two lower left selection buttons at the same time.

   The following is displayed:



4. Use the up/down keys to change the temperature count.

   Temperature is given as ±50 counts from a nominal setting. The system is shipped from the factory at a calibrated setting somewhere between 0 and ±25 counts. Press the "Reset" button to return the SHG doubling crystal to this factory temperature setting.
5. Press the Main menu button to leave the crystal adjust mode and return to the Main menu. Allow the SHG to stabilize for 1 to 2 hours before operating the system.

The RS-232 Serial Port

The RS-232 port is used for controlling the system via serial commands.

Pinout/Wiring

The *Millennia Pro 2s* serial port is accepts a standard 9-pin D-sub male/female extension cable for hook-up. Only three of the pins are actually used:

Pin Numbers	Usage
2	Transmit data (Millennia Pro 2s out)
3	Receive data (Millennia Pro 2s in)
5	Signal ground

Communications Parameters

Communications must be set to 8 data bits, no parity, one stop bit, using the XON/XOFF protocol (do not use the hardware RTS/CTS setting in your communications software). The baud rate is variable and can be set to 1200, 2400, 4800 or 9600 (default). The rate is determined at system power-up by reading positions 1 and 2 of switch S1 on the laser head Control pc board (located just under the power supply cover). Figure 6-3 shows the location of the DIP switch on the pc board, and the table below describes the function of the switches.

Warning! ESD

Possible electrostatic discharge! Avoid static damage to electronic components by observing proper handling and grounding procedures. Always discharge yourself to a grounded chassis by touching it before touching any electronic component. Always wear a grounding strap.

Table 6-1: Switch S_1 Positions

Position 1	Position 2	Baud Rate
off	off	1200
off	on	2400
on	off	4800
on	on	9600 (default)

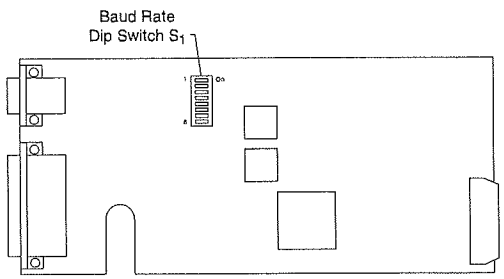


Figure 6-3: The laser head Control pc board (located in the power supply) showing the location of baud rate DIP switch S_1.

Command/Query/Response Format

All commands and responses are in ASCII format. Commands to the *Millennia Pro 2s* system are terminated by an ASCII carriage return, a line feed, or both. All responses from the *Millennia Pro 2s* are terminated by an ASCII line feed character. In the examples below, a carriage return is indicated by <CR> and a line feed by <LF>.

Commands

ON — Turn On Laser

ON<CR>

The response to this command depends on whether or not the system is warmed up. Use the *?Warmup%* query (see "Queries") to determine the progress of the warm-up cycle (see table below).

A response of "0" means the system is in Standby mode. If this is the case, issue an *ON* command to begin the temperature stabilization cycle. When the response to the *?Warmup%* query is "100%", the laser can be started. Do not issue an *On* command while the response to *?Warmup%* is "1 to 99".

If the response to *?WARMUP%* is...	The response to *ON* is...
0	to begin diode laser temperature stabilization. (approximately 2 minutes)
1 to 99	an execution error. (The EXE_ERR bit in the status byte is set.)
100	the diode laser turns on, and the system output ramps to the most recently set power/current.

Note

When the laser turns on, it will be in the mode (power/current) that was in effect when the unit was turned off.

OFF — Turn Off Laser

OFF<CR>

Turns off the diode laser and diode laser temperature regulation (the latter reduces electrical power consumption), but the SHG crystal oven temperature is maintained for quick warm-up time. Latched interlocks are cleared. The system enters Standby mode when the laser has been turned off for more than the delay time set for Standby mode (see the "Setup menu"). If the delay time is set for "never," the system will not enter Standby mode.

P:x.x — Set Power

Sets laser output power to the nearest tenth watt if the unit has been previously set to Power mode using the "M" command. This command is ignored when the system is in Current mode. The minimum setting is 0.2 W, the maximum is 2 W. Commands outside this range are ignored.

P:2<CR>	Sets the output power to 2.0 W.
P:2.0<CR>	Sets the output power to 2.0 W (no change).
P:1.9<CR>	Sets the output power to 1.9 W.

C%:xx — Set Percent Current

Sets the laser current to a percentage of maximum current if the unit has been previously set to Current mode using the "M" command. This command is ignored when the system is in Power mode or when settings less than zero or greater than one hundred percent are requested.

C%:50<CR>	Sets the diode laser to 50% current.

Mx — Set Mode

Sets the laser mode so that output is current regulated or power regulated. The diode laser current or output power is ramped to the previous set value.

M1<CR>	Sets the laser to Power mode.
M0<CR>	Sets the laser to Current mode.

SHGOPT:x — Run SGH Optimization

SHGOPT:1<CR>	Begins SHG optimization.
SHGOPT:0<CR>	Abort SHG optimization.

SHG:±xx — Sets SHG Value (Range: ±50)

SHG:+10<CR>	Sets the SHG value to 10.
SHG:–05<CR>	Sets the SHG value to –5.

SHUTTER:x — Open or close the shutter

SHUTTER:1<CR>	Opens the shutter.
SHUTTER:0<CR>	Closes the shutter.

Queries

?P — Get Power Status

?P<CR> Requests the value of the laser output power in watts. The response looks like "1.90 W<LF>".

?Cx — Get Diode Operating Current Status

?C1<CR> Requests the value of the drive current for diode laser 1 (C1). A typical response is "25.36A1<LF>," interpreted as 25.36 Amps for diode laser 1.

?M — Get Mode Status

?M<CR> Requests system mode status. The system responds with "1<LF>" for Power mode, or "0<LF>" for Current mode.

?PCTOPT — Get SHG Percent Optimization Routine Status

?PCTOPT<CR> Requests system status of completion (in percent) of the optimization routine. The system responds with:
"0<LF>" if it is inactive (not running),
"xxx%<LF>" when it is xxx% completed, (e.g., 50%)
"–1<LF>" if the routine was aborted,
"–2<LF>" if the routine has timed out,
"–3<LF>" if the coarse search failed, or
"–4<LF>" if the fine search was exhausted.

?SHGOPT — Get SHG Optimization Routine Status

?SHGOPT<CR> Requests the status of the SHG optimization routine (it checks to see if it is running). The system responds with "Ø<LF>" if it is not running and "1<LF>" if it is running.

?SHGS — Get SHG Oven Status

?SHGS<CR> Requests the status of the SHG oven. The system responds with "ØS<LF>" if the temperature is settled, "1S<LF>" if the oven is heating, and "2S<LF>" if it is cooling. Values less than zero indicate an error (such as a broken wire or loose cable).

?IDN — Get Identification String

?IDN<CR> Requests a system identification string. The system returns an ASCII string that consists of four fields: manufacturer, product, software revision number, and serial number ("Ø" if the latter is not implemented). A typical return would be: "Spectra-Physics, Millennia, 1.02, 0<LF>."

?STB — Get Status Byte

This query requests a system status byte that indicates which command errors (if any) have occurred and whether the laser is on or off. The integer value returned represents the sum of the value of the bits in the status byte. The bit positions are defined by Table 6-2 on page 6-18. Each time a status byte is requested, its register is cleared so that a new status byte can be generated.

The status register accumulates the most recent commands and tracks their validity. Consider the following sequence of commands:

P:10<CR> Since the requested power is out of range, the EXE_ERR bit is set.

P:2<CR> Valid command, sets power to 2 W.

M1<CR> Valid command, sets unit to Power mode.

ON<CR> Valid command, turns on the diode laser.

?STB<CR> Reads and clears the status byte.

The status byte returned would be "194<LF>" since the ANY_ERR, LASER _ON, and EXE_ERR bits are set (194=2+64+128). Table 6-2 on page 6-18 describes all the possible errors; Table 6-3 lists all the possible combinations.

?SHUTTER — Get Shutter Status

?SHUTTER<CR> Requests the status of the shutter. The system responds "1<LF>" if the shutter is open and "0<LF>" if it is closed.

?WARMUP% — Get Warm-up Status

?WARMUP%<CR> Reads the status of the system warm-up time as a percent of the predicted total time (see the table). The system responds with a value similar to "050%<LF>. When the response is "100%<LF>", the laser can be turned on.

Note: an error condition, such as an open interlock, may not affect the *?Warmup%* command. To check for other errors, request the status byte with the *?STB* query command.

System Status	?WARMUP%
Initial ac power-on warm-up	Between 1% and 99%
System is ready to turn on the diode lasers	100%
System is in Standby mode	0%
System is warming up after leaving Standby mode	between 1% and 99%

?HDREV — Get Head Software Revision

?HDREV<CR> Returns a *Millennia Pro 2s* laser head software revision number similar to "2.01<LF>".

?PSREV — Power supply Software Revision Query

?PSREV<CR> Returns a *Model J20i* power supply software revision number similar to "4420 REV D<LF>".

?RMREV — Controller Software Revision Query

?RMREV<CR> Returns the controller software revision number. A typical response is "1.10<LF>".

?EC — System Status Code Query

?EC<CR> Returns the current status code. The code returned is the same as that displayed on the controller, if it is attached. Refer to the status code listing in Appendix A for explanations.

?H — History Buffer Query

?H<CR> Returns a 16-byte (16 code) status code list from the "history buffer" with the most recent status codes listed first. The history buffer only stores status codes generated by the power supply, numbers 0 – 126. Status codes from the *Millennia Pro 2s* laser head are not recorded and, therefore, will not be returned.

?C%SET — Last Current Command Query

?C%SET<CR> Returns the value for the last percentage current commanded ("C%"), not the actual diode laser current. A typical response might be "75.1%<LF>".

?PSET — Last Power Command Query

?PSET<CR> Returns the value for the last power command ("P%"), not the actual laser output power. A typical response might be "0.20 W<LF>".

?C%<CR> — Actual Current Setting Query

?C%<CR> Returns a value equal to the actual operating percentage of maximum diode laser current. A typical response might be "75.1%<LF>".

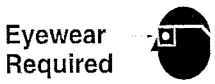
Table 6-2: Query Errors

Binary Digit	Decimal Value	Name	Interpretation
0	1	CMD_ERR (CE)	Command error. Something was wrong with the command format, the command was not understood
1	2	EXE_ERR (EE)	Execution Error A command was properly formatted, but could not be executed. For example, a power command of "P:0<CR>" was sent, when the minimum allowed power is 0.2 W.
2	4	(reserved)	
3	8	SHGOPT_ACT	If set, the SHG optimization routine is active; if not set, it is inactive.
4	16	(reserved	
5	32	SYS_ERR (SE)	Any "system" error. (An open interlock, or an internal diagnostic)
6	64	LASER_ON (LO)	Indicates that laser emission is possible.
7	128	ANY_ERR (AE)	Any of the error bits are set.

Table 6-3: Error Return List

Binary DigitS	Decimal Value	Errors Returned
0100 0000	64	LO
1000 0001	129	CE + AE
1000 0010	130	EE + AE
1000 0011	131	CE + EE + AE
1010 0000	160	SE + AE
1010 0001	161	CE + SE + AE
1010 0010	162	EE + SE + AE
1010 0011	163	CE + SE + EE + AE
1100 0001	193	CE + LO + AE
1100 0010	194	EE + LO + AE
1100 0011	195	CE + EE + LO + AE
1110 0000	224	SE + LO + AE
1110 0001	225	CE + SE + LO + AE
1110 0010	226	EE + SE + LO + AE
1110 0011	227	CE + EE + SE + LO + AE

Chapter 7 Maintenance and Service



The Spectra-Physics *Millennia® Pro 2s* laser is a *Class IV—High Power Laser* whose beam is, by definition, a safety and fire hazard. Take precautions to prevent accidental exposure to both direct and reflected beams. Diffuse as well as specular beam reflections can cause severe eye or skin damage. Always wear proper eye protection when working on the laser, and follow the safety precautions in Chapter 2, "Laser Safety."

Maintenance

The *Millennia Pro 2s* laser head requires no routine maintenance. *There is no reason to remove the outer cover; there are no user-serviceable parts inside the laser head!* This cover is secured to the base plate with four fasteners that should only be removed by a service engineer.

To retain a clean intracavity environment, all components are cleaned to stringent standards prior to assembly and alignment at the factory. The cover of the laser module inside the laser head is secured and sealed and should never be opened. *Removing the module cover will compromise the cleanliness of the intracavity space, degrade laser performance, and void the warranty!*

Replacing the fiber-optic bundles and/or diode lasers by the user is not recommended. This procedure should only be performed by someone trained by Spectra-Physics. Call your Spectra-Physics service representative when you suspect a diode module is damaged or needs replacement.

All parts that normally come in contact with laboratory or industrial environments retain surface contamination that can be transferred to optical components during handling. Indeed, skin oils can be very damaging to optical surfaces and coatings and can lead to serious degradation problems under intense laser illumination. It is therefore essential that only clean items come into contact with optical components and the mechanical parts immediately surrounding them.

Service Training Programs

Millennia Pro 2s diode-pumped, solid state lasers manufactured by Spectra-Physics are designed for hands-off operation. These scientific products do not require alignment or routine cleaning of cavity optics. Service is generally limited to the power supply. All components in the power supply are replaceable. However, unauthorized repair may 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.

Troubleshooting

This troubleshooting guide is for use by you, the user. It is provided to assist you in isolating some of the problems that might arise while using the system. A complete repair procedure is beyond the scope of this manual. 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 Chapter 8. Before you call, note your current software revision number and the model serial number; they can be found on the Info Menu by scrolling to the bottom of the list of specifications that are displayed on the screen.

Symptom: The Controller screen does not light up.

Possible Causes	Corrective Action
Power is not available to the system.	If the power supply fan is off: a. verify the power cord is plugged in. b. verify the internal voltages are correct (call your Spectra-Physics service representative). c. verify that the fuses in the power supply are not blown.
Power supply has failed.	Call your Spectra-Physics service representative.

Symptom: Low power.

Possible Causes	Corrective Action
The beam is clipped.	Call your Spectra-Physics service representative.
The SHG temperature is not adjusted correctly.	Set the *Millennia Pro 2s* to Current mode, 100% current. Adjust the SHG temperature for maximum output power. Then allow the unit to stabilize for 1 to 2 hours and, if necessary, adjust again. For long term stability, lower the SHG count in the Setup menu by about 5 to 10 counts.

Symptom: High optical noise.

Possible Causes	Corrective Action
The SHG temperature is not adjusted correctly.	Set the *Millennia Pro 2s* to Current mode, 100% current. Adjust the SHG temperature for maximum output power. Then allow the unit to stabilize for 1 to 2 hours and, if necessary, adjust again. For long term stability, lower the SHG count in the Setup menu by about 5 to 10 counts.

Symptom: Bad mode.

Possible Causes	Corrective Action
The SHG temperature is not adjusted correctly	Set the *Millennia Pro 2s* to Current mode, 100% current. Adjust the SHG temperature for maximum output power. Then allow the unit to stabilize for 1 to 2 hours and, if necessary, adjust again. For long term stability, lower the SHG count in the Setup menu by about 5 to 10 counts. Note: This is very common at low power level due to the lack of self-heating from the 1064 nm beam. Readjust the SHG temperature as needed.
The beam is clipping the output telescope assembly.	Call your Spectra-Physics service representative.

Symptom: The *Millennia Pro 2s* shuts itself off in Power mode.

Possible Causes	Corrective Action
The SHG temperature is not adjusted correctly.	Set the *Millennia Pro 2s* to Current mode, 100% current. Adjust the SHG temperature for maximum output power. Then allow the unit to stabilize for 1 to 2 hours and, if necessary, adjust again. For long term stability, lower the SHG count in the Setup menu by about 5 to 10 counts.
Incorrect pick-off calibration (power readout).	Call your Spectra-Physics service representative.

Symptom: The *Millennia Pro 2s* shuts itself off in Current mode.

Possible Causes	Corrective Action
There should be no reason for the unit to shut down in Current mode other than for power failure or an interlock interruption. This will show up on the controller as an error message.	Call your Spectra-Physics service representative.

Symptom: The *Millennia Pro 2s* will not lase.

Possible Causes	Corrective Action
The shutter is not open.	Open the shutter using the Setup menu.
The *Millennia Pro 2s* and power supply have not completed the turn-on sequence.	The *Millennia Pro 2s* turn-on will take approximately 30 min. to complete from a cold start. Allow enough time for the turn-on sequence.
An interlock is either open or has been opened and closed.	An error message should be displayed on the controller. Verify that any switch connected to the INTERLOCK connector on the power supply is closed or that the jumper plug is in place. Verify that the ANALOG jumper plug is in place. Press the LASER POWER button once to clear the error, then restart the system as you would normally.

Symptom: Long-term stability/beam pointing is poor.

Possible Causes	Corrective Action
The laser head is not properly mounted.	Review the "Laser Head Mounting Considerations" section in Chapter 6, and verify the laser head is mounted properly.
The routing mirrors are not installed correctly.	If routing mirrors are used as part of the beam delivery setup, verify they are assembled and locked down correctly.

Replacement Parts

The following is a list of parts that may be purchased to replace broken or misplaced components. Also listed are optional components that may be purchased to enhance your system.

Table 7-1: Replacement Parts

Description	Part Number
Diode module assembly, new	PDMJ-M225
Diode module assembly, ETN	PDMJ-M225-ETN
Controller, *Millennia*	TREM-C2-08

Chapter 8 Customer Service

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 the "Service Centers" listing located at the end of this section.

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.

Return of the Instrument for Repair

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

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

Service Centers

Benelux

Telephone: (31) 40 265 99 59

France

Telephone: (33) 1-69 18 63 10

Germany and Export Countries*

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

Japan (East)

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

Japan (West)

Spectra-Physics KK
West Regional Office
Nishi-honmachi Solar Building
3-1-43 Nishi-honmachi
Nishi-ku, Osaka 550-0005
Telephone: (81) 6-4390-6770
Fax: (81) 6-4390-2760
e-mail: niwamuro@splasers.co.jp

United Kingdom

Telephone: (44) 1442-258100

United States and Export Countries**

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

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

Appendix A Status Codes

Listed below are all the status codes and messages that might be displayed on the *Millennia* controller (not the *Model J20i* power supply) while using the *Millennia® Pro 2s* system. Most codes are self-explanatory and most errors can be corrected by the user. In the event the error cannot be corrected, or the action required to correct the error is not known, write down the code and message and call your Spectra-Physics service representative.

Codes 0 to 126 are generated by the *Model J20i* power supply, codes 127 and up are generated by the *Millennia Pro 2s* laser head. Codes 142 to 147 are latched interlock messages that indicate the *Model J20i* shut off without a command to do so. These latched interlock messages are cleared by either:

a. pressing the LASER POWER switch on the controller, or

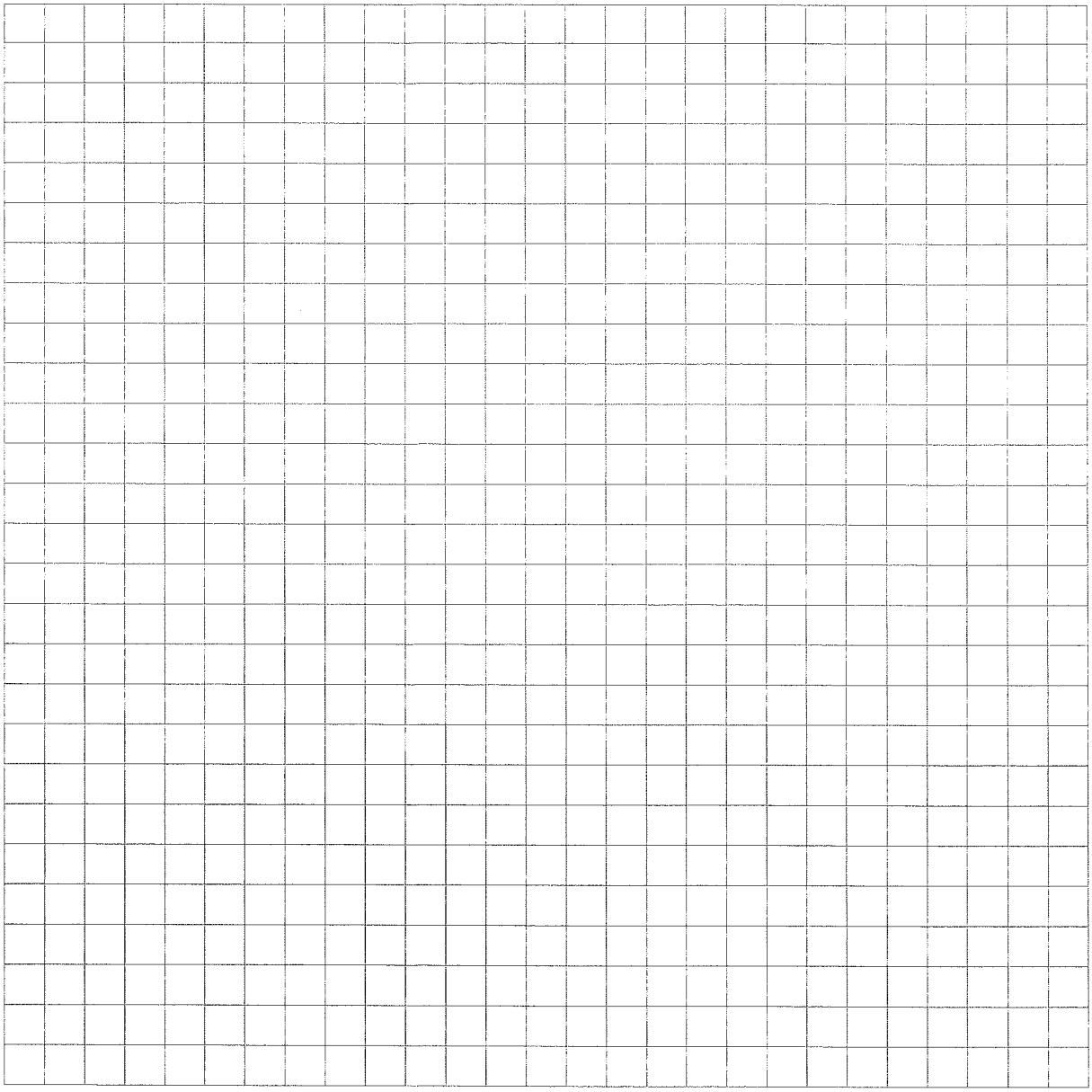
b. sending the OFF command through the RS-232 port.

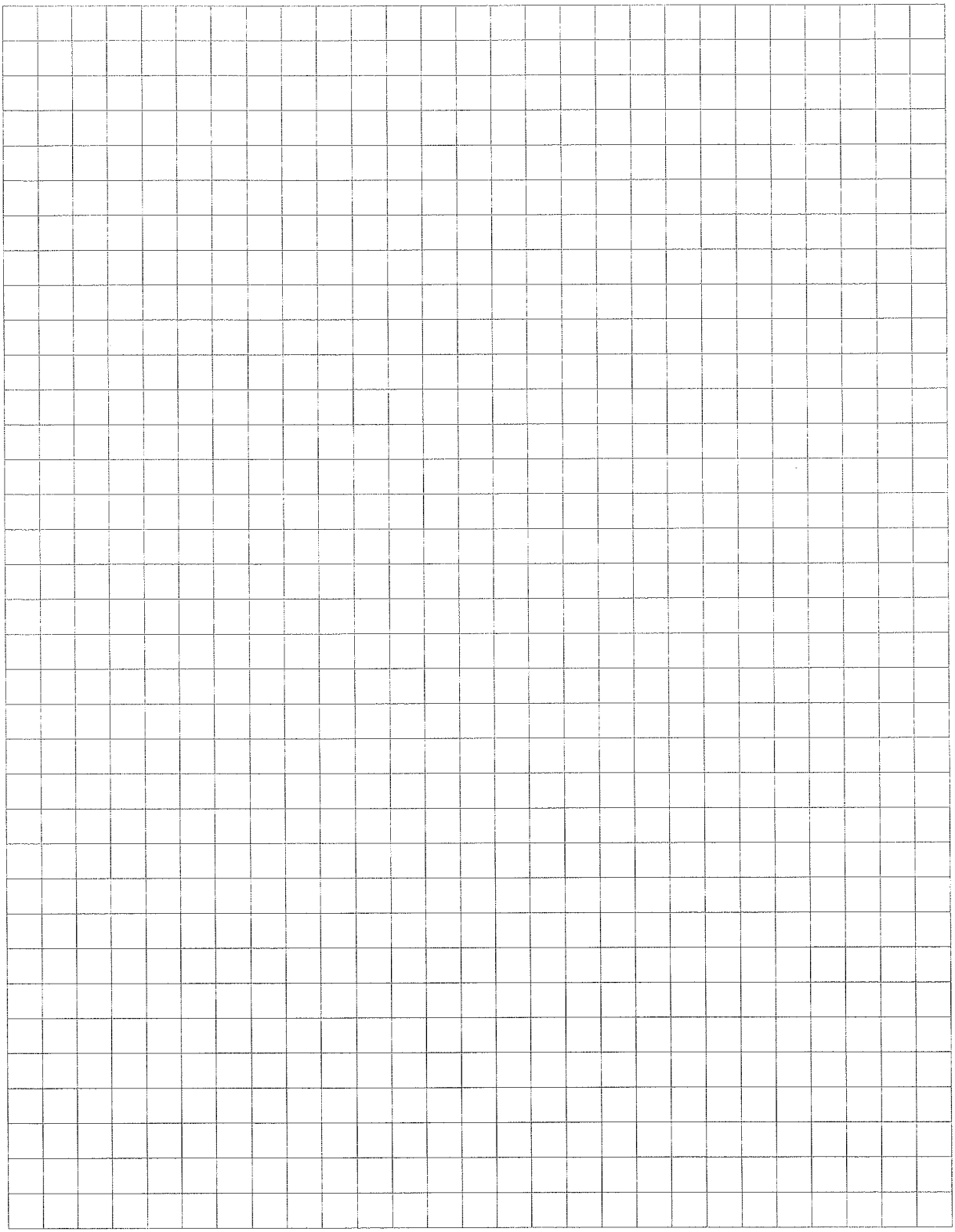
The Info menu HST line on the controller lists the three most recent status codes with the most recent error listed first. The RS232 *?H* query reports the most recent 16 codes, again with the most recent one listed first.

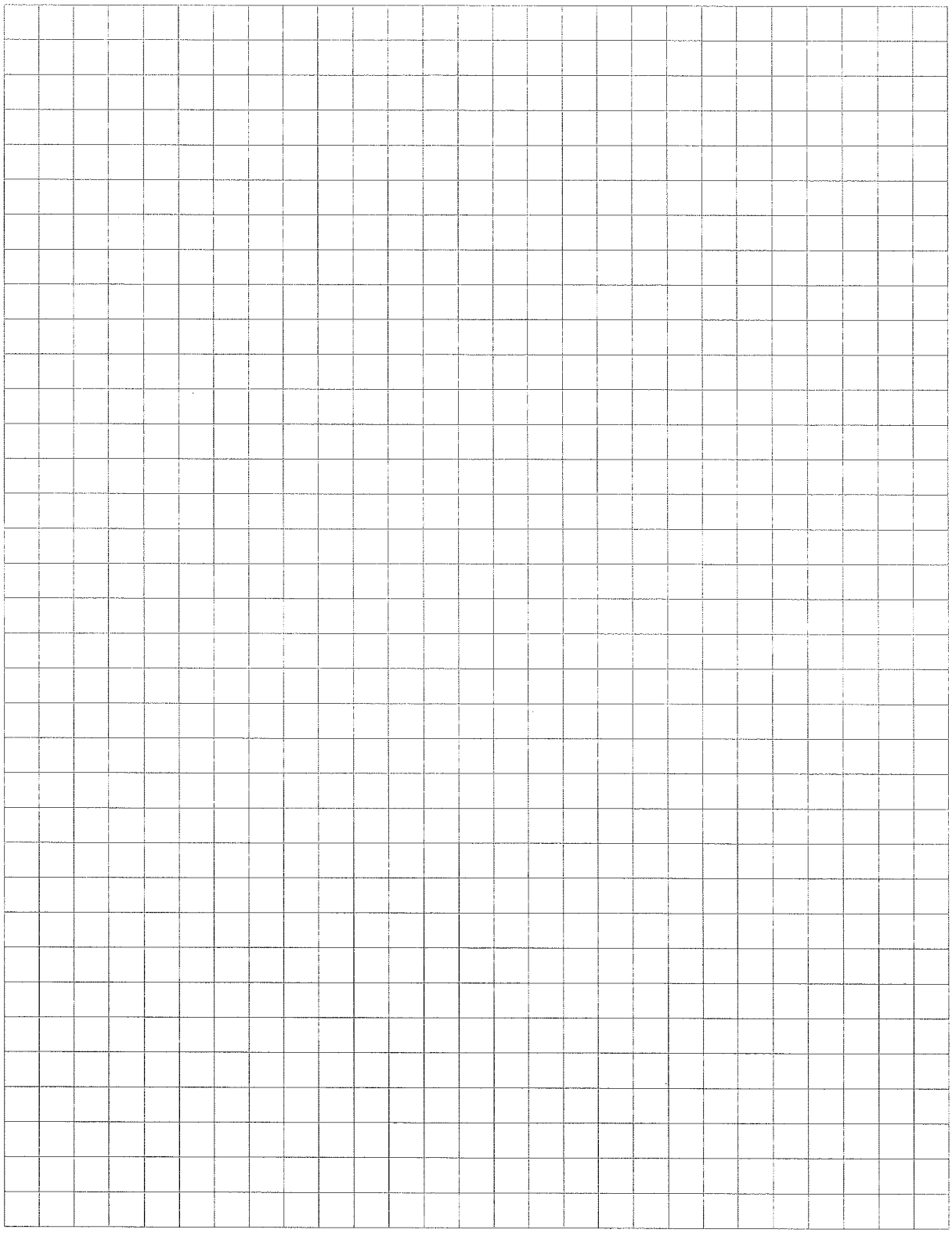
Code	Message	Action
0	Everything is fine	
1	Power Mode Ready	
2	Current Mode Ready	
3	Power Mode Adjust	
4	Current Mode Adjust	
5	Diode lasers off, temperature stable, ready to turn on	
8	Power Supply in Standby mode	Press Power Button
61	EEPROM data read error	Call Spectra-Physics Service
62	AC Fault, >50ms	Check power cord and/or line voltage
63	System Boot Marker	Call Spectra-Physics Service
64	Communications error	Check RS-232 cable
65	Laser Power Outside Ready Range	Call Spectra-Physics Service
66	Power adjust timeout	Call Spectra-Physics Service
67	Passbank over temp	Call Spectra-Physics Service
68	Passbanks current limited	Call Spectra-Physics Service
69	Diode Laser Module ilock test: bad voltage	Call Spectra-Physics Service
70	Diode Laser Module ilock test: bad logic	Call Spectra-Physics Service
71	N/A	
72	NA	

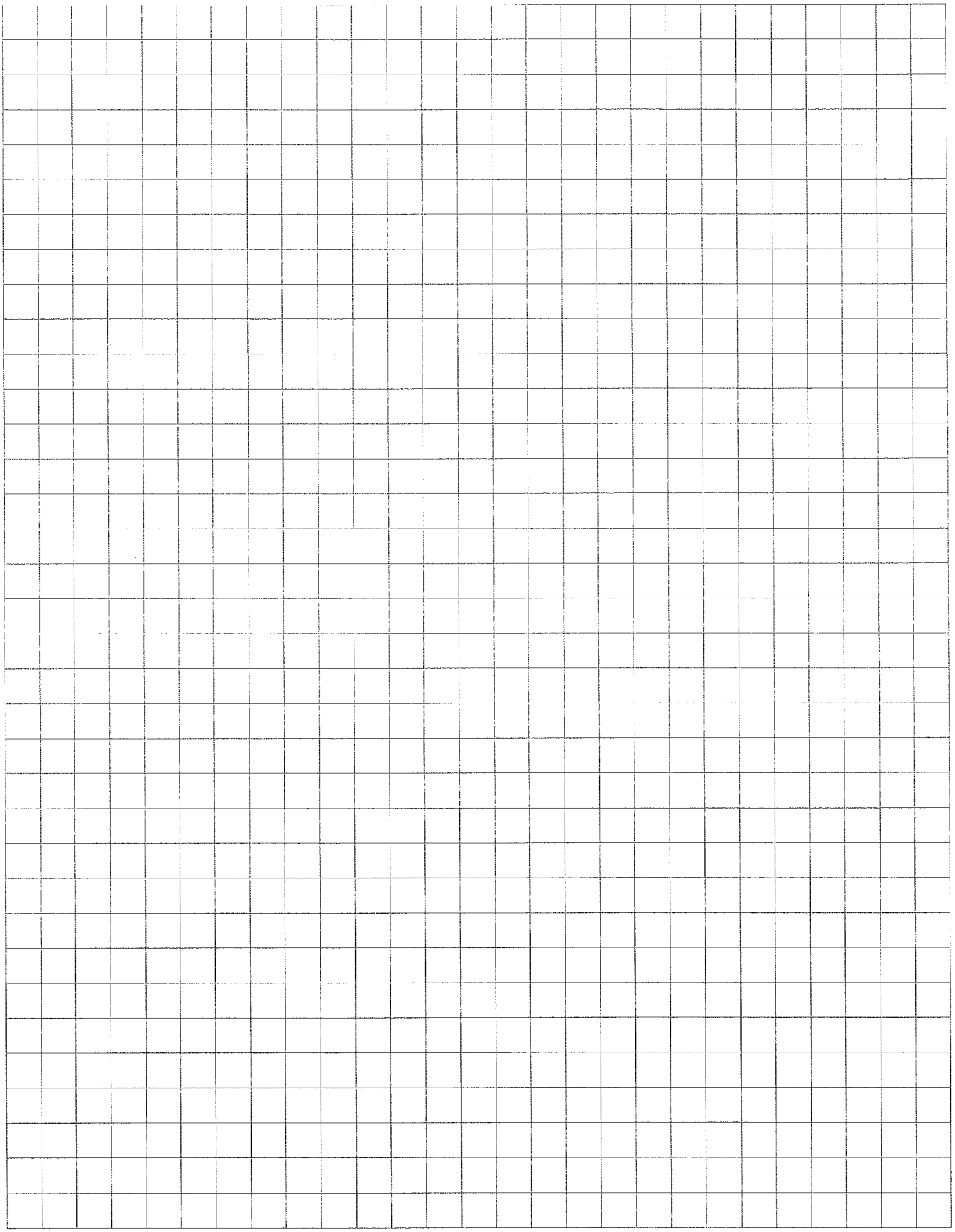
Code	Message	Action
73	Diode Laser Module Safety Check 1: bad voltage	Call Spectra-Physics Service
74	Diode Laser Module Safety Check 1: bad logic	Call Spectra-Physics Service
81	EEPROM data not available @ startup	Call Spectra-Physics Service
82	EEPROM fault on write condition	Call Spectra-Physics Service
83	Bad config for uP	Call Spectra-Physics Service
84	N/A	
85	Heater failed startup test	Call Spectra-Physics Service
86	N/A	
87	N/A	
88	Shorted therm #1 in power supply	Call Spectra-Physics Service
89	Open thermistr #1 in power supply	Call Spectra-Physics Service
90	Multiple errors	Reboot; Call Spectra-Physics Service
91	Diode laser over temperature	Call Spectra-Physics Service
92	Diode laser under temperature	Call Spectra-Physics Service
93	N/A	
94	Current limit passbank 1 active	Call Spectra-Physics Service
95	Power supply interlock active	Check jumper plugs
96	NA	
97	NA	
98	Safety relay for D1 closed, s.b. open	Call Spectra-Physics Service
99	Safety relay for D1 open, s.b. closed	Call Spectra-Physics Service
127	Everything's fine	
133	SHG duty cycle error	Call Spectra-Physics Service
134	SHG thermistor shorted	Call Spectra-Physics Service
135	SHG thermistor or heater open (check cable)	Call Spectra-Physics Service
140	Controller interlock open	Check Interlock jumper plug
141	Communications error between head & supply	Check cable connections
142	System shut off: check HST on info menu	Check History on INFO menu
143	System shut off: pwr sply interlock	Check all power supply interlocks
145	System shut off: REMOTE interlock	Check REMOTE Interlock
146	System shut off: power adjust timeout	Call Spectra-Physics Service
147	System shut off: current limit	Call Spectra-Physics Service
148	Controller communications time out	Verify control conncetion; reboot
200	Diode laser calibration required	Call Spectra-Physics Service
201	Diode laser 1 curr calib required	Call Spectra-Physics Service
202	NA	
203	NA	
204	NA	
205	Diode laser 1 temp calib required	Call Spectra-Physics Service
206	NA	
207	NA	
208	NA	
209	SHG Initialization error; read error	Call Spectra-Physics Service
210	SHG Initialization error; value out of range	Call Spectra-Physics Service
211	SHG Initialization error; write error	Call Spectra-Physics Service

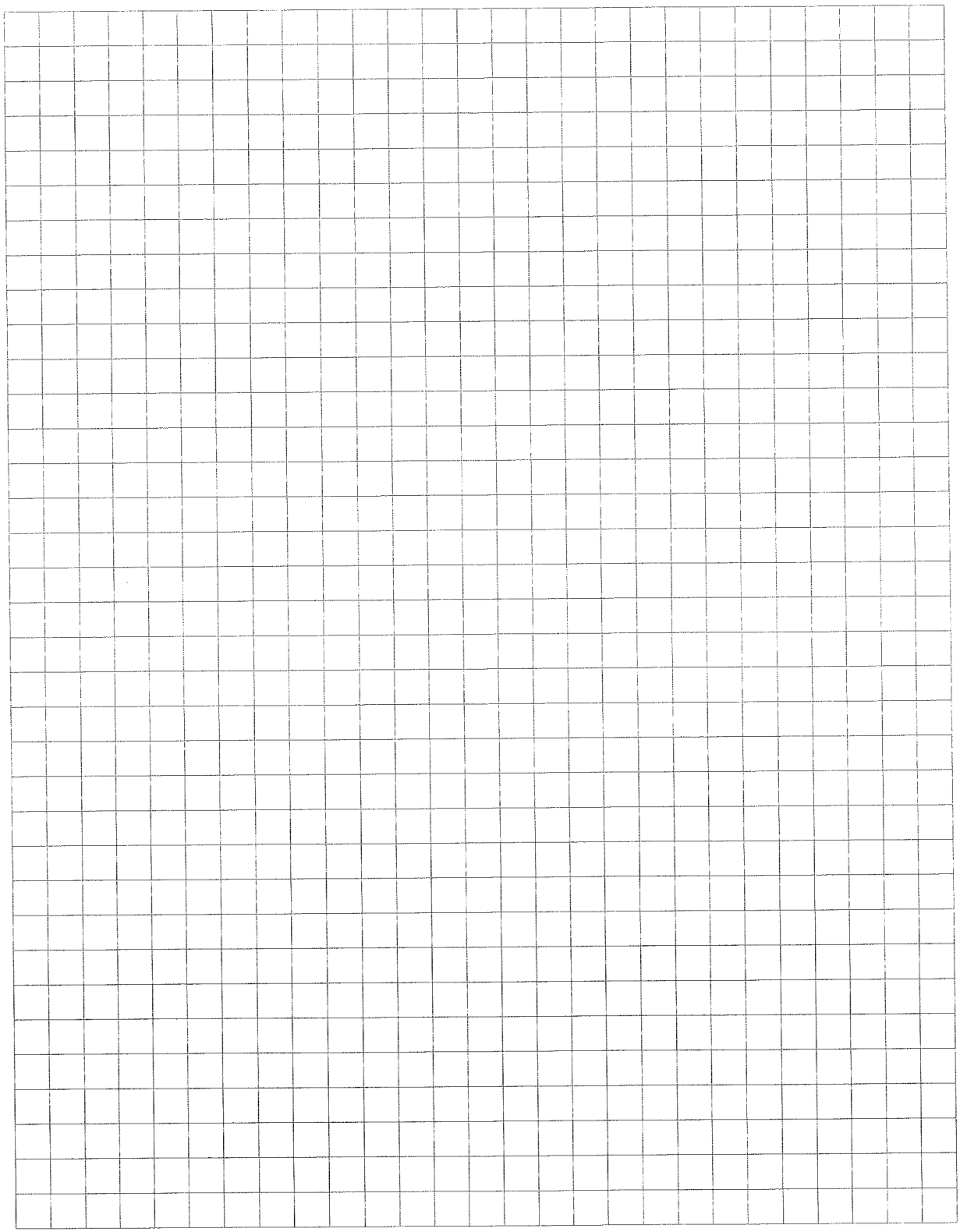
Notes

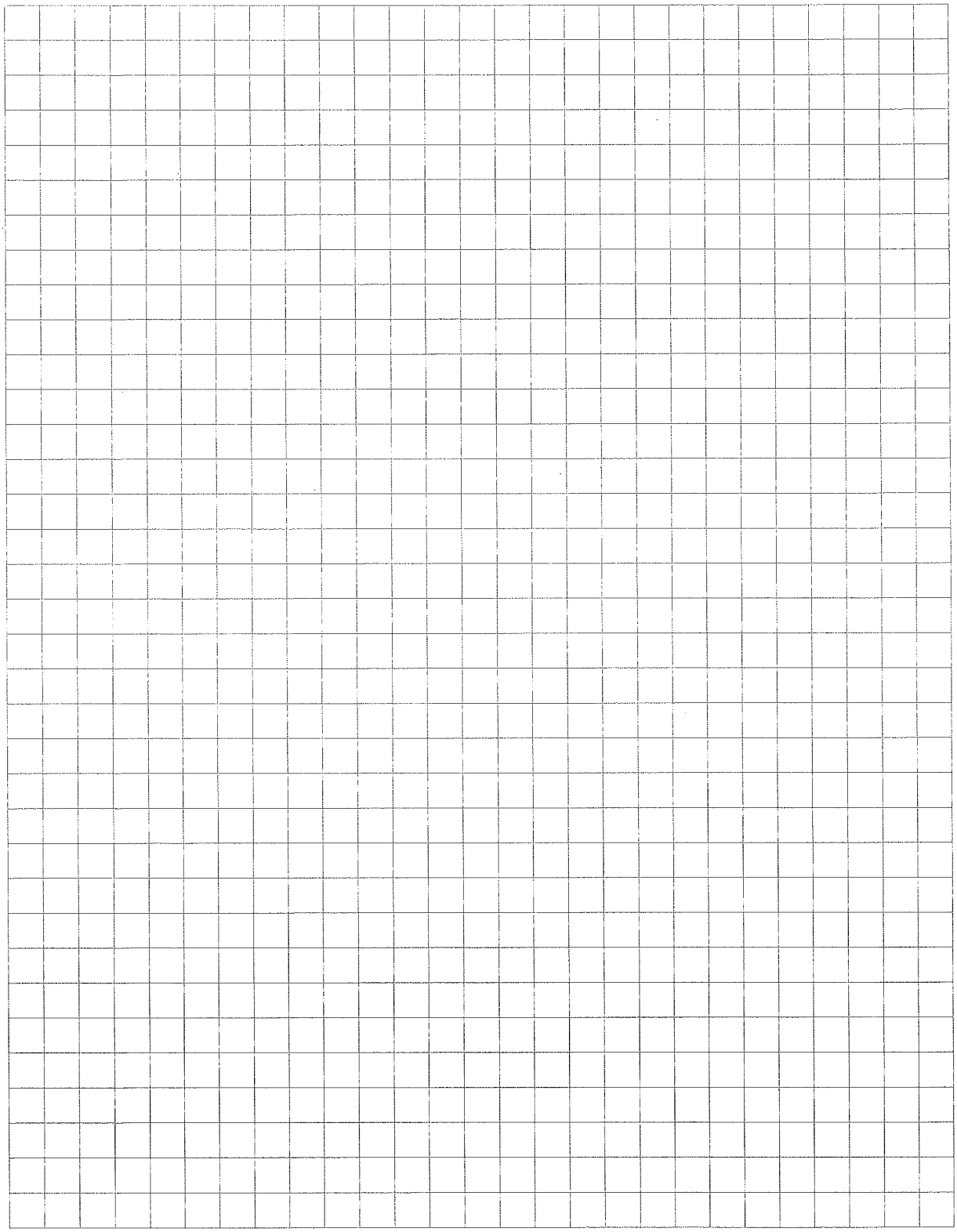












Report Form for Problems and Solutions

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

Thank you.

From:

Name _____

Company or Institution _____

Department _____

Address _____

_____

Instrument Model Number _____ Serial Number _____

Problem: _____

_____

_____

_____

_____

Suggested Solution(s): _____

_____

_____

Mail To:

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