R-SERIES LASER SYSTEMS

USER MANUAL

(For R-Series Track Mounted
Diode Pumped Laser Systems)

Spectra-Physics

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Part Number 0129-0391 Rev. E

Declaration of Conformity

Application of Council Directive 89/336/EEC and 73/23/EEC
Standards to which Conformity is Declared:

EN50082-1, EN55011, EN61010-1, EN60825-1

Manufacturer's Name:
Spectra-Physics Lasers, Inc.

Manufacturer's Address:
1305 Terra Bella Avenue, P.O. Box 7013
Mountain View, CA 94043-7013

Equipment Tested: Lasers

Model(s):
R05-S15-104Q, R2-S-104c, R2-S-106c, R1-S10-104Q, R1-S10-523Q, R1-S12-106Q, R1-S12-532Q, R2-E12-104Q, R2-E12-104Q-16, R2-E12-523Q, R2-V38-104Q, R2-V50-104Q, R2-E20-106Q, R2-E20-532Q, R2-VS5-104Q, R2-I10-104Q.
Above Models with GPIB and Remote Options.
Power Supply 7300X-L2 with Laser Head 7960-L2-S,
Power Supply 7300X-L4-80 with Laser Head 7960-L4-I-80,
Power Supply 7300E-L3-80 with Laser Head 7960-L4-I-80,
Power Supply 7300E-L4-80 with Laser Head 7960-L4-VS,
7960-L4-I, or 7960-L4-I-80.

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

For: Spectra-Physics Lasers, Inc.
Name: Charles E. Chandler
Title: Vice President and G.M. OEM
Signature: Charles E Chandler

Date: 9/24/97

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Preface

R-Series Laser Systems

This manual describes the installation, operation, and service requirements of the R-Series Industrial Diode Pumped Laser System. Including Power Supply, Laser Heads, Frequency Doubler and Remote Control.

The R-Series Q-switched laser head and the Model 7300 laser diode module emit laser radiation that can permanently damage eyes and skin, ignite fires, and vaporize substances. The Laser Safety section contains information and guidance about these hazards. To minimize the risk of injury or expensive repairs, carefully follow these instructions.

The Service and Repair section is intended to help guide you to the source of common problems. Do not attempt repairs while the unit is under warranty. Instead, report all problems to Spectra-Physics for warranty repair.

We welcome your comments on the content and style of this manual. Thank you for your purchase of Spectra-Physics instruments.

Quantity	Unit	Abbrev.	Prefixes		
mass	gram	g	tera	(10^{12})	T
length	meter	m	giga	(10^{9})	G
time	second	s	mega	(10^{6})	M
frequency	hertz	Hz	kilo	(10^{3})	k
force	newton	N	deci	(10^{-1})	d
energy	joule	J	centi	(10^{-2})	c
power	watt	W	milli	(10^{-3})	m
electric current	ampere	A	micro	(10^{-6})	µ
electric charge	coulomb	C	nano	(10^{-9})	n
electric potential	volt	V	pico	(10^{-12})	p
resistance	ohm	Ω	femto	(10^{-15})	f
inductance	henry	H	atto	(10^{-18})	a
magnetic flux	weber	Wb			
magnetic flux density	testa	T			
luminous intensity	candela	cd			
temperature	kelvin	K			

FIGURE p-1: SI Units

This product is manufactured under one or more of the following Spectra-Physics Patents:

U.S. PATENT NUMBERS

4,653,056	4,837,771	5,351,121	5,608,742
4,656,635	4,872,177	5,410,559	5,638,388
4,665,529	4,894,839	5,412,683	5,651,020
4,701,929	4,908,832	5,436,990	5,745,519
4,723,257	4,913,533	5,446,749	5,801,403
4,739,507	4,942,582	5,504,762	5,812,583
4,756,003	5,018,152	5,550,852	5,835,513
4,761,786	5,080,706	5,561,547	5,907,570
4,785,459	5,127,068	5,577,060	
4,829,529	5,155,631	5,579,422	

Introduction

Chapter One

Theory of Operation

Spectra-Physics diode pumped, solid-state lasers use temperature- tuned phased array GaAlAs laser diodes. These diodes replace arc lamps or incandescent light sources as the optical pumping source.

The principal advantages of this approach include:

- Longer lifetime
- More compact size
- Elimination of the need for water cooling
- Elimination of thermal lensing in the active medium.

Laser Head Optical Parameters

The laser head uses a hemispherical cavity design and an axial pump geometry to excite the solid-state laser medium (Figure 1-1). The laser medium is a 5 mm long rod of either neodymium-doped yttrium aluminum garnet (Nd:YAG) or yttrium lithium fluoride (Nd:YLF).

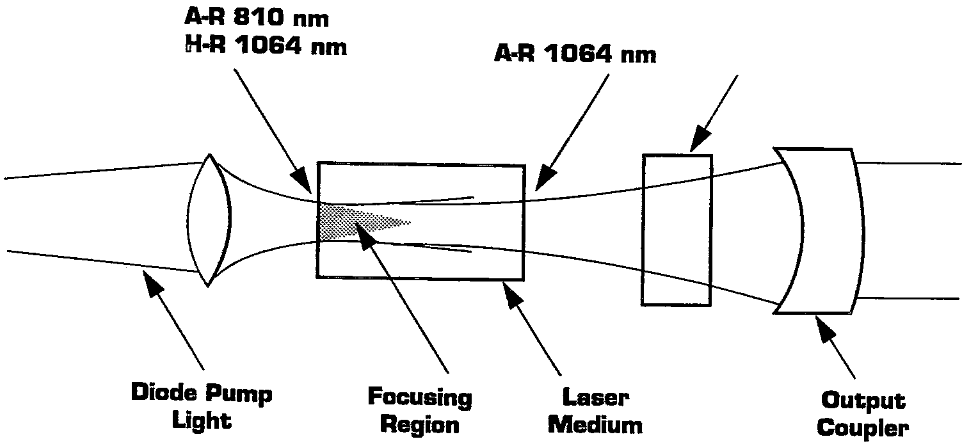


FIGURE 1-1: Optical Schematic of Diode Pumped Nd:YAG Laser

Both ends of the rod are optically polished. Typically, the input end is coated to be a high transmitter in the absorption band of neodymium, and a high reflector in its emission wavelengths. The output end of the rod is antireflection coated at the lasing wavelength. An acousto-optic Q-switch is placed between the laser rod and output coupler. The input-end surface of the rod and the output coupler form the laser cavity.

The laser diode pump light is coupled into the laser medium through a fast lens that matches the pump volume to the TEM_{00}mode volume of the laser cavity. Through this "mode matching," the maximum absorption of the pump wavelength takes place within the TEM_{00}laser mode volume (Figure 1-2). This approach ensures maximum coupling efficiency of the pump light into the laser medium and optimizes laser operation in the TEM_{00} mode.

Pump light is delivered to the laser medium through a flexible optical fiber. This design makes it possible to replace the laser diode pump source without realignment of the laser head to the optical beamtrain

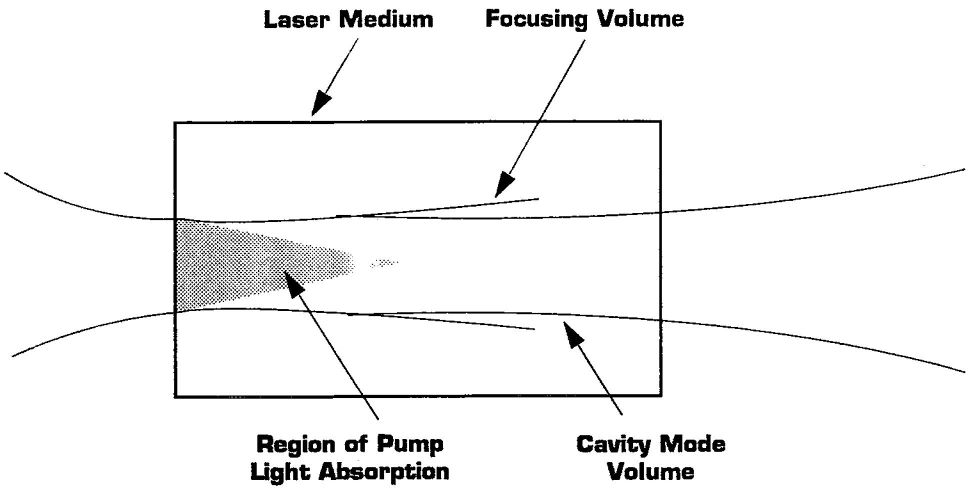


FIGURE 1-2: Mode Matching the Pump Volume

Temperature Tuning of the Laser Diode

The laser diode is located in the Power Supply. For maximum efficiency, the output wavelength of the diode must match the absorption characteristics of the laser medium. The absorption spectrum of Nd:YAG and a depiction of the diode pump wavelength are shown in Figure 1-3. The output spectrum of a conventional pump source for Nd:YAG operation, the krypton arc lamp, is shown for comparison

The process involved in the manufacture of the GaAlAs laser diodes produces a broad distribution of output wavelengths. To match the diode output to an absorption peak of the laser medium, it is necessary to select diodes with outputs near the absorption peak and then temperature tune them for maximum absorption: 0.3 nm of wavelength shift occurs for every 1° C change in temperature of the diode junction. Cooling shortens the wavelength, and heating lengthens it.

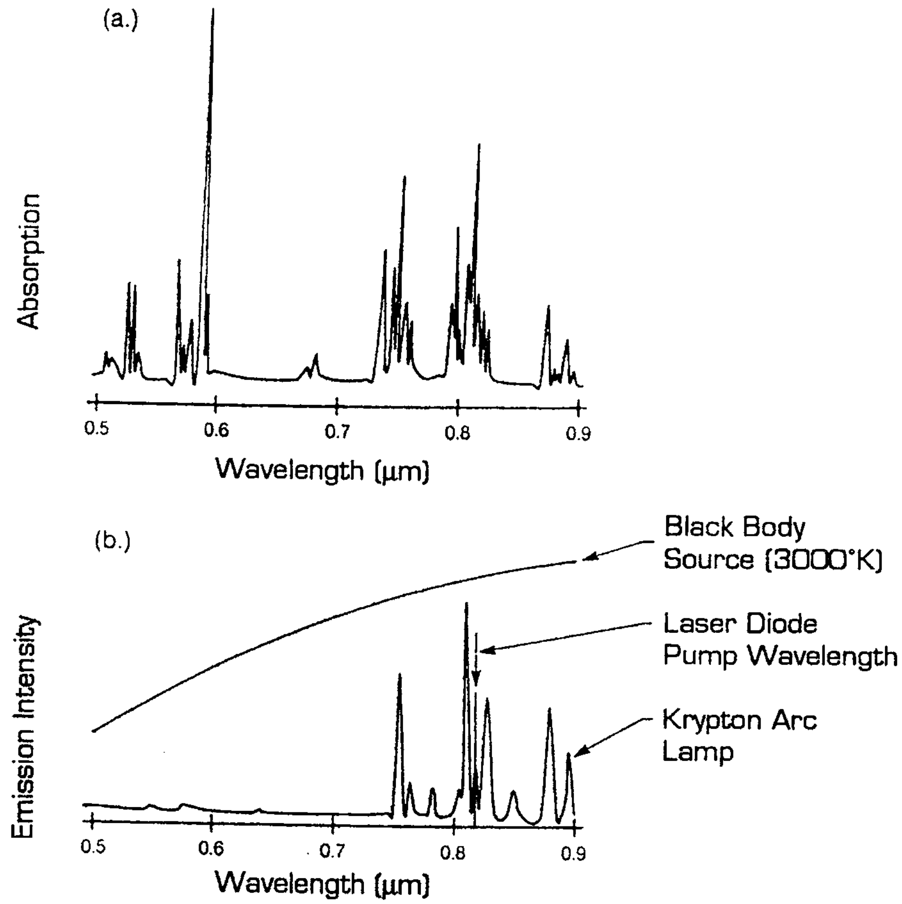


FIGURE 1-3: Nd:YAG Absorption Spectrum (a) and Pump Source Emission Spectra (b)

The R-Series Power Supply uses laser diodes with wavelengths longer than the absorption peak of the laser medium when measured at room temperature. A thermoelectric (TE) cooler brings the diode temperature down until the output wavelength matches the absorption peak.

Cooling the diodes results in slightly lower electrical efficiencies for the system because of the drive current requirements of the TE coolers, but it extends system lifetime by running the diodes at lower temperatures.

The absorption maxima for YAG and YLF are separated by approximately 10 nm. A R-Series Power Supply with diodes optimized for one active medium will not optimally pump laser heads using the other medium.

Q-switch Operation

An acousto-optic Q-switch is the variable loss element in the laser cavity of the laser head. An rf driver in the Power Supply controls the Q-switch, allowing pulse rates from 1 Hz to 10 kHz using the internal clock. Pulse rates to 50 kHz can be generated using an external trigger source. Single Q-switched pulses may also be obtained.

The Q-switch consists of a block of optical quality glass with a piezoelectric transducer bonded to it. When an rf signal is applied to the transducer, an acoustic wave is produced in the glass, causing a variation in the index of refraction by means of the photoelastic effect. This variation acts as a diffraction grating that causes Bragg scattering of the light and results in high loss in the laser cavity. With the rf on, no lasing takes place, and energy is stored in the laser rod. When the rf is switched off, the laser begins to oscillate. A laser pulse builds rapidly to a maximum, then falls as the population inversion is depleted. The rf is then once again applied to the Q-switch so the process can be repeated.

Maximum energy per pulse is achieved when the rf is on long enough to establish a steady-state population inversion, a time that is related to the stored energy and fluorescence lifetime of the laser material at maximum pump levels. The energy per pulse begins to decrease at a pulse rate of around 800 pps for Nd:YLF and at around 1500 pps for Nd:YAG. At higher pulse rates, the energy per pulse falls until, at 10,000 pps, the energy is 20 to 30% of maximum.

The pulse width is similarly affected by pulse rate: it is shortest at the maximum population inversion and lengthens as the pulse rate increases.

System Description

The Laser Head and Power Supply comprise a compact, efficient laser system capable of delivering coherent pulsed energy at two different infrared wavelengths. The Laser Head is chosen by matching its performance characteristics to the requirements of the application. Optional accessories include a frequency doubler for green output , a remote control and a General Purpose Interface Card with RS-232/IEEE 488 compatibility.

The laser diode module in the power supply is available with either one or two laser diodes installed, depending on output power requirements. A flexible, detachable fiber-optic cable couples the output of the laser diode to the laser head, where it pumps the solid-state laser medium.

The laser medium can be a Nd:YAG or Nd:YLF rod depending on the model selected. The laser head is compact, rugged, and contains no user adjustable components.

An rf driver in the Power Supply supplies rf power to the Q-switch in the laser head.

The R-Series system is controlled either manually through the optional Model 7310 remote control or by the user system via the 37-pin D-connector on the back panel. The Power Supply can also incorporate the GPIB/RS232 interface card for interface through a computer.

The system complies with all safety regulations set by the Center for Devices and Radiological Health (CDRH) for a Class IV laser device.

R-Series Power Supply

Components

The Power Supply consists of six main sections:

- DC Power supply
- Diode driver board
- Diode module board
- Motherboard
- Laser diode assembly
- rf driver for Q-switch

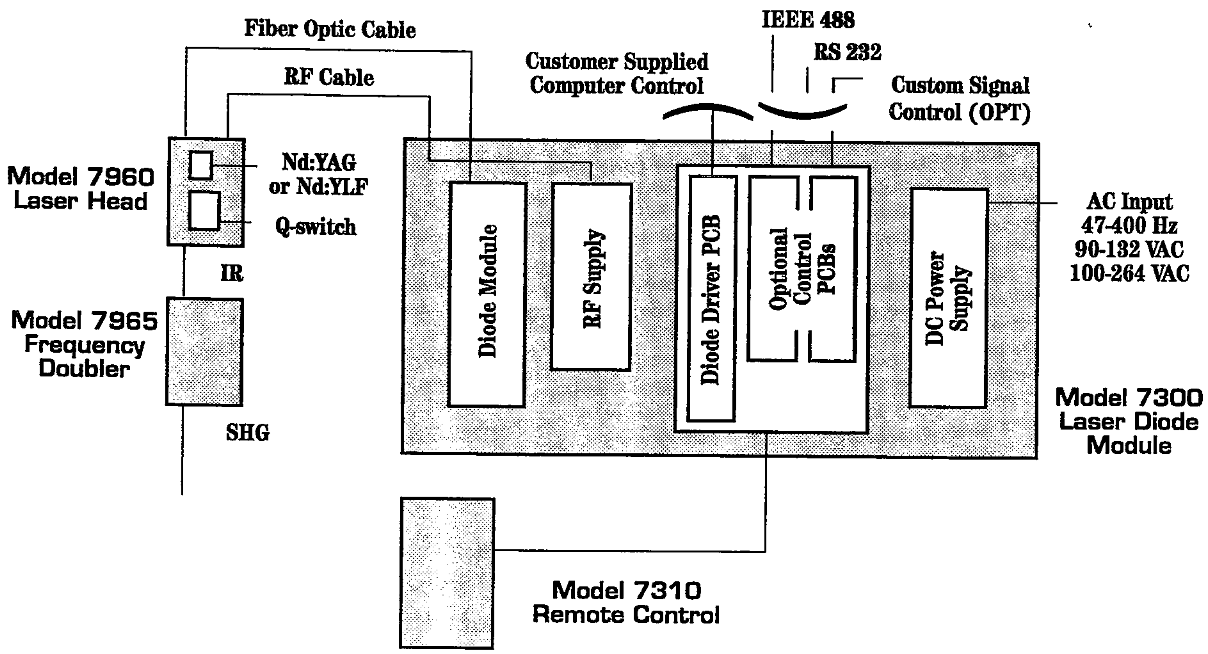


FIGURE 1-4: System Block Diagram Showing Laser Head, Power Supply, and Remote Control Unit.

Component Descriptions

AC/DC Power Supply

The power supply is an autoranging, switching regulator supply for high efficiency and low heat generation. Any AC line voltage between 90 and 264 volts is permitted. The power supply is a self-contained and internally fused component that provides the DC power to operate the system.

Motherboard

The motherboard contains an Intel 80C31 microprocessor, 2KB of nonvolatile static RAM, a 32 KB system PROM and factory-adjusted DIP switches for system configuration. The microprocessor, running the firmware in the system PROM, senses user input and system status and controls the functioning of the system

Diode Driver Board

The diode driver board conditions the input signals and controls the laser either in diode current mode or diode power mode. The diode drive current may be varied continuously from zero to its rated output power.

As the diode ages, more current will be required to produce a given power setting. There is a current limit setting in the power supply to protect the laser diode from damage caused by excessive current. It is preset at the factory at 110% of the rated output power of the diode. A procedure for changing the current limit is given in the manual.

Laser Diode Assembly

The output of the laser diode is collimated and focused inside a separate assembly that serves as a heat sink for both the laser diode and its TE cooler. A small fan directs outside air across the heat sink fins of the laser diode assembly and cools the power supply in the Model 7300. The assembly focuses the optical output of the laser diode into an FC (SMA for 500 mW model) fiber-optic connector that protrudes through the rear panel of the laser diode module. The assembly can be configured with either one or two laser diodes to pump either Nd:YAG or Nd:YLF. When two diodes are installed, the assembly also includes a beam combining dielectric mirror.

Diode Module Board

The diode module board controls the laser diode junction temperature and thus the wavelength setting. A thermistor in the laser diode senses the diode junction temperature and provides feedback to circuitry on the diode module board to operate the TE cooler. If the TE cooler cannot achieve the desired temperature, then this out-of-temperature-range condition will cause the red temperature LED on the diode module board to light.

rf Driver for Q-switch

The rf driver supplies rf power to the Q-switch. The power level is internally set to provide hold-off in the laser cavity and requires no adjustment during operation. The module responds to on/off commands from the microprocessor to produce Q-switched pulses. Alternatively, external triggering can be used. The rf can be turned off completely for cw operation. The microprocessor provides the timing for the rf power module at pulse rates and input conditions set by the operator. When Q-switching, the rf power is turned off for a fixed time period during which the pulse occurs. This time period is not adjustable by the operator and is the same length at all repetition rates. The microprocessor also provides a sync signal, available at the rear panel, for each Q-switched pulse.

System Software

Operation of the system software is outlined in the flow chart shown in Figure 1-5. This diagram is composed of three parts -- system activation, the system loop, and system interrupts. The software architecture consists of several operation-specific routines that are accessed from the system loop.

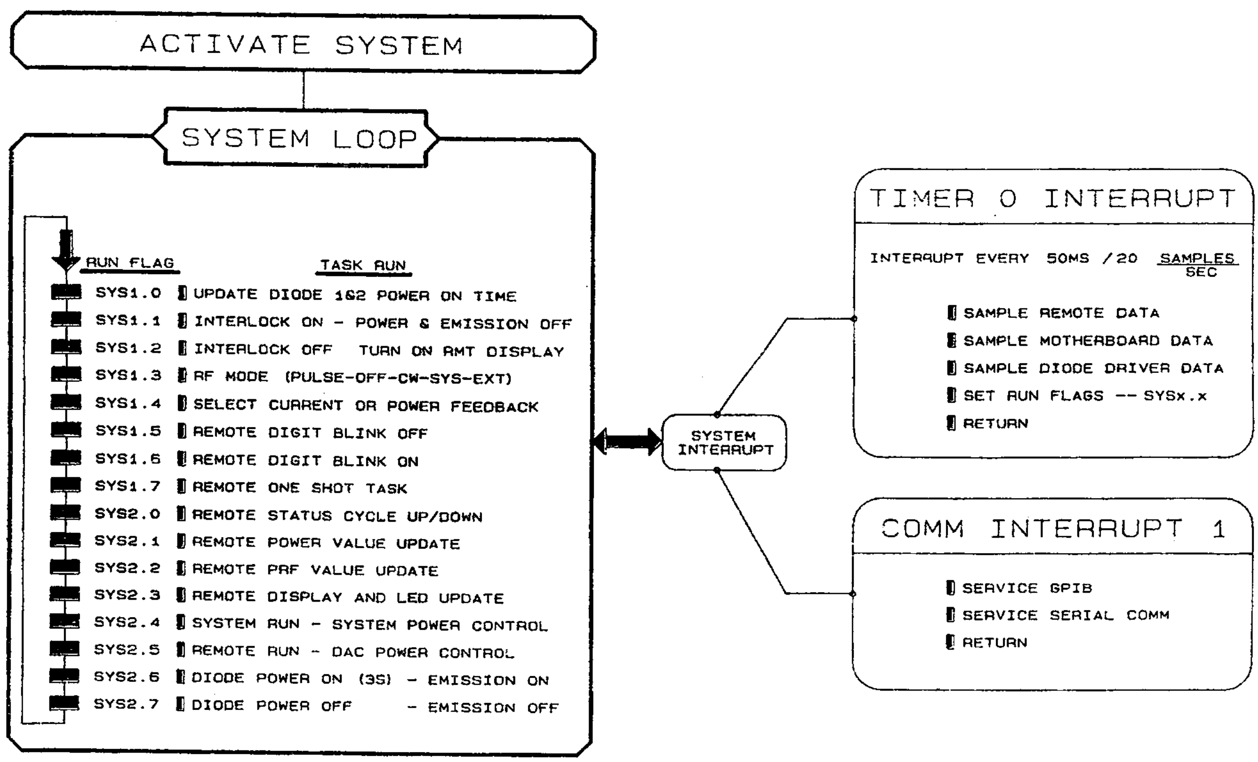


FIGURE 1-5: R-Series Software Flow Chart

During system activation, the microprocessor performs several self- tests to assure proper operation. During these tests, the message "TEST" is displayed on the remote control. System memory and communications are tested for accuracy with write and read operations. If the remote control is detected, then its switch positions are tested. A failure of one of these basic tests will halt system operation. Indication of a failure will be noted on the back-panel connector as TTL high on the SYSTEM FAULT line (J7 Pin 27). If the remote control is installed, an error message indicating the source of the fault will also be displayed.

The microprocessor reads the dip switches on the motherboard that determine the 7300 system configuration. These are set at the factory and should not require adjustment by the user. Figure 1-6 shows the micro-processor dip switch functions.

Switch #	OFF	ON
1	normal operation	system reset
2	Q-switch system	cw system
3	1.0 W diode	500 mW diode
4	asynchronous Q-switch	synchronous
5 & 6	diode driver feedback mode (see below)	
7	diode 1 not present	diode 1 present
8	diode 2 not present	diode 2 present

Switches 5	6	Diode Driver Feedback Mode
off	off	Current
off	on	Unused
on	off	Power
on	on	Unused

FIGURE 1-6: Microprocessor Dip Switch Functions (motherboard sw1)

After system initialization, system loop execution begins. In this loop, software flags are tested to determine if a particular routine requires execution. If the flag tests positive, program execution jumps from the loop to the software routine, returning upon completion. For example, when the SYS1.1 flag is set high, the interlock routine turning off diode emissions and locking out user input is initiated. After the interlock is cleared, execution of the system loop continues by testing the SYS1.2 flag. All of the 7300 system functions are controlled by the microprocessor in this manner.

System interrupts are used to stop execution of the system loop to perform housekeeping functions. Every 50 ms (or 20 times a second) the system loop is stopped by the Timer 0 Interrupt to update the software flags. Data is obtained from the diode driver, the microprocessor board, and the 7310 remote if it is present. After this interrupt is executed. the system loop continues using new values for the system variables. The GPIB/RS-232 controller option operates in a similar manner, interrupting the operation of the microprocessor to update the system variables.

Electrical System

An overview of the electrical system is shown in Figure 1-7. The system is comprised of several components -- an off-line switching power supply, a microprocessor-based controller board (motherboard). a laser diode assembly, an rf driver module, and the remote control. The two expansion slots for the system originate on the motherboard (J11. and J12). J10 is dedicated to the laser diode driver board, and J11 is committed to the communications board. The remaining expansion slot, J12, is used for the heater controller, or can be customized for specific applications, such as custom interface card.

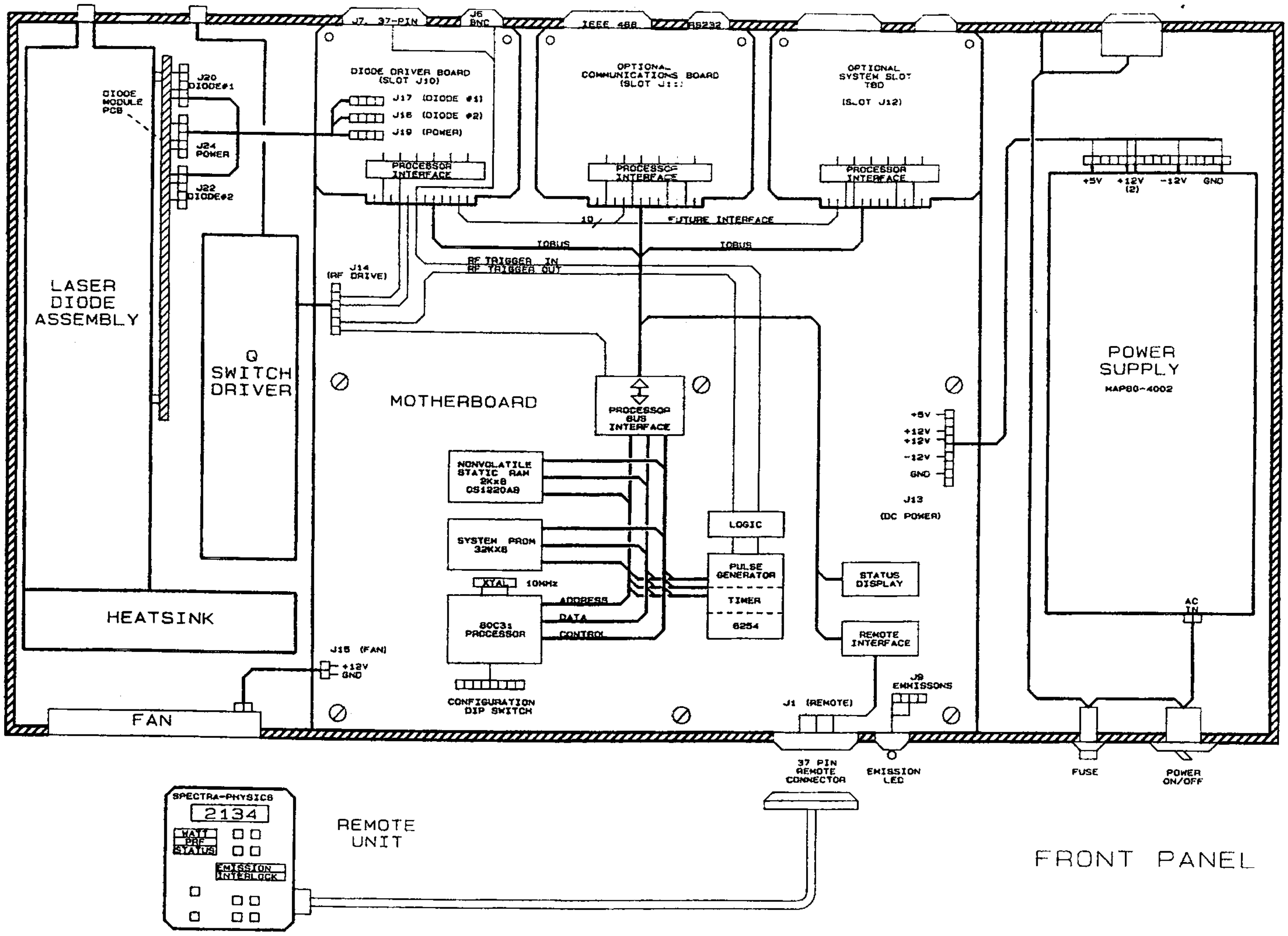


FIGURE 1-7: Electrical System Block Diagram

The off-line switching power supply is located on the right-hand side of the system. To protect the user from exposure to the AC line, the switcher is isolated inside a metal housing. The switcher converts the AC line (90-264V, 47-63Hz) to three, regulated, DC-output voltages (+5V, +12V, and -12V). These outputs are connected from the switcher to the J13 connector on the motherboard via a wire harness. DC power is distributed to the system from the motherboard. Also, the input to the switcher is fused to protect against any power supply faults. The main power switch (key-operated) on the front panel disconnects the AC line from the switching supply and terminates operation of the 7300 system by removing DC power from the motherboard.

The motherboard contains a microprocessor-based controller that regulates the operations of the system. Based on the 80C31 processor, this processor operates with a 10 MHz clock rate and is equipped with a 2 KB, non-volatile SRAM. The processor is capable of retaining data settings after power down because of the SRAM. The operating software for the system is stored on a 32 KB PROM.

The microprocessor interface bus connects the remote control unit and the three expansion slots (J10, J11, and J12) to the microprocessor system. This bus consists of address, data, and control lines that are used to exchange user input data and system output data. The 37-pin connector (J7) on the rear panel utilizes the diode driver board to interface with the processor through expansion slot J10. The communications board allows user input using an IEEE-488 (GPIB) or RS-232 interface via expansion slot J11. If these options do not satisfy a specific need, then the micro-processor interface bus can be accessed through a customized board that plugs into the system slot (J12).

Drive pulses for the rf driver module are generated on the motherboard. The pulses can be initiated using either the remote control unit (microprocessor system clock) or an external source. Using BNC connector J8, the rf driver triggers the laser head to emit Q-switched pulses. When using the remote, the rf driver can pulse the laser head in single-pulse mode or repetitively from 1 Hz to 9.999 kHz. Using either the external BNC connector (J6) or SYSTEM EXT TRIG (J7 pin 9) the laser head may be triggered with an external system. The motherboard also controls the system cooling fan and the front panel diode emissions lamp using J15 and J9, respectively. In addition to user I/O provided through expansion slot J10, the laser diode driver board monitors laser diode performance and adjusts the current drive to both the diode and its thermoelectric cooler (TEC). The system is capable of driving two 1W diodes. An analog-to-digital converter on this board allows real-time readings of laser diode current, power, and temperature. Additionally, diode current or power can be chosen as the control variable with the driver board.

Connector J19 provides power to the laser diode module, and connector J17 (and J18, for a two diode system) relay diode control signals to the module.

The laser diode module produces laser light that is transmitted over a fiber-optic cable to the laser head. The laser diode module board attached to the side of the module contains diode protection circuitry, temperature control circuitry, and photo-diode calibration circuitry. With this circuitry, the diode module calibration for TEC temperature and diode output power is possible at the factory, allowing direct shipping of replacement laser modules to customers. The diode module board is connected to the diode driver board via connectors J20, J22, and J24.

The R-Series Laser Head

The Model 7960 laser head is available in two variations: Nd:YAG, which lases at 1064 nm, and Nd:YLF, which lases at 1047 nm.

The rectangular head has an FC connector at its input end for attaching a fiber-optic cable from the power supply. The fiber-optic cable used and the connector at the power supply vary with the diode power. The 500 mW versions use a 100 micron fiber-optic cable with an SMA connector at the power supply diode module output. The 1W and 2W versions use a 150 micron fiber-optic cable with an FC connection at the power supply.

An input lens focuses incoming pump power onto the laser rod. Both the input lens and the output mirror are permanently aligned for optimum power and the laser head is sealed. No disassembly or alignment of the laser head is possible.

The head also has an SMA electrical connector for attaching an rf cable from the Q-switch driver in the power supply. A 183 cm (72 in.) rf cable with an SMA connector on one end and BNC connector on the other is used.

A safety beam attenuator (shutter) is attached to the output end of the head and is opened and closed by rotating the knurled ring.

R-Series Frequency Doubler

Visible light radiation is attainable by using the external frequency doubler in conjuction with the Q-switched laser head. This doubler can be removed and replaced by the end user, allowing access to both the fundamental and the second harmonic.

The nonlinear material in the doubler is heated. A Controller board is added to one of the option slots in the power supply to regulate the oven temperature.

A cable connects the doubler to the controller board mounted in the power supply.

R-Series Remote Control

An optional hand-held remote control accesses all of the functions of the laser system through a connector on the front panel. It can be used to control the laser during the R & D phase of product development, and as a run box for diagnosis of problems in the field. It can also be used to monitor status variables such as diode pump power and PRF while the laser is being controlled by the user's system through the back panel connector.

R-Series GPIB/RS-232

An optional interface card is available. It gives the power supply both GPIB and RS-232 interface capability.

Laser Safety

CHAPTER TWO

Introduction

Please read this section carefully before installing or operating your laser. To preserve your warranty, we recommend that all service and repair operations be performed by a Spectra-Physics service engineer. If you do plan to service your laser yourself, please follow the procedures in the Service and Repair section of this manual.

DANGER

The Spectra-Physics MR-Series Power Supply, is a Class IV-High Power Laser. The R-Series laser heads and frequency doubler are classified as Class IV High Power Lasers. The output beam from each is, by definition, a safety hazard. Avoid eye or skin exposure to direct or scattered radiation.

The laser diode module in the power supply emits invisible laser radiation from the FIBER-OPTIC CONNECTOR port on the rear panel when the fiber-optic cable is disconnected. When the cable is connected and its beam attenuator cap is removed, the system emits invisible laser radiation from the end of the cable.

When the laser head is connected to the fiber-optic cable and the laser head beam attenuator is open, the system emits invisible pulsed or cw laser radiation from the output end of the laser head.

When the frequency doubler is attached to the laser head and the beam attenuator is open, the system emits visible pulsed laser radiation. If the laser is operated in cw mode, invisible infrared radiation will be emitted.

Follow instructions contained in this manual for proper installation and safe operation of your laser. Refer to the table of Maximum Emission Levels. We recommend the use of protective eye wear whenever possible. Selection depends on the energy and wavelength of the laser beam as well as operating conditions. Consult ANSI, ACGIH, EN or OSHA standards for guidance.

CAUTION

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

DANGER

At all times during installation , operation, maintenance, or service of your laser, avoid exposure to laser or collateral radiation exceeding the accessible emission limits listed in "Performance Standards for Laser Products" United States Code of Federal Regulations, 21 CFR 1040 10(d).

Precautions for Safe Operation of Class IV Lasers

- Never look directly into the laser beam. Even diffuse reflections are hazardous.
- Wear protective eyewear.
- Avoid blocking the output beam or its reflection(s) with any part of the body.
- Set aside a controlled-access area for laser operation; limit access to those trained in the principles of laser safety.
- Post warning signs in prominent locations near the laser operation area.
- Enclose beam paths wherever possible.
- Set up a beam dump to capture the laser beam and prevent accidental exposure.
- Set up experiments so the laser beam is below eye level.
- Maintain a high ambient light level in the laser operation area so that the eye's pupil remains constricted, reducing the possibility of retinal damage.
- Set up shields to prevent reflected beams from escaping the laser operation area.

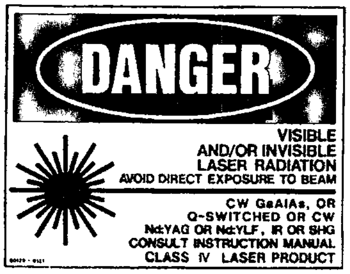


FIGURE 2-1: Standard Safety Warning Sign

Schedule of 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), check to see that all features of the product identified on the following figures function properly. Also, make sure that all warning labels (Figure 2-2) remain firmly attached.

1. Verify that opening the INTERLOCK circuit on the 37-pin rear connector prevents laser operation.

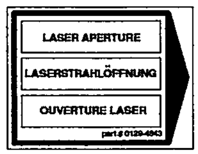
2. Verify that the laser can only be turned on when the key switch (Figure 3-1) is in the ON position, and that the key can only be removed when the switch is in the OFF position.

3. Verify that the emission indicator (Figure 3-1) provides a visible signal when the laser emits accessible laser radiation. Also verify that the signal provides an advance warning sufficient to allow action to avoid radiation exposure.

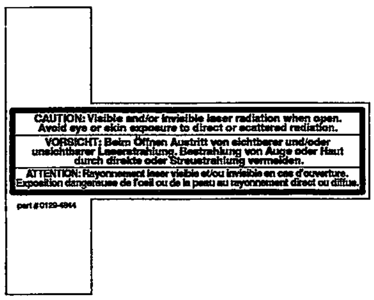
4. Verify that both the cap at the end of the fiber-optic cable and the shutter on the laser head actually block invisible IR laser radiation.

5. Verify that the fiber connector brackets are properly installed and that they prevent the fiber from being disconnected at either end.

IEC 825-1 Laser Warning, Class 4



IEC 825-1 Laser Aperture Label



IEC 825-1 Service Connection Warning Label

Supplementary Warning Label for Laser Head

FIGURE 2-2: Standard System Safety Labels