series48

L Version Lasers
Operator's Manual

SYNRAD®

An Excel Technology Company

4600 Campus Place
Mukilteo, WA 98275 USA
1.800.SYNRAD1
tel 1.425.349.3500
fax 1.425.349.3667
e-mail synrad@synrad.com
www.synrad.com

series48

Series L48 Lasers
Operator's Manual

Model 48-1

Model 48-2

Model 48-5

Version 7.0

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Warranty information

This is to certify that Series 48 lasers are guaranteed by SYNRAD, Inc. to be free of all defects in materials and workmanship for a period of one year from the date of purchase. This warranty does not apply to any defect caused by negligence, misuse (including environmental factors), accident, alteration, or improper maintenance.

If, within one year from the date of purchase, any part of the Series 48 laser should fail to operate, contact the SYNRAD Customer Service department at 1.800.SYNRAD1 (outside the U.S. call 1.425.349.3500) and report the problem. When calling for support, please be prepared to provide the date of purchase, model number and serial number of the unit, and a brief description of the problem. When returning a unit for service, a Return Authorization (RA) number is required; this number must be clearly marked on the outside of the shipping container in order for the unit to be properly processed. If replacement parts are sent to you, then you are required to send the failed parts back to SYNRAD for evaluation unless otherwise instructed.

If your Series 48 laser fails within the first 45 days after purchase, SYNRAD, Inc. will pay all shipping charges to and from SYNRAD when shipped as specified by SYNRAD Customer Service. After the first 45 days, SYNRAD will continue to pay for the costs of shipping the repaired unit or replacement parts back to the customer from SYNRAD. The customer, however, will be responsible for shipping charges incurred when sending the failed unit or parts back to SYNRAD or a SYNRAD Authorized Distributor. In order to maintain your product warranty and to ensure the safe and efficient operation of your Series 48 laser, only authorized SYNRAD replacement parts can be used. This warranty is void if any parts other than those provided by SYNRAD, Inc. are used.

SYNRAD, Inc. and SYNRAD Authorized Distributors have the sole authority to make warranty statements regarding SYNRAD products. SYNRAD, Inc. and its Authorized Distributors neither assumes nor authorizes any representative or other person to assume for us any other warranties in connection with the sale, service, or shipment of our products. SYNRAD, Inc. reserves the right to make changes and improvements in the design of our products at any time without incurring any obligation to make equivalent changes in products previously manufactured or shipped. Buyer agrees to hold SYNRAD harmless from any and all damages, costs, and expenses relating to any claim arising from the design, manufacture, or use of the product, or arising from a claim that such product furnished Buyer by SYNRAD, or the use thereof, infringes upon any Patent, foreign or domestic.

Trademark/copyright information

Duo-Lase and Power Wizard are registered trademarks of SYNRAD, Inc.

All other trademarks or registered trademarks are the property of their respective owners.

Contact information

Worldwide headquarters

SYNRAD's worldwide headquarters are located north of Seattle in Mukilteo, Washington, U.S.A. Our mailing address is:

SYNRAD, Inc.
4600 Campus Place
Mukilteo, WA 98275
U.S.A.

Phone us at:	1.800.SYNRAD1 (1.800.796.7231)
Outside the U.S.:	1.425.349.3500
Fax:	1.425.349.3667
Email:	synrad@synrad.com

Sales and Applications

SYNRAD's Regional Sales Managers work with customers to identify and develop the best CO_2 laser solution for a given application. Because they are familiar with you and your laser application, use them as a first point of contact when questions arise. Regional Sales Managers also serve as the liaison between you and our Applications Lab in processing material samples per your specifications. To speak to the Regional Sales Manager in your area, call SYNRAD at 1.800.SYNRAD1.

Customer Service

For assistance with order or delivery status, service status, or to obtain a Return Authorization (RA) number, contact SYNRAD at 1.800.SYNRAD1 and ask to speak to a Customer Service representative.

Technical Support

SYNRAD's Regional Sales Managers are able to answer many technical questions regarding the installation, use, troubleshooting, and maintenance of our products. In some cases, they may transfer your call to a Laser, Marking Head, or Software Support Specialist. You may also email questions to the Technical Support Group by sending your message to support@synrad.com or to support@winmark.com.

Reference materials

Your Regional Sales Manager can provide reference materials including Outline & Mounting drawings, Operator's Manuals, Technical Bulletins, and Application Newsletters. Most of these materials are also available directly from SYNRAD's web site at http://www.synrad.com.

European headquarters

SYNRAD's European subsidiary, Excel Technology Europe GmbH, covers Austria, Germany, and Italy. Contact Excel Technology at:

Excel Technology Europe GmbH
Münchner Str. 2a
D-82152 Planegg
Germany

Phone:	49 89 891 462-0
Fax:	49 89 891 462-69

laser safety

Hazard information

Hazard information includes terms, symbols, and instructions used in this manual or on the equipment to alert both operating and service personnel to the recommended precautions in the care, use, and handling of Class IV laser equipment.

Terms

Certain terms are used throughout this manual or on the equipment labels. Please familiarize yourself with their definitions and significance.

⚠ Danger: Imminent hazards which, if not avoided, will result in death or serious injury.

⚠ Warning: Potential hazards which, if not avoided, could result in death or serious injury.

⚠ Caution: Potential hazards or unsafe practices which, if not avoided, may result in minor or moderate injury.

Caution: Potential hazards or unsafe practices which, if not avoided, may result in product damage.

Note: Points of particular interest for more efficient or convenient equipment operation; additional information or explanation concerning the subject under discussion.

General hazards

Following are descriptions of general hazards and unsafe practices that could result in death, severe injury, or product damage. Specific warnings and cautions not appearing in this section are found throughout the manual.

⚠ Danger
serious personal injury

This Class IV laser product emits ***invisible*** infrared laser radiation in the 10.6 µm CO_2 wavelength band.

Do not allow laser radiation to enter the eye by viewing direct or reflected laser energy. CO_2 laser radiation can be reflected from metallic objects even though the surface is darkened. Direct or diffuse laser radiation can inflict severe corneal injuries leading to permanent eye damage or blindness. All personnel must wear eye protection suitable for 10.6 µm CO_2 radiation when in the same area as an exposed laser beam. Eyewear protects against scattered energy but is not intended to protect against direct viewing of the beam—never look directly into the laser output aperture or view scattered laser reflections from metallic surfaces.

Enclose the beam path whenever possible. Exposure to direct or diffuse CO_2 laser radiation can seriously burn human or animal tissue, which may cause permanent damage.

laser safety

Hazard information

Danger
serious personal injury

This product is not intended for use in explosive, or potentially explosive, atmospheres.

Warning
serious personal injury

U.S. customers should refer to and follow the laser safety precautions described in the American National Standards Institute (ANSI) Z136.1-2000 document, *Safe Use of Lasers*. Procedures listed in this Standard include the appointment of a Laser Safety Officer (LSO), operation of the product in an area of limited access by trained personnel, servicing of equipment only by trained and authorized personnel, and posting of signs warning of the potential hazards.

European customers should appoint a Laser Safety Officer (LSO) who should refer to and follow the laser safety precautions described in EN 60825-1, 2001 – *Safety of Laser Products*.

Warning
serious personal injury

Materials processing with a laser can generate air contaminants such as vapors, fumes, and/or particles that may be noxious, toxic, or even fatal. Material Safety Data Sheets (MSDS) for materials being processed should be thoroughly evaluated and the adequacy of provisions for fume extraction, filtering, and venting should be carefully considered. Review the following references for further information on exposure criteria:

ANSI Z136.1-2000, *Safe Use of Lasers*, section 7.3.

United States Government's *Code of Federal Regulations*: 29 CFR 1910, Subpart Z.

Threshold Limit Values (TLV's) published by the American Conference of Governmental Industrial Hygienists (ACGIH).

It may be necessary to consult with local governmental agencies regarding restrictions on the venting of processing vapors.

Warning
serious personal injury

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

laser safety

Hazard information

Series 48 lasers should be installed and operated in manufacturing or laboratory facilities by trained personnel only. Due to the considerable risks and hazards associated with the installation and operational use of any equipment incorporating a laser, the operator must follow product warning labels and instructions to the user regarding laser safety.

Exercise safe operating practices per ANSI Z136.1-2000 at all times when actively lasing.

To prevent exposure to direct or scattered laser radiation, follow all safety precautions specified throughout this manual.

Do not place your body or any combustible object in the path of the laser beam.

Always wear safety glasses or protective goggles with side shields to reduce the risk of damage to the eyes when operating the laser.

A CO_2 laser is an intense heat source and will ignite most non-metallic materials under the proper conditions. Never operate the laser in the presence of flammable or explosive materials, gases, liquids, or vapors.

The use of controls or adjustments or performance of procedures other than those specified herein may result in exposure to hazardous ***invisible*** laser radiation, damage to, or malfunction of the laser. Severe burns will result from exposure to the laser beam.

Safe operation of the laser requires the use of an external beam block to safely block the beam from traveling beyond the desired work area. Use a water-cooled beam dump or power meter, or similar non-scattering, noncombustible material as the beam block. Never use organic material or metals as the beam blocker; organic materials, in general, are apt to combust or melt and metals act as specular reflectors which may create a serious hazard outside the immediate work area.

Other hazards

The following hazards would be typical for this product family when incorporated for intended use: (A) risk of injury when lifting or moving the unit; (B) risk of exposure to hazardous laser energy through unauthorized removal of access panels, doors, or protective barriers; (C) risk of exposure to hazardous laser energy and injury due to failure of personnel to use proper eye protection and/or failure to adhere to applicable laser safety procedures; (D) risk of exposure to hazardous or lethal voltages through unauthorized removal of covers, doors, or access panels; (E) generation of hazardous air contaminants that may be noxious, toxic, or even fatal.

Disposal

If a situation occurs where the Series 48 laser is rendered non-functional and cannot be repaired, it may be returned, at the User's expense, to SYNRAD, Inc. who will ensure adequate disassembly, recycling, and/or disposal of the product.

Additional laser safety information

The SYNRAD web site (http://www.synrad.com/LaserFacts/lasersafety.html) contains an online laser safety handbook that provides information on (1) Laser Safety Standards for OEM's/System Integrators, (2) Laser Safety Standards for End Users, (3) References and Sources, and (4) Assistance with Requirements. In addition, the Occupational Safety and Health Administration (OSHA) provides an online Technical Manual (located at http://www.osha-slc.gov/dts/osta/otm/otm_iii/otm_iii_6.html). Section III, Chapter 6 and Appendix III are good resources for laser safety information. Another excellent laser safety resource is the Laser Institute of America (LIA). Their comprehensive web site is located at http://www.laserinstitute.org.

laser safety

48-1 label locations

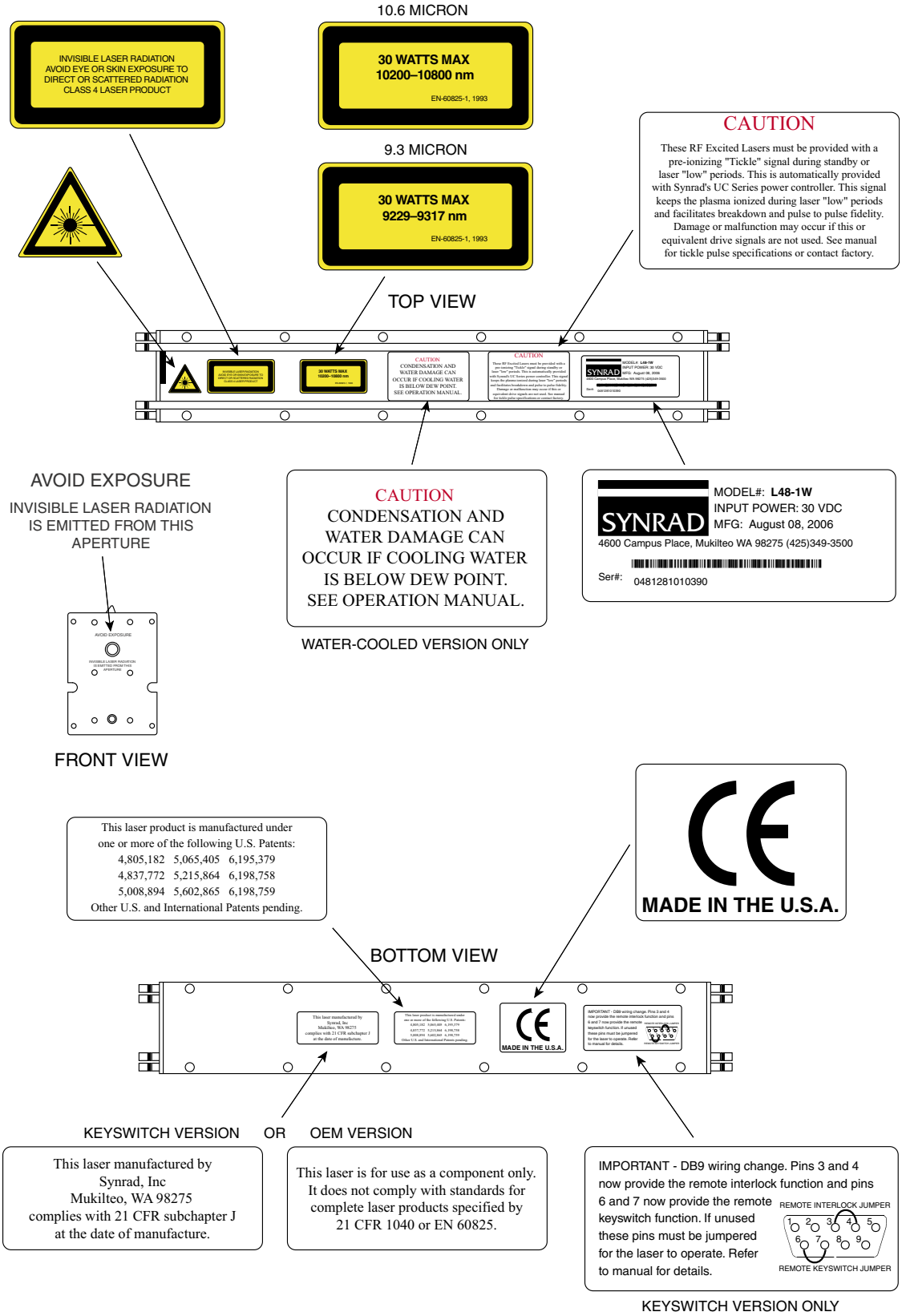


Figure 1 48-1 hazard label and CE label locations

laser safety

48-2 label locations

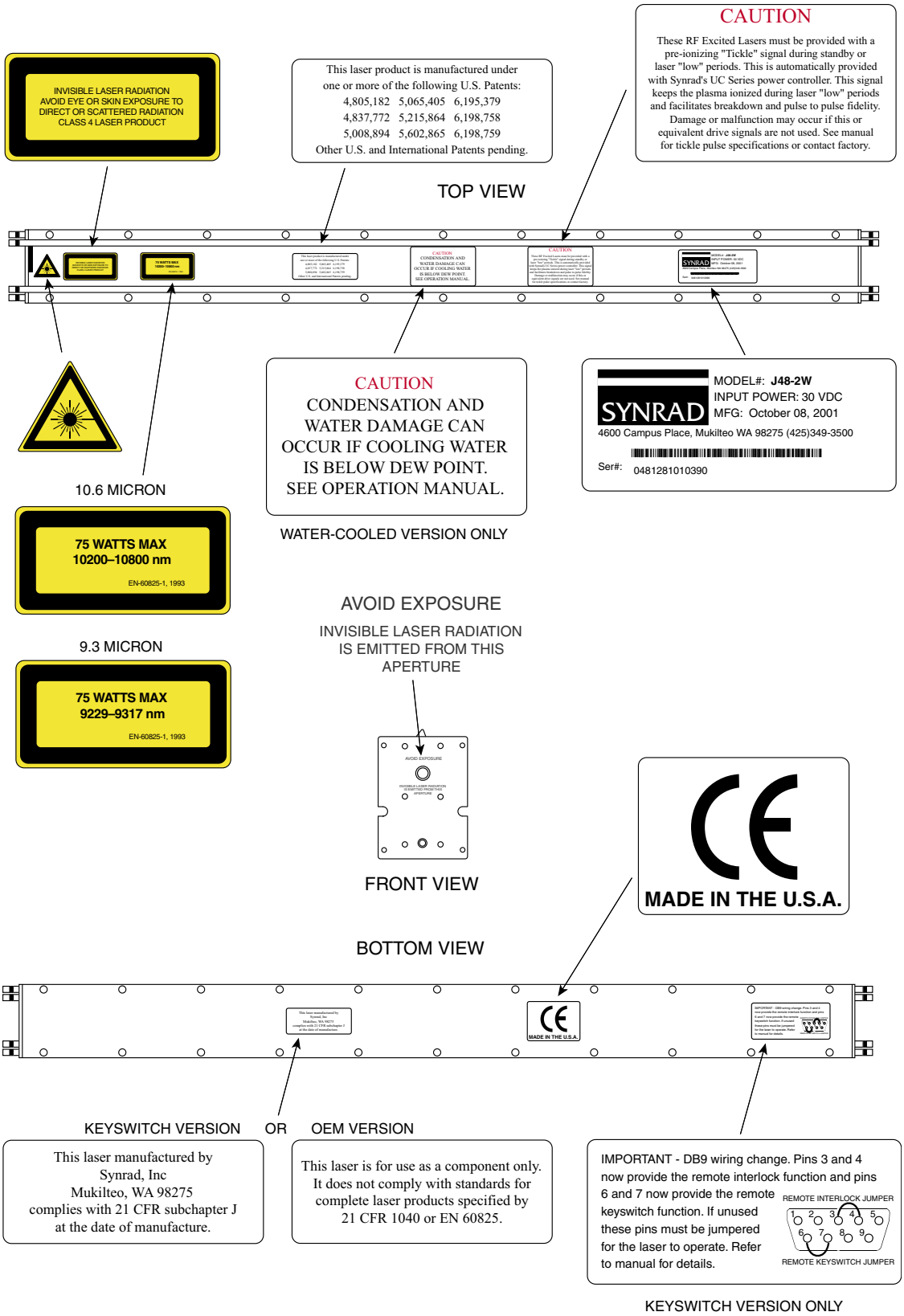


Figure 2 48-2 hazard label and CE label locations

laser safety

48-5 label locations

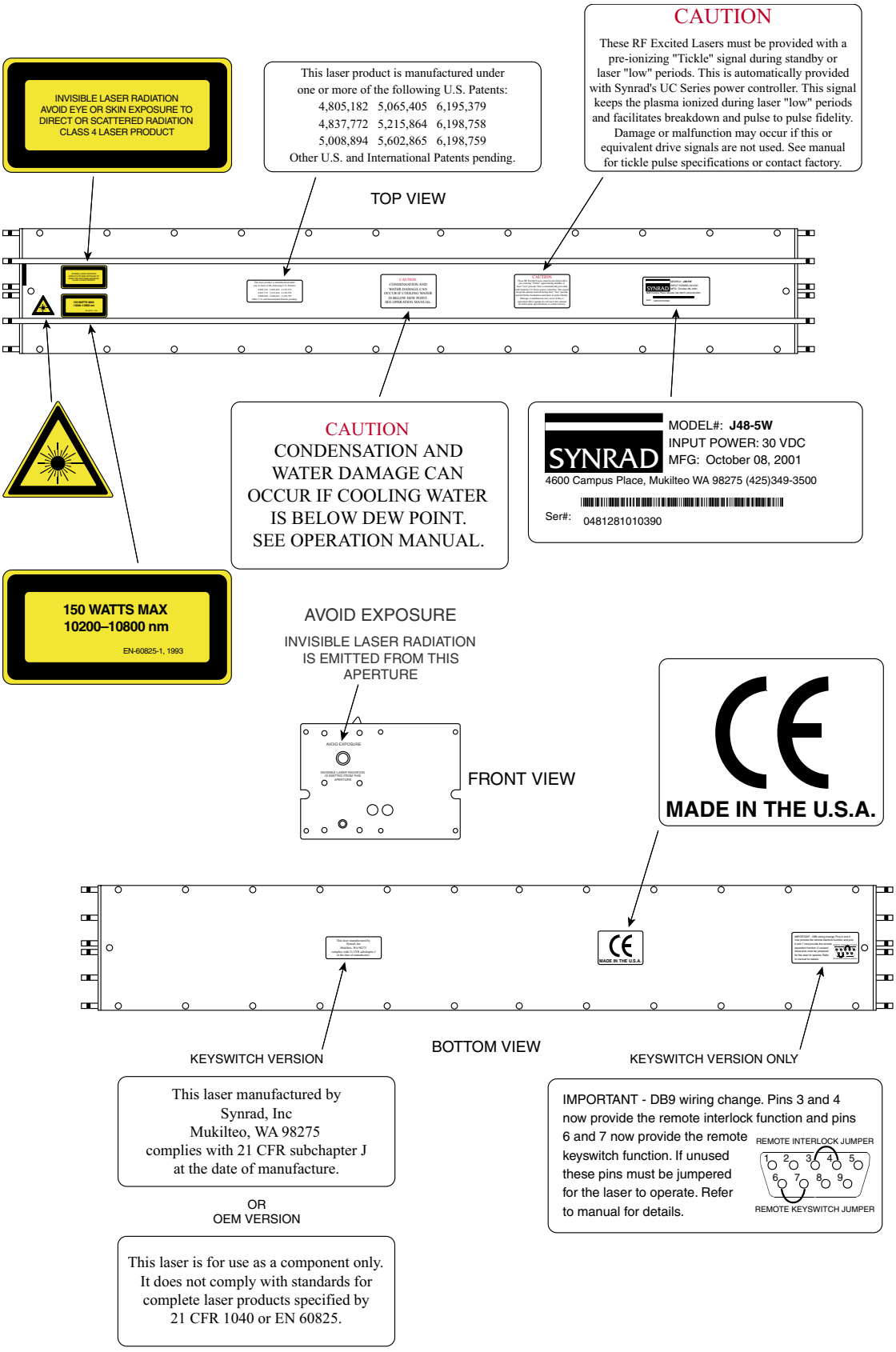


Figure 3 48-5 hazard label and CE label locations

laser safety

Agency compliance

The *Agency compliance* section includes subsections:

- Center for Devices and Radiological Health (CDRH) requirements
- Federal Communications Commission (FCC) requirements
- European Union (EU) requirements

SYNRAD lasers are designed, tested, and certified to comply with certain United States (U.S.) and European Union (EU) regulations. These regulations impose product performance requirements related to electromagnetic compatibility (EMC) and product safety characteristics for industrial, scientific, and medical (ISM) equipment. The specific provisions to which systems containing Series 48 lasers must comply are identified and described in the following paragraphs. Note that compliance to CDRH, FCC, and EU requirements depends in part on the laser version selected—Keyswitch or OEM.

In the U.S., laser safety requirements are governed by the Center for Devices and Radiological Health (CDRH) under the auspices of the U.S. Food and Drug Administration (FDA) while radiated emission standards fall under the jurisdiction of the U.S. Federal Communications Commission (FCC). Outside the U.S., laser safety and emissions are governed by European Union (EU) Directives and Standards.

In the matter of CE-compliant laser products, SYNRAD, Inc. assumes no responsibility for the compliance of the system into which the product is integrated, other than to supply and/or recommend laser components that are CE marked for compliance with applicable European Union Directives.

Because OEM laser products are intended for incorporation as components in a laser processing system, they do not meet all of the Standards for complete laser processing systems as specified by 21 CFR, Part 1040 or EN 60825-1. SYNRAD, Inc. assumes no responsibility for the compliance of the system into which OEM laser products are integrated.

Center for Devices and Radiological Health (CDRH) requirements

Keyswitch models

Series 48 Keyswitch model lasers comply with requirements for Class IV laser products imposed by the Radiation Control for Health and Safety Act of 1968. Under this Act, the U.S. Food and Drug Administration (FDA) issued a performance standard in the *Code of Federal Regulations* (CFR) for laser products. This performance standard, (21 CFR, Subchapter J, Part 1040.10) was developed to protect public health and safety by imposing requirements upon manufacturers of laser products to provide an indication of the presence of laser radiation, to provide the user with certain means to control radiation, and to assure that all personnel are adequately warned of potential hazards through the use of product labels and instructions.

Product features incorporated into the design of Series 48 lasers to comply with CDRH requirements are integrated as panel controls or indicators, internal circuit elements, or input/output signal interfaces. Specifically, these features include a keyswitch (Keyswitch versions), lase and laser ready indicators, remote interlock for power on/off, a laser aperture shutter switch, and a five-second delay between power on and lasing. Incorporation of certain features is dependent on the laser version (Keyswitch or OEM). Table 1, *Class IV safety features*, indicates which features are available on Series 48 lasers, the type and description of the feature, and if the feature is required by CDRH regulations.

laser safety

Agency compliance

OEM models

Series 48 OEM lasers are OEM products intended for incorporation as components in laser processing systems. As supplied by SYNRAD, these lasers do not meet the requirements of 21 CFR, Subchapter J without additional safeguards. In the U.S., the Buyer of these OEM laser components is solely responsible for the assurance that the laser processing system sold to an end user complies with all laser safety requirements before the actual sale of the system. Under CDRH regulations, the Buyer must submit a report to the CDRH prior to shipping the system. In jurisdictions outside the U.S., it is the sole responsibility of the Buyer of these OEM components to ensure that they meet all applicable local laser safety requirements. In cases where the Buyer is also the end-user of the OEM laser product, the Buyer/end-user must integrate the laser so that it complies with all applicable laser safety standards as set forth above.

Federal Communications Commission (FCC) requirements

The United States Communication Act of 1934 vested the Federal Communications Commission (FCC) with the authority to regulate equipment that emits electromagnetic radiation in the radio frequency spectrum. The purpose of the Communication Act was to prevent harmful electromagnetic interference (EMI) from affecting authorized radio communication services. The FCC regulations that govern industrial, scientific, and medical (ISM) equipment are fully described in 47 CFR, Part 18, Subpart C.

SYNRAD's Series 48 lasers have been tested and found to comply by demonstrating performance characteristics that have met or exceeded the requirements of 47 CFR, Part 18, Radiated and Conducted Emissions.

FCC information to the user

NOTE: The following FCC information to the user is provided to comply with the requirements of 47 CFR, Part 18, Section 213.

Interference Potential

In our testing, SYNRAD, Inc. has not discovered any significant electrical interference traceable to Series 48 lasers.

System Maintenance

Ensure that all exterior covers are properly fastened in position.

Measures to Correct Interference

If you suspect that your Series 48 laser interferes with other equipment, take the following steps to minimize this interference:

1. Use shielded cables to and from the equipment that is experiencing interference problems.
2. Ensure that the Series 48 laser is properly grounded to the same electrical potential as the equipment or system it is connected to.
3. Install bisected ferrite on the laser's DC power cables; locate them as close as possible to the laser housing.

laser safety

Agency compliance

FCC caution to the user

The Federal Communications Commission warns the user that changes or modifications of the unit not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

European Union (EU) requirements

Laser safety standards

Under the Low Voltage Directive, 73/23/EEC, the European Norm (EN) document EN 60825-1 was developed to protect persons from laser radiation by imposing requirements upon manufacturers of laser products to provide an indication of laser radiation; to classify laser products according to the degree of hazard; to require both user and manufacturer to establish procedures so that proper precautions are adopted; to ensure adequate warning of the hazards associated with accessible radiation through signs, labels, and instructions; to improve control of laser radiation through protective features; and to provide safe usage of laser products by specifying user control measures.

Keyswitch models

Series 48 Keyswitch models are designed to comply with the requirements imposed by EN 60825-1 for Class IV laser products. Table 1, *Class IV safety features*, summarizes Series 48 product features, indicating the type and description of features and whether those features are required by European Union regulations.

OEM models

Series 48 OEM lasers are OEM products intended for incorporation as components in laser processing systems. As supplied by SYNRAD, these lasers do not meet the requirements of EN 60825-1 without additional safeguards. European Union Directives state that "OEM laser products which are sold to other manufacturers for use as components of any system for subsequent sale are not subject to this Standard, since the final product will itself be subject to the Standard." This means that Buyers of OEM laser components are solely responsible for the assurance that the laser processing system sold to an end-user complies with all laser safety requirements before the actual sale of the system. Note that when an OEM laser component is incorporated into another device or system, the entire machinery installation may be required to conform to EN 60204/292, *Safety of Machinery*; the Machinery Directive EN 89/392/EEC; and/or any other applicable Standards. In cases where the Buyer is also the end-user of the OEM laser product, the Buyer/end-user must integrate the laser so that it complies with all applicable laser safety standards as set forth above.

Electromagnetic interference standards

The European Union's Electromagnetic Compatibility (EMC) Directive, 89/336/EEC, is the sole Directive developed to address electromagnetic interference (EMI) issues in electronic equipment. In particular, the Directive calls out European Norm (EN) documents that define the emission and immunity standards for specific product categories. For Series 48 lasers, EN 55011 and CISPR:11 define radiated and conducted RF emission limits while the generic Standards EN 61326 and EN 50082-1 define immunity requirements published by the International Electromechanical Commission (IEC).

SYNRAD's Series 48 lasers have demonstrated performance characteristics that have met or exceeded the requirements of EMC Directive 89/336/EEC.

laser safety

Agency compliance

Table 1 Class IV safety features

Feature	Location/Description	Required by: CDRH	EN60825-1
Keyswitch[1]	Panel control On/Off Keyswitch controls power to laser electronics. Key can not be removed from switch in the "On" position.	Yes	Yes
Shutter function[1]	Laser control Attenuates beam / disables RF driver/laser output when closed.	Yes	Yes
Power[2] indicator	Panel indicator (Green) Indicates that laser has power applied and is capable of lasing.	Yes	No
Lase indicator	Panel indicator (Red) Indicates laser is actively lasing. Illuminates when duty cycle of Command signal is long enough to produce laser output.	Yes	Yes
Five-second delay	Circuit element Disables RF driver/laser output for five to ten seconds after Keyswitch is turned to "On" and remote keyswitch is closed.	Yes	No
Power-on reset	Circuit element Disables RF driver/laser output if input power is removed then later reapplied (AC power failure) while Keyswitch is in "On" position.	Yes	No
Remote Interlock[1]	Panel connection Disables RF driver/laser output when remote interlock switch on equipment door or panel is opened.	Yes	Yes
Remote Keyswitch	Panel connection Allows operator to turn laser On/Off from a remote location.	No	No
Over/under voltage protection	Circuit element Fault shutdown occurs if supply voltage falls below +15 V or rises above +36 V. Reset laser to restore operation.	No	No
Reverse voltage protection	Circuit element Internal diode protects circuitry from reverse input voltages. External fuse will blow.	No	No
Overtemp protection	Circuit element Over temperature shutdown occurs when temperature of tube reaches 60 °C ±2 °C. Reset laser to restore operation.	No	No
PWM failure protection	Circuit element Disables laser if output power exceeds Command input by 20% or more due to electronics failure. Reset laser to restore operation.	No	No
Fault signal	Signal output Latches to a logic low state when a fault shutdown occurs.	No	No
Message signal	Signal output Pre-shutdown warning latches to a logic low state when tube temperature reaches 54 °C ±2 °C.	No	No
Warning labels	Exterior housing Labels attached to various locations to warn of potential hazards.	Yes	Yes

1 Keyswitch version only

2 On OEM versions, the Power indicator illuminates and the five-second delay begins when DC power is applied to the laser

laser safety

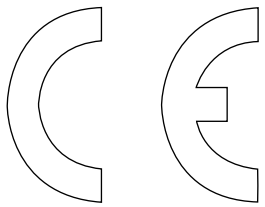
Agency compliance

When integrating SYNRAD's Series 48 OEM lasers, the Buyer and/or integrator of the end system is responsible for meeting all applicable Standards to obtain the CE mark. To aid this compliance process, SYNRAD's testing program has demonstrated that Series 48 lasers comply with the relevant requirements of 89/336/EEC, the Electromagnetic Compatibility Directive, as summarized in Table 2 below.

Table 2 European Union Directives

Applicable Standards/Norms	
89/336/EEC	Electromagnetic Compatibility Directive
EN 55011	Radiated Emissions, Class A, Group 2
EN 50082-1	Generic Immunity
IEC 801-2	Electrostatic Discharge
IEC 801-3	RF Radiated
IEC 801-4	Fast Transients

After a laser or laser processing system has met the requirements of all applicable EU Directives, the product can bear the official compliance mark of the European Union as shown in Figure 4 and a Declaration of Conformity is provided for the compliant component.



MADE IN U.S.A.

Figure 4 European compliance mark

RoHS Compliance

SYNRAD Series 48 L version lasers meet the requirements of the European Parliament and Council Directive 2002/95/EC on the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment, as amended by Decision 2005/618/EC establishing maximum concentration values for certain hazardous substances in electrical and electronic equipment.

laser safety

Declaration of Conformity

Declaration Of Conformity

Applicable EU Directive(s):	89/336/EEC	EMC Directive
	2002/95/EC	RoHS Directive (amended by 2005/618/EC)
Applicable Standards/Norms:	EN 55011	Radiated, Class A, Group 2
	EN 50082-1	Generic Immunity
	IEC 801-2	Electrostatic Discharge
	IEC 801-3	RF Radiated
	IEC 801-4	Fast Transients
Manufacturer:	SYNRAD, Inc. 4600 Campus Place Mukilteo, WA 98275	

Model Number:	Serial Number (Compliant Unit)	Date Of Compliance
48-1		29 October 1998
48-2		29 October 1998
48-5	J48-5S-2197	29 October 1998

We, SYNRAD, Inc., hereby declare under our sole responsibility that the equipment specified above conforms to the above Directive(s) and Standard(s).

Corporate Officer:

Dave Clarke, President of SYNRAD

29 October 1998
Date

European Contact:

Excel Technology Europe GmbH
Münchner Str. 2a
D-82152 Planegg
Germany

getting started

Use information in this section to prepare your Series 48 laser for operation. The order of information presented in this section is the same as the order of tasks that you need to perform. The best way to get your laser ready for operation is to start at *Unpacking* and work your way through *Connecting*.

This section contains the following information:

- Introduction – introduces Series 48 lasers and lists important features.
- Unpacking – provides important information about shipping your Series 48 laser.
- Inventory – displays and describes all components shipped with your laser.
- Mounting – describes how to attach laser components to a mounting surface.
- Connecting – explains how to connect power and control cables as well as cooling connections for water-cooled models.

getting started

Introduction

Thank you for purchasing a Series 48 laser from SYNRAD, Inc. The Series 48 family of lasers incorporates the latest developments in sealed carbon dioxide devices, combining the best features of both waveguide and free space CO_2 laser technology in an innovative aluminum tube design. Series 48 lasers utilize state-of-the-art surface mount electronics, newly patented RF excitation technology, and fully CE-compliant systems for EMI containment, heat removal, and laser safety. In the 10 W to 50 W range of continuous optical output, these lasers represent an ideal balance between proven, mature laser tube technology and reliable, simplified electronic control.

Series 48 features include:

- Compact resonator design
- RF power supply integrated into laser chassis
- Keyswitch air- or water-cooled models available
- OEM (no Keyswitch/no shutter) air- or water-cooled models available

Series 48 nomenclature

Series 48 lasers are divided into two distinct functional categories: Keyswitch and OEM models. In addition to a manual *Keyswitch*, all *Keyswitch*-equipped lasers include a manual *Shutter Switch* that allows the laser output aperture to be blocked. OEM lasers do not incorporate either a manual keyswitch or shutter assembly since they are primarily designed as components for integration into a larger processing system by an Original Equipment Manufacturer (OEM) or System Integrator who bears the responsibility for meeting the appropriate laser safety requirements for Class IV laser systems.

⚠ Caution
serious personal injury

Please read this manual completely before using your laser. To prevent injury to personnel or damage to the laser, follow all safety precautions, handling, and setup instructions as described herein.

getting started

Unpacking

The *Unpacking* section includes subsections:

- Incoming inspection
- Packaging guidelines

Incoming inspection

Upon arrival at your facility, inspect all shipping containers for signs of damage. If you discover shipping damage, document the damage (photographically if possible), then immediately notify the shipping carrier and SYNRAD. The shipping carrier is responsible for any damage occurring during transportation from SYNRAD, Inc. to your receiving dock.

Carefully remove your Series 48 laser from the shipping container and remove the outer foam packing material. Inspect the laser housing for any signs of shipping damage. Verify that all external labels are attached to the housing (refer to label location drawings in the "Laser Safety" section). Contact SYNRAD Customer Service if the laser housing is damaged or if any of the required accessory materials or labels are missing.

Packaging guidelines

- To prevent equipment damage or loss of small components, use care when removing packaging materials.
- Save all shipping containers and packaging materials, including covers and plugs. Use these specialized packing materials when shipping the laser to another location.
- After unpacking, review the *Inventory* section and verify that all components are on hand.
- When packing a laser for shipment, be sure to remove all accessory items not originally attached to the laser including beam delivery components, cooling tubing, fittings, etc.
- When shipping water-cooled lasers, remember to drain all cooling water from the laser and then cap the open fittings to prevent debris from entering the coolant path.
- Do not lift or support the laser using the cooling fittings; lift the laser by the mounting feet or baseplate only.

getting started

Inventory

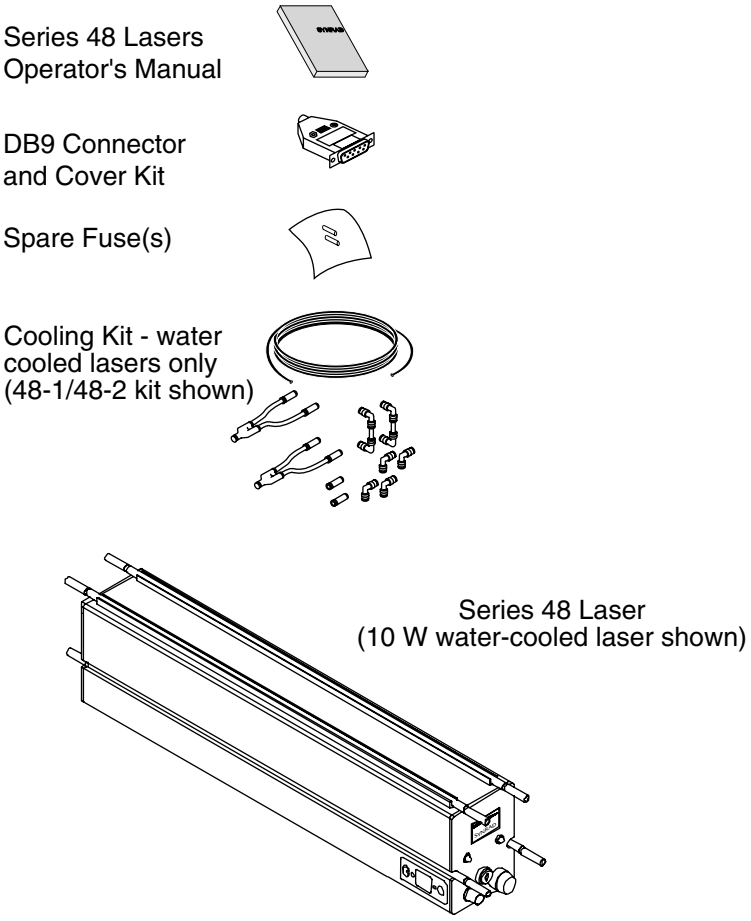


Figure 1-1 Series 48 shipping box contents

Table 1-1 lists items included in the Series 48 ship kit.

Table 1-1 Ship kit contents

Shipping Box Contents	Qty
SYNRAD Series 48 Laser	1
Series L48 Lasers Operator's Manual	1
DB9 Connector and Cover Kit	1
Spare Fuse(s)	1
Cooling Kit (water-cooled lasers only)	1
Final Test Report (not shown)	1

getting started

Inventory

Contents description

Each item listed in Table 1-1 is described below.

SYNRAD Series 48 Laser – for cutting, welding, drilling, and marking a wide variety of products and materials.

Series 48 L Version Lasers Operator's Manual – provides setup, operation, and maintenance information for your Synrad L Version Series 48 laser.

DB9 Connector and Cover Kit – connects to the Series 48 *DB9 Connector*. Use this connector to replace the factory jumper plug when integrating Series 48 laser signals into your control system.

Spare Fuse(s) – fast-blow fuse protects Series 48 internal circuitry. A 10 A fuse is included with 48-1 lasers, a 20 A fuse with 48-2 lasers, and two 20 A fuses are shipped with 48-5 lasers.

Cooling Kit (water-cooled lasers only)

(48-1/48-2) – includes quick-disconnect inlet and outlet cooling manifolds, extra 1/4" union elbows, extra straight 1/8" NPT to 1/4" tube fittings, and 20 feet of 1/4 inch O.D. black polyethylene tubing.

(48-5) – includes quick-disconnect inlet and outlet cooling manifolds, extra 1/4" union elbows, extra straight 1/4" NPT to 3/8" tube fittings, and 20 feet of 3/8 inch O.D. black polyethylene tubing.

Final Test Report (not shown) – contains data collected during the laser's final pre-shipment test.

getting started

Mounting

The *Mounting* section includes subsections:

- Standard mounting
- With an FH Series marking head

The recommended mounting orientation for Series 48 lasers is horizontal. If this cannot be accomplished then the laser may be mounted at an angle of > 20° to the vertical. Consult the factory for limitations if the laser is mounted in a vertical orientation.

Note: To allow for proper airflow, air-cooled units must have at least 2.25" of unobstructed clearance between the outside edge of the cooling fan housing and any enclosure or mounting surface.

Standard mounting

Series 48 lasers may be hard-mounted to equipment by removing several of the bottom panel screws and replacing these with longer screws to secure the laser to optical assemblies. This mounting method is only recommended as long as the screws do not support the weight of the laser. For a sturdier attachment, the laser may be clamped to optical assemblies by applying clamping forces between top and bottom cover screws. Do not apply clamping forces on the longitudinal centerline.

1 Refer to the appropriate outline and mounting diagram in the "Technical Reference" section for mounting screw locations and then drill four (48-1) or six (48-2/48-5) holes into your mounting surface. Locate holes in a symmetrical pattern to properly distribute mounting forces.

Note: Do not remove covers from the laser housing when mounting.

2 Place your Series 48 laser on the mounting surface so that the threaded holes on the laser housing line up with the holes drilled through the mounting surface.

3 Measure the 6–32 screws (48-1/48-2) or 10–32 screws (48-5) you removed from the laser housing and add a length equivalent to the thickness of the mounting surface.

4 Insert these new screws through the mounting surface into the threaded holes of the laser housing. Turn the screws by hand until the threads engage and then tighten using an Allen wrench.

With an FH Series marking head

To mount your Series 48 laser to an FH Series marking head, perform the following steps:

Note: The laser's mounting feet are precisely aligned and shimmed at the factory to ensure alignment between the marking head and the *Mounting Rail*. Do not loosen or remove the mounting feet from the laser. See the *FH Series Marking Head Operator's Manual* for further details.

1 Orient the laser on the FH *Mounting Rail* with the laser's output aperture facing the *L-bracket*.

2 Ease the laser forward until the dowel pins on the mounting feet drop into the dowel pin holes in the *Mounting Rail*. The screw holes on the ends of the mounting feet should be positioned over the appropriate mounting holes in the *Mounting Rail*.

3 Install and tighten four capscrews to secure the laser to the *Mounting Rail*. 48-1 and 48-2 lasers use 6–32 × 1" socket head capscrews while 48-5 lasers use 10–32 × 3/4" fasteners.

Connecting

The *Connecting* section includes subsections:

- Air-cooled connections
- Water-cooled connections
- Electrical connections
- Control connections
- DB9 connections

The *Connecting* section contains all the information you need to connect your Series 48 laser for operation. Figure 1-7 at the end of this chapter illustrates the connections used in a typical Series 48 laser system.

Air-cooled connections

Note: 48-5 (50 W) lasers must be water-cooled to prevent damage to the laser. See the *Water-cooled connections* section for connection details.

Since air-cooled lasers are shipped without cooling fans, customers must provide air cooling to prevent overheating of the laser. An airflow of 250 cubic feet per minute (CFM) per fan is required to keep laser and heatsink temperatures below 50 °C. 48-1 lasers have a heat load specification of 300 W maximum and requires two cooling fans for a total of 500 CFM. 48-2 lasers have a 500 W heat load and requires four cooling fans for a total air flow of 1000 CFM.

Place cooling fans symmetrically on each side of the laser so that air flow is directed perpendicular to the laser's cooling fins as shown in Figure 1-2. The fans should have a diameter of approximately 4.5" to 5" and have at least 2.25" of unobstructed clearance between the outside edge of the cooling fan housing and any enclosure or mounting surface.

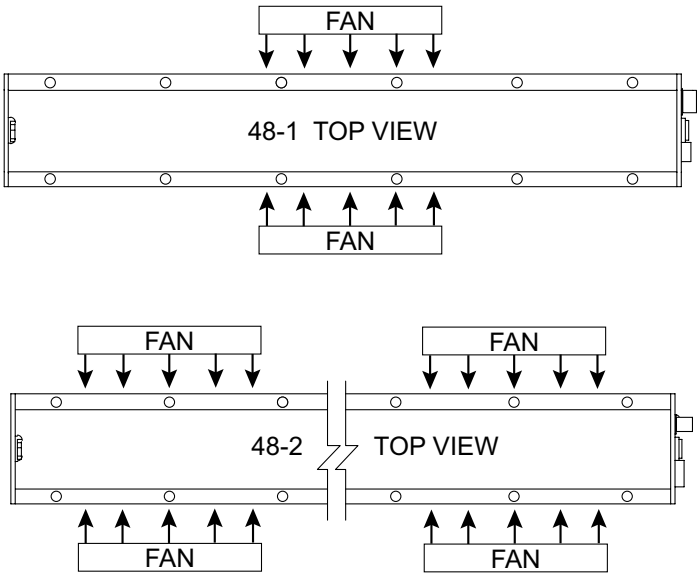


Figure 1-2 48-1 / 48-2 cooling fan placement

getting started

Connecting

Water-cooled connections

Read *Guidelines for cutting and installing tubing* before installing any cooling tubing and then make sure to connect the cooling system exactly as described for your particular laser.

Guidelines for cutting and installing tubing

- Cut tubing lengths generously to allow for trimming.
- Cut tubing squarely; diagonal cuts may not seal properly. Trim away any burrs if the cut is "ragged".
- Avoid excessive stress on fittings by creating a gentle radius when bends in the tubing are close to fittings. Bending tubing too sharply will compromise the sealing properties of the fitting.
- Never allow the tubing to kink, since kinking severely restricts coolant flow.
- Push tubing completely into the fitting, then pull the tubing to verify that it is locked into place. Tubing extends into the fitting approximately 7/8 of an inch.
- If tubing must be disconnected from a fitting, first push and hold the tubing slightly into the fitting. Next push the white fitting ring evenly towards the fitting, and then pull the tubing free.
- After disconnecting tubing from a fitting, trim 1/2 inch from its end before reconnecting. Trimming the end of the tubing before reconnecting the fitting provides an undisturbed sealing surface.

Laser cooling fittings

If your integrated laser application uses metric cooling tubing, we recommend the installation of tubing adaptors to convert 48-1/48-2 cooling kit fittings from 1/4 inch tubing to 6 mm metric tubing. For 48-5 cooling kits, convert the 3/8 inch tubing to 8 mm metric tubing. These tubing adaptors are available from many tubing and fitting manufacturers.

Chiller preparation guidelines

- You must provide fittings that will adapt the laser's 1/4 inch or 3/8 inch O.D. polyethylene cooling tubing to your chiller's Inlet and Outlet ports. These fittings can be either "quick disconnect" or compression type fittings.
- Because Series 48 cooling tubing is specified in inch sizes, the use of metric tube fittings is discouraged unless you have installed the appropriate inch-to-metric tubing adaptors. The use of metric fittings on inch size tubing will lead to coolant leaks or may allow pressurized tubing to blow-off the fitting.

Coolants

SYNRAD recommends that the laser's cooling fluid contain at least 90% water (distilled or tap) by volume. In closed-loop systems, use a corrosion inhibitor/algaecide such as Optishield® Plus or equivalent. Avoid glycol-based additives because they reduce the coolant's heat capacity and high concentrations may affect power stability. For SYNRAD lasers, the minimum coolant setpoint is 18 °C (64 °F) so glycol is not necessary unless the chiller is subjected to freezing temperatures. In applications where biocides containing chlorides are used, concentrations should not exceed 25 parts per million (PPM). Maintain a coolant pH level above 7.0. We recommend the installation of a filter on the chiller's return line, especially in areas where water hardness is a problem.

Setting coolant temperature

Choosing the correct coolant temperature is important to the proper operation and longevity of your laser. When coolant temperature is lower than the dew point (the temperature at which moisture condenses out of the surrounding air), condensation forms inside the laser housing leading to failure of laser electronics as well as damage to optical surfaces.

The greatest risk of condensation damage occurs when water-cooled lasers are run in a high heat/high humidity environment and the chiller's coolant temperature is colder than the dew point of the surrounding air or when the system is shut down, but coolant continues to flow through the laser for extended periods of time.

The chiller's temperature setpoint must always be set above the dew point temperature. In cases where this is not possible within the specified coolant temperature range of 18 °C to 22 °C (64 °F to 72 °F), then the following steps MUST be taken to reduce the risk of condensation damage.

- Stop coolant flow when the laser is shut down.
- Increase coolant flow by an additional 1.0 GPM. Do not exceed a coolant pressure of 60 PSI.
- Air-condition the room or the enclosure containing the laser.
- Install a dehumidifier to reduce the humidity of the enclosure containing the laser.

Table 1-2 provides dew point temperatures for a range of air temperature and relative humidity values. Remember that the laser's coolant temperature must be set above the dew point temperatures shown in the chart, but for best results and performance do not exceed a coolant temperature of 22 °C (72 °F).

Caution possible equipment damage	Operating the laser at coolant temperatures above 22 °C (72 °F) may result in decreased performance and/or premature failure of electronic components.

Connecting

Table 1-2 Dew point temperatures

Dew Point Temperature Chart °F (°C)

Air Temp °F (°C)	Relative Humidity (%) 20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
60 (16)	—	—	—	32 (0)	36 (2)	39 (4)	41 (5)	44 (7)	46 (8)	48 (9)	50 (10)	52 (11)	54 (12)	55 (13)	57 (14)	59 (15)
65 (18)	—	—	33 (1)	37 (3)	40 (4)	43 (6)	46 (8)	48 (9)	51 (11)	53 (12)	55 (13)	57 (14)	59 (15)	60 (16)	62 (17)	64 (18)
70 (21)	—	33 (1)	37 (3)	41 (5)	45 (7)	48 (9)	51 (11)	53 (12)	56 (13)	58 (14)	60 (16)	62 (17)	64 (18)	65 (18)	67 (19)	69 (21)
75 (24)	—	37 (3)	42 (6)	46 (8)	49 (9)	52 (11)	55 (13)	58 (14)	60 (16)	62 (17)	65 (18)	67 (19)	68 (20)	70 (21)	72 (22)	73 (23)
80 (27)	35 (2)	41 (5)	46 (8)	50 (10)	54 (12)	57 (14)	60 (16)	62 (17)	65 (18)	67 (19)	69 (21)	71 (22)	73 (23)	75 (24)	77 (25)	78 (26)
85 (29)	40 (4)	45 (7)	50 (10)	54 (12)	58 (14)	61 (16)	64 (18)	67 (19)	70 (21)	72 (22)	74 (23)	76 (24)	78 (26)	80 (27)	82 (28)	83 (28)
90 (32)	44 (7)	50 (10)	54 (12)	59 (15)	62 (17)	66 (19)	69 (21)	72 (22)	74 (23)	77 (25)	79 (26)	81 (27)	83 (28)	85 (29)	87 (31)	88 (31)
95 (35)	48 (9)	54 (12)	59 (15)	63 (17)	67 (19)	70 (21)	73 (23)	76 (24)	79 (26)	81 (27)	84 (29)	86 (30)	88 (31)	90 (32)	92 (33)	93 (34)
100 (38)	52 (11)	58 (14)	63 (17)	68 (20)	71 (22)	75 (24)	78 (26)	81 (27)	84 (29)	86 (30)	88 (31)	91 (33)	93 (34)	95 (35)	97 (36)	98 (37)

To use Table 1-2, look down the *Air Temp* column and locate an air temperature in Fahrenheit or Celsius (°C values are shown in parentheses) that corresponds to the air temperature in the area where your laser is operating. Follow this row across until you reach a column matching the relative humidity in your location. The value at the intersection of the *Air Temp* and *Relative Humidity* columns is the *Dew Point* temperature in °F (or °C). The chiller's temperature setpoint must be set above the dew point temperature.

For example, if the air temperature is 85 °F (29 °C) and the relative humidity is 60%, then the dew point temperature is 70 °F (21 °C). Adjust the chiller's temperature setpoint to 72 °F (22 °C) to prevent condensation from forming inside the laser.

Connecting

48-1 / 48-2 cooling tubing connections

Water enters at the laser's rear plate through the lower side-mounted 1/4 inch diameter cooling tubes and exits through the top-mounted cooling tubes. Both circuits must be used in parallel to maintain thermal balance. The two right angle connections are installed on the front plate. The cooling kit also includes quantities of both straight and elbow fittings; you can order other compatible fittings from your local fitting supply house. All fittings are quick-disconnect types.

To connect cooling tubing to your 48-1 or 48-2 water-cooled laser, refer to Figure 1-3 and perform the following steps:

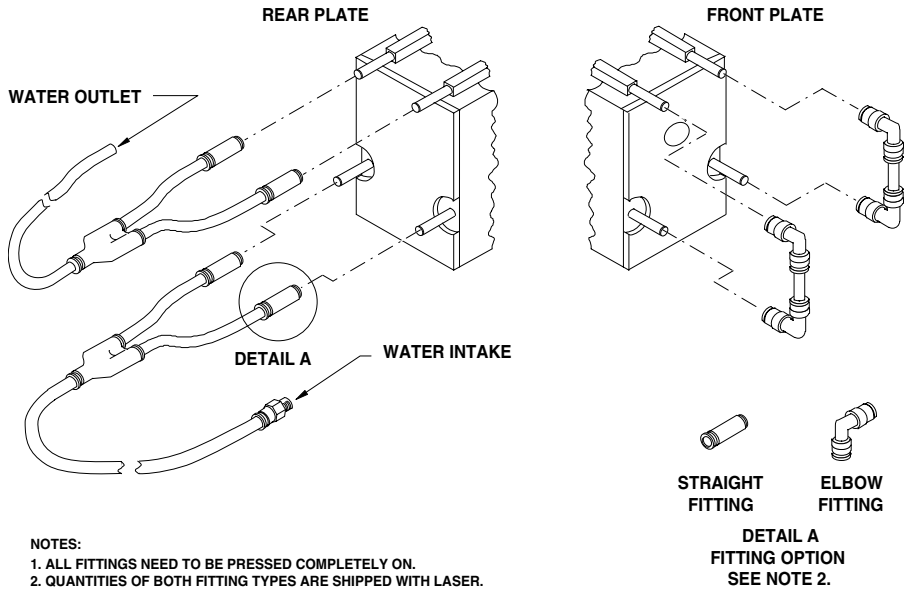


Figure 1-3 48-1 / 48-2 cooling connections

1. Connect the Water Intake manifold to both of the laser's lower coolant tubes on the rear plate.
2. Connect the Water Intake fitting to your coolant source.
3. Connect the Water Outlet manifold to both of the laser's upper coolant tubes on the rear plate.
4. Connect the Water Outlet fitting to your coolant return or drain.
5. On the front plate, connect one right angle connection between one of the lower coolant tubes and its corresponding upper coolant tube. Repeat this step on the other set of lower/upper tubes.

Caution possible equipment damage	Inlet cooling water temperature must always be maintained above the dew point to prevent condensation and water damage to your laser.

Connecting

6 Turn on the chiller and adjust the temperature setpoint between 18 °C and 22 °C. Regulate coolant flow to 0.5 GPM (48-1) or 0.8 GPM (48-2) at less than 60 PSI of pressure.

7 Closely examine all cooling connections and verify that there are no leaks.

48-5 cooling tubing connections

Cooling water enters the laser through the two lower side-mounted tubes plus one of the center-mounted cooling tubes located on the laser's rear plate. Cooling water flows through the tubes and out the two top-mounted cooling tubes and the other center-mounted tube. The front central tubes are "jumpered" using a "U" fitting while the front side and top connections on the front plate are also jumpered using two right angle connections. The cooling kit also includes quantities of both straight and elbow fittings; you can order other compatible fittings from your local fitting supply house. All fittings are quick-disconnect types.

To connect cooling tubing to your 48-5 laser, refer to Figure 1-4 and perform the following steps:

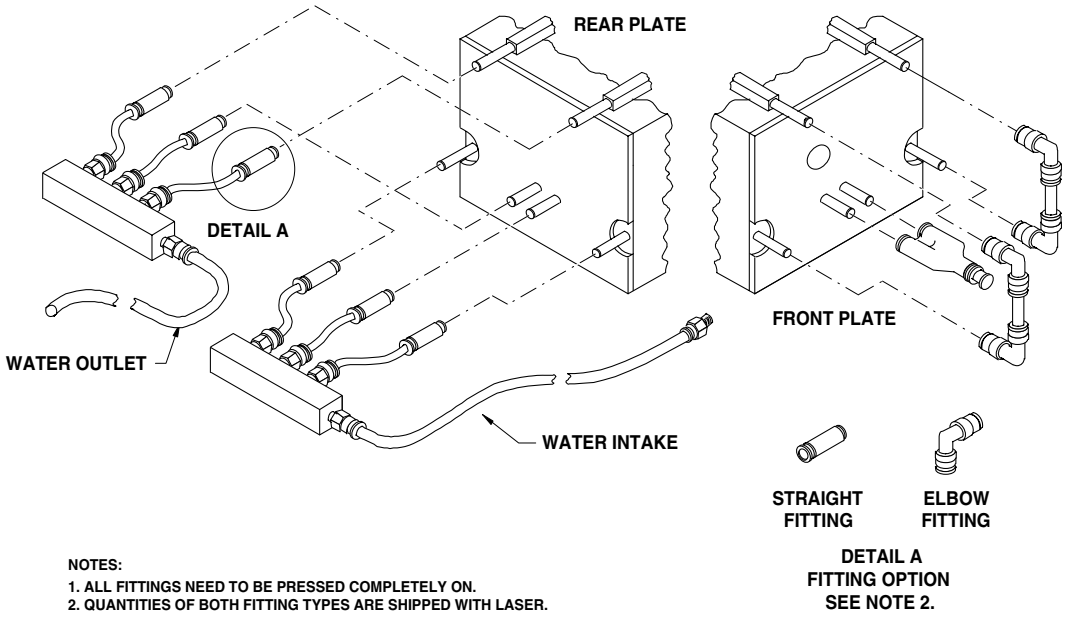


Figure 1-4 48-5 cooling connections

1 Connect the Water Intake manifold tubing to both of the laser's lower side-mounted coolant tubes and one of the center coolant tubes on the rear plate.

2 Connect the Water Intake fitting to your coolant source.

3 Connect the Water Outlet manifold tubing to both of the laser's upper coolant tubes and one of the center coolant tubes on the rear plate.

4 Connect the Water Outlet fitting to your coolant return or drain.

5 On the front plate, connect one right angle connection between one of the lower coolant tubes and its corresponding upper coolant tube. Repeat this step on the other set of lower/upper tubes.

6 Connect the "U" connector between both of the center coolant tubes.

Connecting

Caution possible equipment damage	Inlet cooling water temperature must always be maintained above the dew point to prevent condensation and water damage to your laser.

7 Turn on the chiller and adjust the temperature setpoint between 18 °C and 22 °C. Regulate coolant flow to 1.5 GPM at less than 60 PSI of pressure.

8 Closely examine all cooling connections and verify that there are no leaks.

Electrical connections

DC power supply

SYNRAD power supplies, models DC-1, DC-2, and DC-5, are sized to power 48-1, 48-2, and 48-5 lasers respectively. The 48-1 laser requires a SYNRAD DC-1 or equivalent power supply capable of providing 30 VDC at 7 A maximum; the 48-2 laser requires a SYNRAD DC-2 power supply (30 VDC at 14 A max.); and the 48-5 requires a SYNRAD DC-5 power supply (30 VDC at 28 A max.).

If substituting power supplies, use a well-regulated DC power supply in the range of 30 V to 32 V with no more than 3 V overshoot under a 10–90% modulation load. The use of short leads and terminations rated for the appropriate output current is recommended.

Note: SYNRAD lasers are tested to meet published specifications at an input voltage of 30 VDC.

AC input power requirements for the DC-1 power supply are 85–264 VAC, single phase (1Ø), 20 A max, 47–440 Hz. Input requirements for both DC-2 and DC-5 supplies are 90–132 VAC (low range) or 175–264 VAC (high range), single phase (1Ø), 13 A (DC-2) or 25 A (DC-5) max, 47–440 Hz.

DC-1 power supply

To connect the DC-1 power supply, refer to Figure 1-5 and perform the following steps:

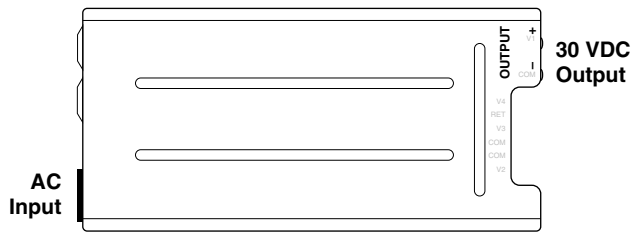


Figure 1-5 DC-1 (Astec) power supply

getting started

Connecting

1 Verify that input AC to the DC power supply is physically locked out or disconnected.

2 Locate the 30 VDC output terminals on the power supply's output section and connect the black (–) *DC Power* cable from the laser to the negative (– COM) output terminal.

3 Connect the red (+) *DC Power* cable from the laser to the positive (+ V1) 30 VDC output terminal.

4 Connect the AC line cord to the AC receptacle located on the fan end of the DC-1 power supply.

Note: U.S., European, and UK line cords are available for the DC-1 power supply. If the line cord provided does not fit your available AC outlet, you will need to provide a cable with the proper AC outlet plug on one end and a standard IEC 320 female connector on the power supply end.

DC-2 / DC-5 power supply

To connect either the DC-2 or DC-5 power supply for 120 VAC (low range) input, refer to Figure 1-6 and follow the steps listed in the *120 VAC input operation* section. If you are connecting the DC-2/DC-5 power supply for 240 VAC (high range) input, refer to Figure 1-6 and follow the steps listed in the *240 VAC input operation* section.

Note: Because AC input connections and requirements vary from facility to facility, our DC-2 and DC-5 power supplies do not include an AC power cord. Customers must provide the appropriately sized AC power cable or wiring.

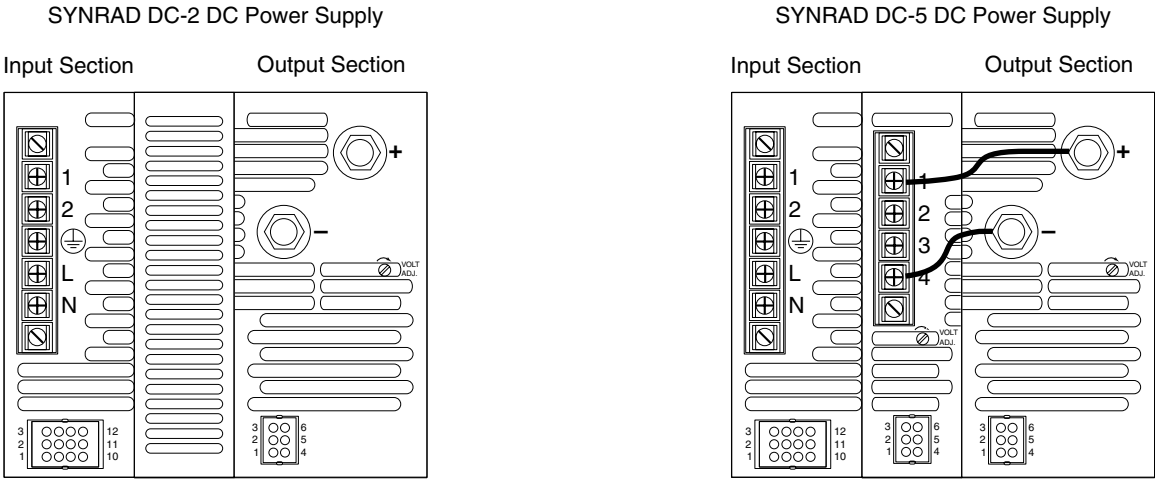


Figure 1-6 DC-2/DC-5 (Power-One) power supplies

120 VAC input operation

1 Verify that input AC power to the DC power supply is physically locked out or disconnected.

2 Locate the 30 VDC output terminals on the power supply's output section and connect the black (–) *DC Power* cable from the laser to the negative (–) output terminal.

3 Connect the red (+) *DC Power* cable from the laser to the positive (+) 30 VDC output terminal.

4 Locate the 5-pin terminal strip on the power supply's input section, under the protective snap-on cover.

5 Connect a jumper wire (16 AWG or heavier) between terminals 1 and 2.

6 Connect the AC hot wire, typically black, from your 120 VAC source to the terminal labeled "L" (AC Line).

7 Connect the neutral wire, typically white, from your voltage source to terminal "N" (AC Neutral).

8 Connect the ground (earth) wire, typically green, from your AC voltage source to the terminal labeled with the ground symbol.

240 VAC input operation

1 Verify that input AC power to the DC power supply is physically locked out or disconnected.

2 Locate the 30 VDC output terminals on the power supply's output section and connect the black (–) *DC Power* cable from the laser to the negative (–) output terminal.

3 Connect the red (+) *DC Power* cable from the laser to the positive (+) 30 VDC output terminal.

4 Locate the 5-pin terminal strip on the supply's input section, under the protective snap-on cover.

5 Connect one of the two AC hot wires, typically black, from your 240 VAC source to the terminal labeled "L" (AC Line).

6 Connect the other hot wire, typically black or red, from your voltage source to terminal "N" (AC Neutral).

7 Connect the ground (earth) wire, typically green, from your AC voltage source to the terminal labeled with the ground symbol.

Control connections

Warning
serious personal injury

Always use shielded cable when connecting your PWM Command signal source to the laser's *CTRL* connections. In electrically-noisy environments, long lengths of unshielded wire act like an antenna and may generate enough voltage to trigger uncommanded lasing.

UC-2000 Universal Laser Controller

The operation of Series 48 lasers requires an external controller that can provide the necessary tickle and pulse width modulated (PWM) Command signals. SYNRAD recommends the use of a UC-2000 Universal Laser Controller to generate the PWM signals that control the laser's output power. The UC-2000 requires 15–50 VDC @ 35 mA, supplied from either its wall plug transformer or from the *Auxiliary Power* connector on the side of Series 48 lasers. Refer to the *UC-2000 Laser Controller Operator's Manual* for information about UC-2000 operation.

To connect a UC-2000 Controller (not included with Series 48 lasers), perform the following steps:

1 Connect the mini-DIN connector on the end of the UC-2000 Controller's *Power/Control* cable to the *Laser* connector on the rear panel of the UC-2000.

getting started

Connecting

2 Connect the miniature DC power plug on the UC-2000's *Power/Control* cable to the laser's side-mounted *Auxiliary Power* connector.

To use the UC-2000's wall plug transformer instead, connect the miniature DC power plug on the UC-2000's *Power/Control* cable to the miniature connector on the wall plug transformer cable

3 On 48-1 and 48-2 lasers, attach the BNC connector on the end of the UC-2000's *Power/Control* cable to the BNC connector labeled *CTRL* on the rear of the laser.

On 48-5 lasers, attach the long "leg" of the BNC "Y" control cable to the BNC connector on the UC-2000's *Power/Control* cable. Attach the short "legs" of the "Y" cable to the laser's *CTRL1* and *CTRL2* connectors located on the rear of the laser.

Note: When driving the laser from an FH Series marking head, connect the marking head's *Laser Control* cable between the *Laser Control* connector on the marking head and the *CTRL* connectors on the rear of the laser.

4 If your application uses external gating signals to command On/Off switching of the laser, attach a BNC cable between your gate signal source and the UC-2000's *Gate* connector.

5 If your application uses external analog voltage or current signals to control the PWM duty cycle of the laser, attach a BNC cable between your analog voltage or current source and the UC-2000's *ANV/ANC* connector.

Note: You can control Series 48 lasers from an alternate user-supplied PWM Command signal source. See *Controlling laser power* in the "Technical Reference" section for control signal descriptions.

DB9 connections

Note: The negative (–) side of the DC input to the laser is internally connected so that the laser chassis serves as DC power ground. You should isolate the laser's DC power supply so that the only grounded connection is at the laser. Alternatively, you can mount the laser chassis on an insulating pad or film in order to electrically isolate the laser when other equipment is grounded to the laser's DC power supply.

48 Series lasers are equipped with a female DB9 connector mounted to the sidewall of the laser. This connector provides the user with a convenient method for monitoring fault conditions (over-temperature, control/RF circuitry failure) and adds remote interlock, remote keyswitch (relay or switch), message output, and remote LED indicator capability. For a complete description of DB9 pin assignments and functions, see *DB9 connections* in the "Technical Reference" section.

A factory-installed jumper plug is attached to the *DB9 Connector* on each laser to enable normal operation. Two jumpers (see Figure 3-9) are wired to the plug. One jumper between pins 6 and 7 closes the *Remote Keyswitch* function, and the other jumper between pins 3 and 4 closes the *Remote Interlock*. If this jumper plug is removed, it is essential that pin 3 be jumpered to pin 4 (or pin 2) or be connected to external "remote interlock" circuitry in order to enable lasing.

Note: On lasers manufactured as OEM (-S) version lasers, i.e. without a keyswitch, the "remote interlock" function is bypassed internally. For OEM customers wishing to access the "remote interlock" feature via the *DB9 Connector*, please consult the factory for details.

Connecting

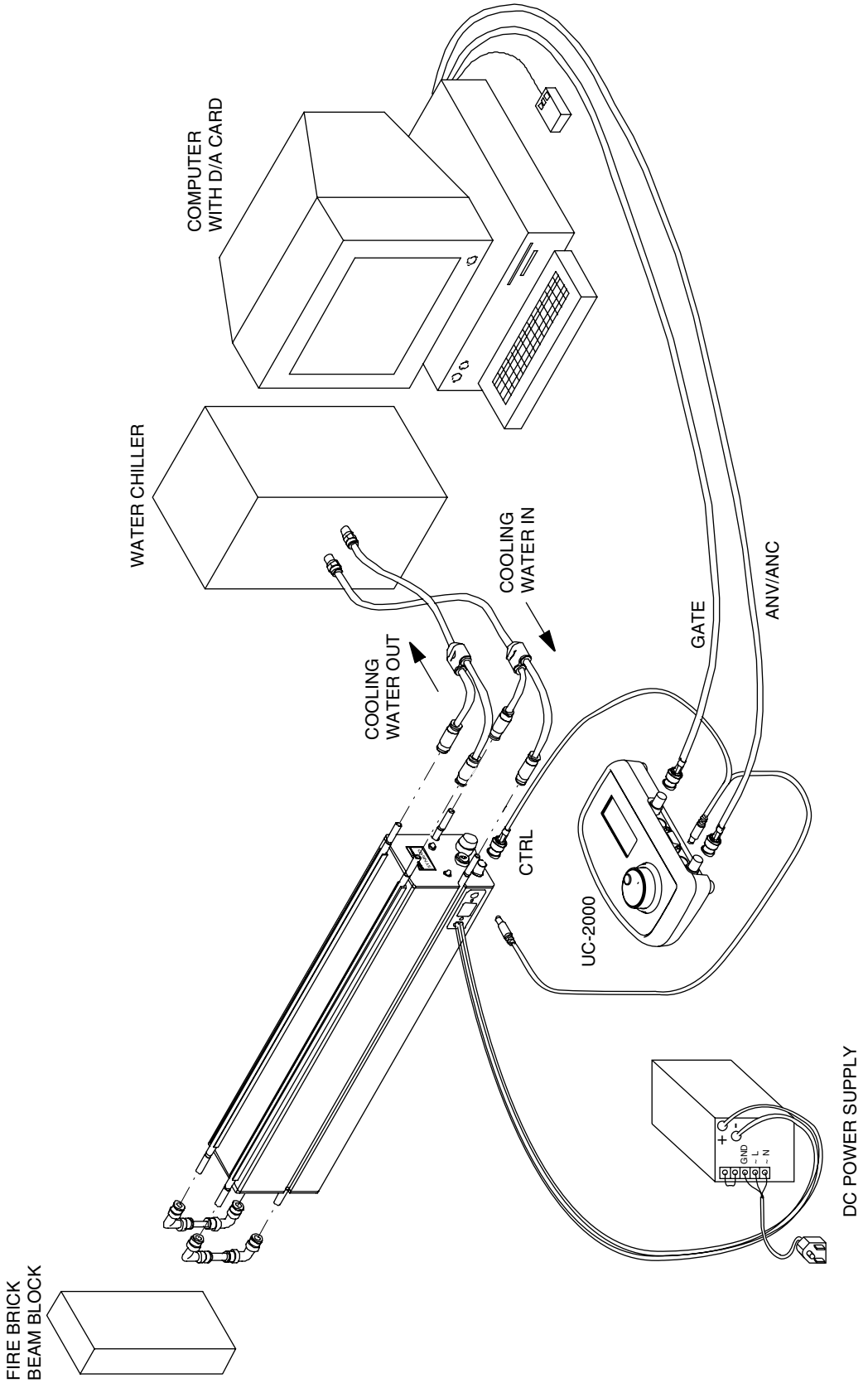


Figure 1-7 Typical Series 48 system interconnection diagram

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operation 2

Use information in this section to familiarize yourself with Series 48 controls and indicators and to begin operating your laser.

This section contains the following information:

- Controls and indicators – displays and describes exterior controls and indicators on Series 48 Keyswitch and OEM lasers.
- Initial start-up – explains how to start your Series 48 laser while verifying proper operation.

operation

Controls and indicators

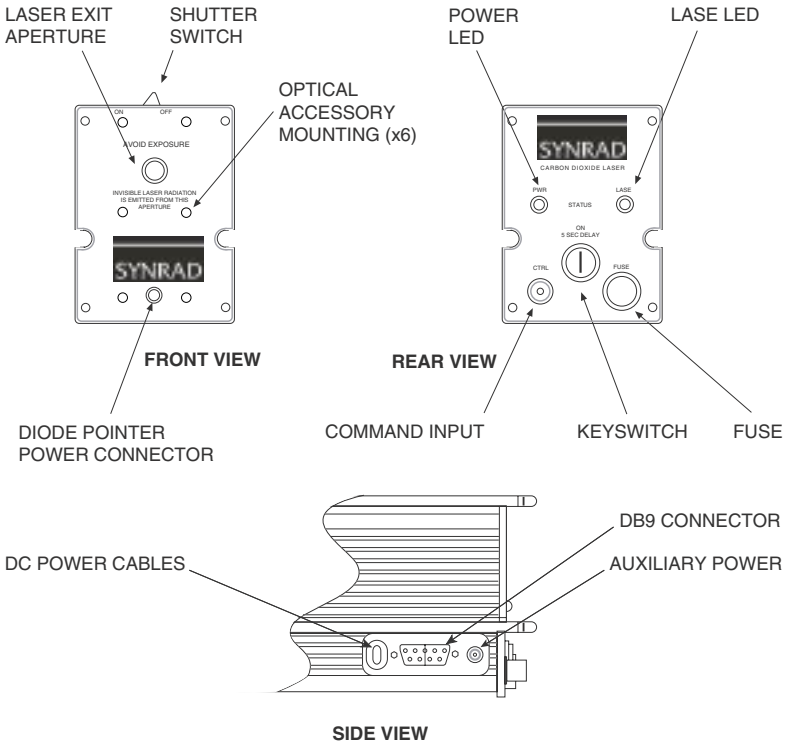

Figure 2-1 48-1 / 48-2 controls and indicators

Shutter Switch (*Keyswitch* models only) – The *Shutter Switch* is a mechanical shutter that closes the laser aperture and also actuates independent micro-switches that interrupt power to the laser section(s). The shutter should not be used to partially block the beam or to control output power.

Power LED – The *PWR* LED is a panel mounted LED that illuminates green when the *Keyswitch* is turned to the ON position (or when an OEM laser is powered up) to indicate that power is applied to internal circuitry.

Lase LED – The *LASE* LED is a panel mounted LED that illuminates red to indicate the lase mode of operation. If a tickle signal is present, the red LED turns on after the five-second delay and becomes brighter as the PWM Command duty cycle is increased.

Keyswitch (*Keyswitch* models only) – The panel-mounted *Keyswitch* is used to turn the laser on, off, and to reset faults. The key cannot be removed when the *Keyswitch* is in the ON position. For OEM lasers, a plug is installed in place of the *Keyswitch* and the keyswitch wires are shorted. The remote keyswitch pins of the *DB9 Connector* then become the external power on/off/reset control means.

Fuse – The panel-mounted fuse(s) provides overcurrent protection for the internal circuitry of the laser. The required fuse is a fast-blow type AGC/3AG rated at 32 V minimum with the following current ratings: 48-1 – 10 A; 48-2 – 20 A; 48-5 – 20 A (2 required)

DB9 Connector – The *DB9 Connector* is a 9-pin, female subminiature-D connector that provides an interconnection for message, fault shutdown, remote interlock, remote keyswitch, and interface signals. Refer to *DB9 connections* in the "Getting Started" section for connection information.

Command *(CTRL)* Input – The *CTRL* connector is a BNC-style jack that accepts tickle and PWM Command signal inputs. The output of the UC-2000 Controller (or FH Series marking head) is attached to this connector. For pure CW operation, a steady +5 V signal can be applied through this connector (a

Controls and indicators

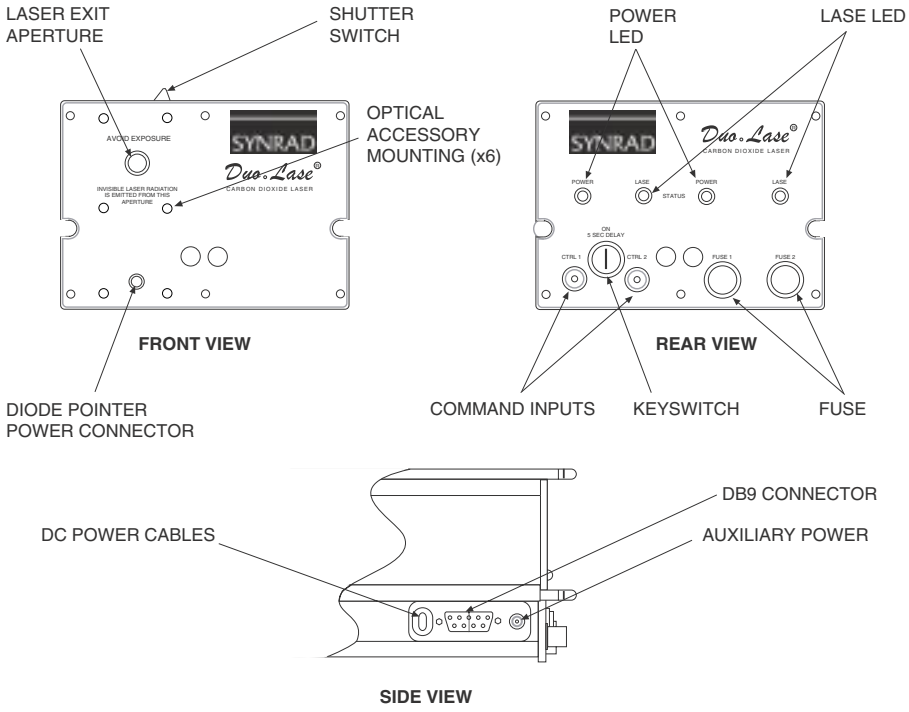

Figure 2-2 48-5 controls and indicators

tickle signal must be applied during laser-off periods). This input is optically-isolated from the chassis and power supply ground circuit but must not be subjected to common mode voltages greater than ±50 VDC from chassis ground. The 48-5 laser has two Command inputs, *CTRL1* and *CTRL2*, that should always be driven identically from the signal source by using a "Y" cable or "T" BNC connector.

DC Power Cables – The red (+) and black (–) *DC Power* input cables provide +30 VDC operating power to the laser. Standard length is 60 inches.

Auxiliary Power Connector – The *Auxiliary Power* connector is installed in the side panel of the laser housing and provides an optional 30 VDC @ 350 mA source for powering the UC-2000 Controller. An auto-resetting solid-state fuse limits line current. Connector power is active after 30 VDC is applied to the laser.

Laser Exit Aperture – The aperture provides an opening from which the beam is emitted when lasing.

Diode Pointer Power Connector (optional) – The *Diode Pointer Power* connector is not installed unless a Diode Pointer is ordered when the laser is built. This connector provides a regulated +5 VDC, 100 mA output for the optional Diode Pointer, available from SYNRAD. The Diode Pointer connector is internally protected against short circuits by an auto-resetting, solid-state fuse.

Optical Accessory Mounting – The front faceplates of Series 48 lasers are designed with a 6-hole mounting pattern (refer to the Outline/Mounting diagrams in the "Technical Reference" section) to provide a convenient method for mounting standard beam delivery components available from SYNRAD. When considering other components not specifically designed as Series 48 options, please consult the factory for restrictions since excessive weight may cause damage to the laser.

Note: To prevent damage to the laser when mounting optical components, the 8–32 mounting screws must not extend further than 3/16" (4.8 mm) into the laser faceplate.

operation

Initial start-up

The *Initial start-up* section includes subsections:

- With a UC-2000 Controller
- Without a UC-2000 Controller

With a UC-2000 Controller

Before your Series 48 laser is put into service for the first time, its functionality should be verified. Follow this procedure to verify the laser system is operating at optimum performance. For this procedure, use the UC-2000 as a stand-alone controller; do not attempt to control the laser or UC-2000 externally.

Danger
serious personal injury

This Class IV laser product emits ***invisible*** infrared laser radiation at the 10.6 µm CO_2 wavelength. Since direct or diffuse laser radiation can inflict severe corneal injuries, always wear eye protection when in the same area as an exposed laser beam. Do not allow the laser beam to contact a person. This product emits an invisible laser beam that is capable of seriously burning human tissue.

Always be aware of the beam's path and always use a beam block while testing.

Note: When performing the initial start-up sequence, check that the factory-installed DB9 jumper plug is installed. If not, you must provide the required Remote Interlock and Remote Keyswitch signals to the *DB9 Connector*. See *DB9 connections* in the "Getting Started" section for DB9 pinouts and signal descriptions.

Starting auxiliary equipment

1. Ensure that all personnel in the area are wearing protective eyewear.
2. Place a beam block 24 inches from the laser aperture to prevent the beam from traveling beyond the work area.
3. On water-cooled systems, turn on the chiller (set between 18 °C and 22 °C) and verify that it is delivering 0.5 GPM (48-1), 0.8 GPM (48-2), or 1.5 GPM (48-5) at less than 60 psi of pressure. Examine all cooling connections carefully for leaks.

Caution
possible equipment damage

Inlet cooling water temperature must always be maintained above the dew point to prevent condensation and water damage to your laser.

operation

Initial start-up

Note: If you have not yet operated your UC-2000 Universal Laser Controller, refer to the *UC-2000 Laser Controller Operator's Manual* for setup and operation instructions before continuing.

4 Set the UC-2000 to *MANUAL* mode, and then set the *PWM Adj Knob* to provide zero percent output (0.0%). The UC-2000's *Lase* indicator should be Off.

5 Verify that the laser's *Keyswitch* (if equipped) is in the OFF position.

Starting your Series 48 laser

1 If the laser has a Diode Pointer installed, remove its aperture dust cover.

2 Move the *Shutter Switch* (if equipped) to the Open position.

3 Turn on the DC power supply.

4 Rotate the *Keyswitch* (if equipped) to the ON position. Verify that the green *PWR* LED illuminates. If the *Keyswitch* is already ON, turn it OFF, then back ON (or cycle the *Remote Keyswitch* input) to reset the laser.

Note: Each time an OEM laser is powered up or a *Keyswitch* version is cycled OFF/ON, a five-second delay occurs between the time that the *PWR* LED illuminates and the laser is permitted to lase.

5 Verify that the red *LASE* LED illuminates dimly after approximately five seconds. This indicates that tickle pulses are being applied to the laser and that it is safe to apply a PWM Command signal.

6 Press the UC-2000's *Lase On/Off* button. The *Lase* indicator on the UC-2000 should illuminate.

7 Use the *PWM Adj Knob* on the UC-2000 to slowly increase power. The intensity of the laser's *LASE* indicator increases in brightness as the PWM duty cycle increases. The spot where the beam hits the beam block should also increase in brightness to indicate increased power output.

Check your laser's output power

1 With the UC-2000 set for maximum power output, measure laser output using a laser power meter (such as SYNRAD's PW-250 Power Wizard®) to verify that output power is consistent with the power rating for your particular model. Refer to *General specifications* in the "Technical Reference" section for output power specifications.

2 Reduce the PWM duty cycle to 0.0% and press the UC-2000's *Lase On/Off* button to stop lasing. The *Lase* indicator on the UC-2000 turns off and the laser's *LASE* LED turns dim.

3 Move the *Shutter Switch* (if equipped) to the Closed position.

4 Turn off the DC power supply.

5 On water-cooled lasers, shut off the chiller or otherwise stop coolant flow through the laser.

Important Note: Do not flow coolant through the laser for an extended period of time when the laser is shutdown. This causes condensation to form inside the laser that may result in catastrophic damage to internal optics and electronic circuits.

If your Series 48 laser fails to lase, refer to *Troubleshooting* in the "Maintenance/Troubleshooting" section for troubleshooting information.

operation

Initial start-up

Without a UC-2000 Controller

If you have chosen not to use a UC-2000 to control the laser, follow the procedure below to verify the laser's functionality. You will need to provide a tickle signal and a pulse width modulated (PWM) Command signal to the laser's *CTRL* input connector. Refer to *Controlling laser power* in the "Technical Reference" section for tickle and PWM Command signal descriptions.

Danger
serious personal injury

This Class IV laser product emits ***invisible*** infrared laser radiation at the 10.6 µm CO_2 wavelength. Since direct or diffuse laser radiation can inflict severe corneal injuries, always wear eye protection when in the same area as an exposed laser beam. Do not allow the laser beam to contact a person. This product emits an invisible laser beam that is capable of seriously burning human tissue.

Always be aware of the beam's path and always use a beam block while testing.

Note: When performing the initial start-up sequence, check that the factory-installed DB9 jumper plug is installed. If not, you must provide the required Remote Interlock and Remote Keyswitch signals to the *DB9 Connector*. See *DB9 connections* in the "Getting Started" section for DB9 pinouts and signal descriptions.

Starting auxiliary equipment

1. Ensure that all personnel in the area are wearing protective eyewear.
2. Place a beam block 24 inches from the laser aperture to prevent the beam from traveling beyond the work area.
3. On water-cooled systems, turn on the chiller (set between 18 °C and 22 °C) and verify it is delivering 0.5 GPM (48-1), 0.8 GPM (48-2), or 1.5 GPM (48-5) at less than 60 psi of pressure. Examine all cooling connections carefully and verify that they do not leak.

Caution
possible equipment damage

Inlet cooling water temperature must always be maintained above the dew point to prevent condensation and water damage to your laser.

4. Ensure that your PWM controller is set to zero percent output (0.0%).
5. Verify that the laser's *Keyswitch* (if equipped) is in the OFF position.

operation

Initial start-up

Starting your Series 48 laser

1 If the laser has a Diode Pointer installed, remove its aperture dust cover.

2 Move the *Shutter Switch* (if equipped) to the Open position.

3 Turn on the DC power supply.

4 Rotate the *Keyswitch* (if equipped) to the ON position; the *PWR* LED illuminates. If the *Keyswitch* is ON, turn it OFF, then back ON (or cycle the *Remote Keyswitch* input) to reset the laser.

Note: Each time an OEM laser is powered up or a *Keyswitch* version is cycled OFF/ON, a five-second delay occurs between the time that the *PWR* LED illuminates and the laser is permitted to lase.

5 Apply a tickle signal (a +5 VDC, 5 kHz square wave of 1 µs duration) to the laser's *CTRL* connector. If operating a 48-5 laser, apply the signal in parallel to both *CTRL1* and *CTRL2* connectors.

Caution possible equipment damage	Series 48 lasers MUST be provided with a pre-ionizing "tickle" signal during standby or laser "low" periods. This signal is automatically provided by SYNRAD's UC-2000 Universal Laser Controller or FH Series marking head. A tickle signal keeps the plasma ionized during laser "low" periods and facilitates plasma breakdown and pulse-to-pulse fidelity. Damage to or malfunction of the laser may occur if this, or equivalent drive signals are not provided.

6 Verify that the red *LASE* LED illuminates dimly after approximately five seconds. This indicates that tickle pulses are being applied to the laser and that it is safe to apply a PWM Command signal.

7 Apply a PWM Command signal (a +5 VDC, 5 kHz square wave of 1 µs to 3 µs duration) to the laser's *CTRL* connector. If operating a 48-5 laser, apply the signal in parallel to both *CTRL1* and *CTRL2* connectors simultaneously.

8 Slowly increase the duty cycle of the signal. The intensity of the laser's *LASE* indicator increases in brightness as the PWM duty cycle increases. The spot where the beam hits the beam block should also increase in brightness to indicate an increasing power output.

Check your laser's output power

1 With your PWM signal source set for maximum power output, measure laser output using a laser power meter (such as SYNRAD's PW-250 Power Wizard®) to verify that output power is consistent with the power rating for your particular model. Refer to *General specifications* in the "Technical Reference" section for output power specifications..

2 Reduce the PWM duty cycle to 0.0%. *The LASE* indicator on the laser dims (tickle signal only).

3 Move the *Shutter Switch* (if equipped) to the Closed position.

4 Turn off the DC power supply.

operation

Initial start-up

5 On water-cooled lasers, shut off the chiller or otherwise stop coolant flow through the laser.

Important Note: Do not flow coolant through the laser for an extended period of time when the laser is shutdown. This causes condensation to form inside the laser that may result in catastrophic damage to internal optics and electronic circuits.

If your Series 48 laser fails to lase, refer to *Troubleshooting* in the "Maintenance/Troubleshooting" section for troubleshooting information.

technical reference

3

Use information in this section as a technical reference for your Series 48 laser.

This section contains the following information:

- Technical overview – briefly describes Series 48 technology and basic optical setup.
- Controlling laser power – explains various aspects of Series 48 control signals.
- DB9 connections – describes signals and specifications for the side-mounted DB9 connector.
- Integrating Series 48 safety features – describes how to integrate Series 48 safety features into your automated control system.
- Series 48 general specifications – provides specifications for Series 48 lasers.
- Model 48-1 package outline drawing – illustrates laser package and mounting dimensions for Keyswitch and OEM 48-1 10 watt lasers.
- Model 48-2 package outline drawing – illustrates laser package and mounting dimensions for Keyswitch and OEM 48-2 25 watt lasers.
- Model 48-5 package outline drawing – illustrates laser package and mounting dimensions for Keyswitch and OEM 48-5 50 watt lasers.

technical reference

Technical overview

The *Technical overview* section includes subsections:

- Introduction
- Plasma section
- Optical resonator
- Control circuitry
- Optical setup

Introduction

Series 48 lasers incorporate the latest technology in sealed carbon dioxide devices, combining the best features of both waveguide and free space CO_2 laser technology. The all-metal laser tube construction features the ruggedness, stable optical support, and small size of waveguide lasers. Its larger bore (4.8 mm) eliminates the high optical power density of waveguide lasers with their predisposition to optical degradation and incorporates the mode purity and easy optical alignment of free space TEM_{00} lasers. Low cost is achieved by using simple extruded and welded aluminum structures packaged together with compact, state-of-the-art RF power supplies. The laser is self-contained requiring only the application of power, cooling air or water, and a control signal. It is therefore ideally suited for overhead installation where the laser is gantry-mounted since no RF cable runs are required.

48 Series lasers emit a laser beam with a wavelength of 10.6 microns (µm). The beam shape is square at the laser output aperture, changing to circular at distances of approximately one meter or more from the laser. The laser beam diverges due to diffraction at a full angle of 4 mrad (milliradians), with the beam waist at the output aperture of the laser.

The method of RF excitation on which the Series 48 is based provides excellent discharge stability, easily controlled output power and modulation, and convenient interfacing to automated systems. Coupling between the RF driver and the laser is based on patented switching and transmission line technology. The RF drive operates at around 45 MHz and is matched to the resonant frequency of the plasma tube.

Power control of the laser beam is achieved by pulse width modulation (PWM) of the RF drive circuit. Modulation control can be used to gate the laser on and off at time intervals synchronized with automated processing equipment. It can also be used to control instantaneous power by adjusting the pulse width (PWM duty cycle) at a fixed modulation frequency. Both methods can be used simultaneously.

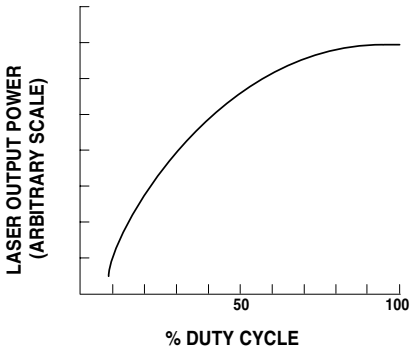

Figure 3-1 Average laser output vs. percent PWM duty cycle

Technical overview

As shown in Figure 3-1, the PWM on-time percentage (PWM duty cycle) exerts a non-linear power function as power saturation is approached, flattening out at approximately 95% duty cycle. We recommend using a 95% maximum PWM signal since little or no increase in laser output power occurs between 95% and 100% PWM duty cycle. It is safe to operate at 100% duty cycle by eliminating all PWM control and simply applying on/off gating; however, you can expect a 5% increase in power draw and heat load.

Plasma section

The laser consists of an RF-excited plasma tube with an adjustable mirror on each end, mounted together with the RF drive assembly in a single aluminum chassis. The plasma tube is made of two-inch square cross-section extruded aluminum tubing with pre-machined ends welded on. The mechanical and electrical arrangement of the internal electrode structure is shown schematically in Figure 3-2. The RF drive power is applied between the lower electrode and the plasma tube. The internal resonant circuit induces RF drive on the upper electrode that is 180 degrees out of phase with that of the lower electrode. Thus the voltage between the two RF electrodes is roughly twice that on either electrode, causing the plasma to form only in the 4.8 mm square bore region. The two sidewalls confine the plasma but carry negligible current. The RF electrodes are anodized to assure uniform distribution of RF power throughout the excitation volume. Waste heat is conducted away by all four metal sides of the bore to the outer walls of the plasma tube, where it is transferred to the chassis. In contrast to waveguide lasers that have a closed bore periphery, Series 48 lasers have four slots (small gaps) extending longitudinally along the length of the bore (shown in Figure 3-2). These slots provide electrical insulation between the two pairs of orthogonal electrodes; however, the slots are also effective for diffusion cooling of the laser gas.

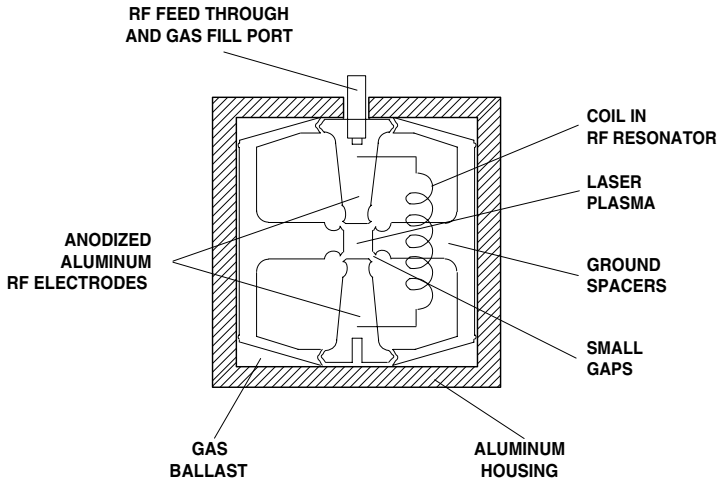

Figure 3-2 Cross section of tube

Optical resonator

The optical resonator consists of a three meter radius of curvature total reflector and a flat Zinc Selenide (ZnSe) output coupler with reflectivities of 95% or 92%. The mirrors are held on with Viton (fluorocarbon) elastomeric o-rings for factory adjustment by means of three Torx head 4–40 screws. No epoxy is used for sealing. The screws are secured by adhesive after alignment.

The 4.8 mm bore, in conjunction with the mirror curvature selected, limits the output beam to TEM_{00} modes when the mirrors are properly aligned. Small variations in output power (up to 10%) are seen during warm-up as the cavity mirror spacing changes due to thermal expansion of the plasma tube.

technical reference

Technical overview

The output wavelength remains at or near 10.6 µm (typically 10.57 µm to 10.63 µm). Beam shape is square at the laser output aperture, changing to circular at distances of approximately one meter or more from the laser with a near gaussian profile in the far field (0.6 m or more). The internal structure and optics of the resonator combine to produce a mode quality of TEM_{00}, 95% purity with an M^2 factor less than 1.2. As shown in Figure 3-3, beam waist diameter is 3.5 mm at the output aperture and full angle divergence due to diffraction is 4 mrad (a 4 mrad full angle divergence means that beam diameter increases 4 mm over every one meter distance traveled).

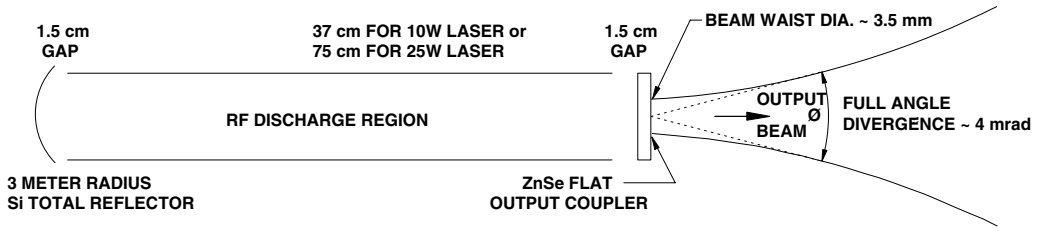

Figure 3-3 Beam characteristics

Control circuitry

Electrical description

Control of laser operation and power output levels is essentially performed using a single PCB. The Control PCB connects the modulated signal to the RF amplifier. It also provides electronics to monitor performance of RF control, output circuitry, input power, temperature, PWM accuracy, provides outputs to an externally accessible connector, and incorporates reverse polarity protection.

Functional differences between model types generally relate to the number of RF channels. Model 48-1 lasers use a single RF electrode requiring a single modulated RF drive input from the Control PCB. The 48-2 uses 2 RF electrodes and requires 2 RF channels, while the 48-5 uses 4 electrodes and 4 RF channels (2 Control PCB's). For the purpose of this description, a single channel will be described. Model specific details relating to differences in electrical characteristics are individually discussed.

The modulated input Command signal is generated externally to the laser and connected to the panel-mounted BNC connector labeled *CTRL*. This signal is connected to an optoisolator, the output of which is applied to the PWM switch control circuit. The PWM switch control circuit gates the PWM switch off and on at the frequency and duty cycle controlled by the modulation source. When the PWM switch closes, a potential of +30 VDC is applied to the RF Driver. The PWM control circuit provides on/off gating of the PWM switch unless disabled by the five-second delay, *Shutter Switch*, or the fault shutdown circuits.

The five-second delay disables PWM output to the RF amplifier for a period of approximately five seconds after the panel-mounted *Keyswitch* and *Remote Keyswitch* link are closed (power ON). On OEM models, the five-second delay period begins on DC power up of the laser.

The *Shutter Switch* allows the operator to temporarily interrupt laser output during active lase modes. A mechanical lever physically blocks the exit aperture and at the same time actuates independent micro-switches that electrically interrupt power to the RF module by disabling the PWM input optoisolator, forcing an "off" state.

Fault shutdown conditions

The power input circuit consists of a panel-mounted fuse for overcurrent protection, a dual Schottky shunt rectifier for reverse-voltage protection, a panel-mounted keyswitch, and a normally open MOSFET safety switch. Application of reverse-voltage will normally require fuse replacement.

The output of the *Keyswitch* is connected to the control board through the *DB9 Connector* user port. Note that the supplied DB9 jumper plug can be removed to allow the user to insert a remotely located relay or switch in series with the *Keyswitch*. If the *Keyswitch* is left on or is electrically bypassed, the user can turn the laser on and off, and reset fault shutdowns from a remote location.

The temperature warning message output (pin 5 of the DB9 connector) goes low when the laser tube temperature reaches 54 °C ±2 °C and remains low until tube temperature falls 2 °C below the trigger temperature. The warning message output does not shut down the laser. Over temperature fault shutdown occurs when laser tube temperature reaches 60 °C ±2 °C.

Control board operation begins when the supply voltage rises above +18 VDC and remains below +36 VDC. After start-up, the control board will shut the laser down if supply voltage falls below +15 VDC or rises above +36 VDC.

If an electronics failure causes the control board to output PWM power to the RF Drivers in excess of 20% of the commanded PWM input, a fault shutdown will occur.

To reset after any fault shutdown, correct the problem(s) then cycle the *Keyswitch* (or *Remote Keyswitch* if one is present) or remove power to the laser for 30 seconds. During any fault shutdown, the fault shutdown output (pin 1 of the DB9 connector) will latch to low state until a keyswitched reset occurs.

Power-On reset

The Power-On Reset feature will not allow lasing to restart after a power failure or shutdown has occurred until the *Keyswitch* or *Remote Keyswitch* is first cycled off (open circuit condition) and then back on (closed circuit). Power-On Reset is defeated on all OEM versions. OEM customers must provide this required safety feature elsewhere as part of their equipment integration.

RF Driver IV

RF power is provided by a patented single MOSFET transistor power oscillator operating in a tuned feedback circuit. The low-impedance MOSFET output is coupled to the relatively high-impedance laser tube electrode by a ceramic-substrate micro-strip transmission line integral to the RF circuit board.

RF rise time is about 1 µs to deliver a striking voltage of over 500 V peak to the discharge electrodes. A pulse-stretching network on the control board widens the incoming Command input so that the tickle pulses delivered from the RF Driver are sufficient to provide a plasma ready state without emission.

The RF drive is not centered on a frequency authorized for significant incidental radiation (ISM bands around 27 and 40 MHz). The power module must therefore be shielded effectively which is accomplished by integrating the plasma tube and drive into a single assembly. Refer to Figure 3-4 for the RF Driver IV circuit schematic.

technical reference

Technical overview

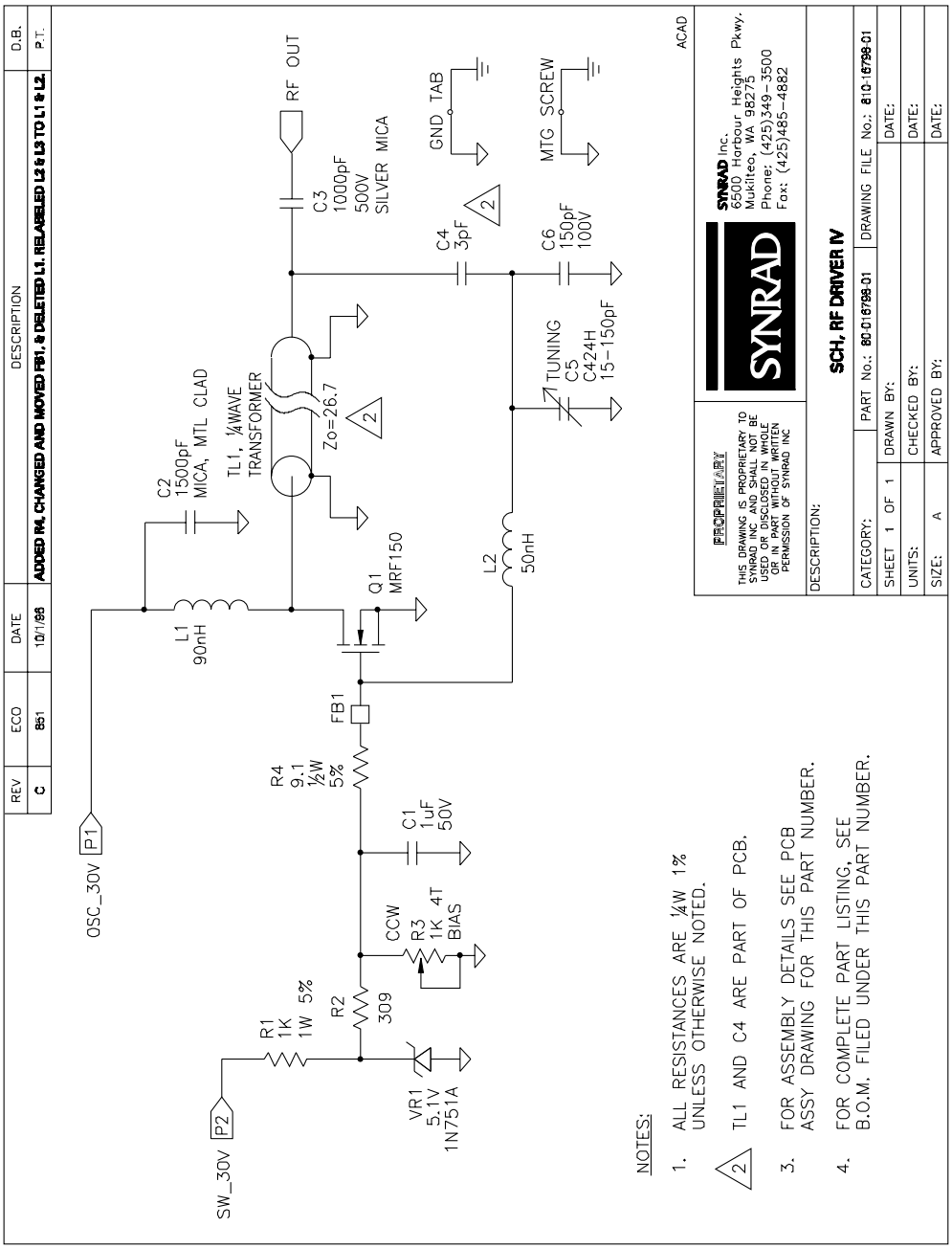

Figure 3-4 RF Driver IV

Cooling requirements

Series 48 electronics are mounted opposite the laser tube in the smaller section of the "H" bay and share the same cooling removal as the plasma tube. Typical efficiency of CO_2 laser plasma tubes operating in a TEM_{00} mode is 10% to 12% (radiation out to RF power in). Factor in the conversion efficiency of AC input to RF output and the overall "wall plug" efficiency of these lasers drops to about 6% to 8%, resulting in a considerable amount of heat removal, even at 10 W and 25 W output power levels; therefore, external cooling in the form of forced air- or water-cooling is required.

Duo-Lase® operation (48-5)

The 48-5 laser combines two laser tubes for twice the output of a standard laser. The outputs from two 25 W sealed CO_2 tubes are combined optically to provide a single diffraction-limited beam at 50 W. This optical combining technique is based on the fact that each laser is linearly polarized, allowing the use of a polarization sensitive beam combiner to achieve 98% efficiency in combining the two beams. The two components of the resulting beam are spatially parallel and collinear, reducing the normal temporal and spatial variations of a single laser. Output polarization is random and therefore superior for many cutting applications.

The 48-5 laser uses two control boards and four RF drivers. The control boards are tied together electronically so that if a failure mode shuts down either board, both laser tubes are turned off. The control boards are equipped with individual fuses for each RF driver PWM output. In the event of an RF driver failure, only that fuse will open, allowing other RF drivers in the system to continue operating. Unless both fuses are open on a given control board, no shutdown will occur, nor is there a fault output signal.

In general, the two Command inputs (*CTRL1* and *CTRL2*) should always be driven identically with a "Y" or "T" connector. For special applications in redundant or ultra-wide dynamic range systems, it is permissible to drive only one Command input; however, the beam's random polarization is compromised.

Optical setup

After selecting a CO_2 laser for your processing system, the two most important elements to consider are: (1) delivery optics to transmit the beam to the work area; and (2) focusing optics to focus the beam onto the part or material to be processed. Each element is crucial in the development of a reliable laser-based material processing system and each element should be approached with same careful attention to detail.

Delivery optics

Divergence, or expansion, of the laser beam is important for materials processing since a larger beam entering the focusing optic produces a smaller focused spot. Because the laser beam diverges slowly, increasing 4 mm in diameter over every meter, Series 48 lasers should be mounted a distance of 1.0 m to 1.5 m (40" to 60") away from the work area. Right angle turning mirrors are often used in conjunction with the laser mounting position to obtain this distance. Figure 3-5 shows how right angle turning mirrors in a "flying optics" setup create this longer beam path.

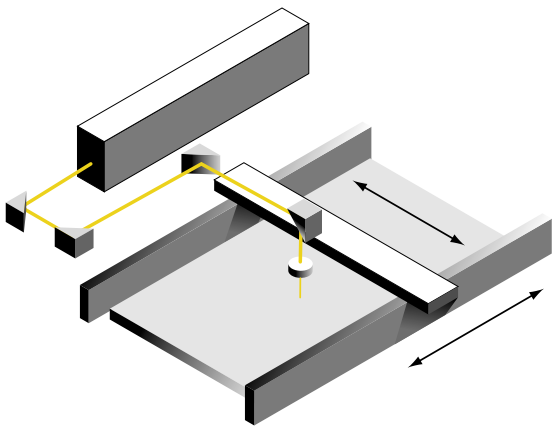

Figure 3-5 "Flying optics" beam path

technical reference

Technical overview

Expander/collimators are optical devices that reduce beam divergence while at the same time increasing beam diameter by a selectable magnification factor. Adding an expander/collimator to the "flying optics" setup shown above would substantially reduce beam divergence and any variance in beam diameter caused by the changing optical path length. In fixed-length delivery systems where the laser is positioned only one meter away from the focusing optic and a small spot size is required, an expander/collimator is again the best solution to provide the required beam expansion before reaching the focusing optic.

Focusing optics

When selecting a focusing optic, the primary consideration should be material thickness and any vertical tolerances that occur during final part positioning rather than making a selection based only on minimum spot size. The chosen focal length should create the smallest possible focused spot while providing the depth of field required for the material to be processed.

Caution possible equipment damage	Small amounts of contaminants on the laser's output window (or on any optic in the beam path) can absorb enough energy to damage the optic. Inspect all beam delivery optics periodically for signs of contaminants and carefully clean as required. In dirty environments, purge laser optics using filtered air or nitrogen to prevent vapor and debris from accumulating on optical surfaces.

Optics are fragile and must be handled carefully, preferably by the mounting ring only. Cleanliness is another important issue affecting performance; a dirty or scratched lens will underperform and exhibit a vastly shortened lifetime. When the application requires air (instead of nitrogen) as a purge gas, use only breathing quality air available in cylinders from a welding supply company. Compressed shop air contains minute particles of oil and other contaminants that will damage optical surfaces. If compressed shop air is the only choice available, it must be filtered to the specifications shown in Table 3-1.

Table 3-1 Gas purity specifications

Purge Gas	Specification	
Nitrogen	High Purity Grade	99.9500% purity or better
Air	Breathing Grade	99.9996% purity or better
Air	Compressed	99.9950% purity or better, water-free; oil filtered to 5 mg/m^3 or better; particulate filtered to < 1.0 micron

technical reference

Controlling laser power

The *Controlling laser power* section includes subsections:

- Control signals
- Operating modes

Control signals

Much of the information provided in this section describes the use of a SYNRAD UC-2000 Universal Laser Controller to provide tickle and PWM Command signals to the laser. If you are using an alternate method of laser control, thoroughly review this section for an understanding of the signal requirements necessary to control SYNRAD Series 48 lasers. Table 3-2 lists input voltage and current specifications for 48 Series control (*CTRL*) inputs. Table 3-3 and Table 3-4 provide specific tickle pulse and PWM Command signal parameters.

Table 3-2 Input signal specifications

Parameter	Specification
Logic Low (Off State)	0.0 V to +0.5 VDC; 0.0 VDC nominal
Logic High (On State)	+3.5 V to +10.0 VDC; +5.0 VDC nominal
Maximum Current Load	6 mA (48-1 / 48-2); 12 mA (48-5)

Tickle pulse

Series 48 lasers require a 1 µs tickle pulse delivered at a nominal 5 kHz clock frequency from the Controller. Tickle pulses pre-ionize the laser gas to just below the lasing threshold so that any further increase in pulse width adds enough energy to the plasma to cause laser emission. This tickle signal causes the laser to respond predictably and almost instantaneously to PWM Command signals, even when there is considerable delay (laser off time) between applied Command signals. The lase threshold is preset for 3 µs ±0.5 µs based on a PWM and tickle frequency input of 5 kHz. See Table 3-3 for tickle specifications.

Caution
possible equipment damage

Applying PWM Command pulses directly to the laser without first sending tickle pulses will cause unpredictable laser emission, degrade optical rise time, and may lead to RF Driver failure.

Table 3-3 Tickle pulse specifications

Parameter	Specification
Tickle Frequency	5 kHz
Pulse Length	1.0 µs ± 0.2 µs
Pulse Rise/Fall Time	≤ 100 ns between +0.5 V to +3.5 VDC

Controlling laser power

The UC-2000 (or FH Series marking head) does not produce tickle pulses continuously, but generates them only when the PWM Command signal is low. Tickle pulses are sent one tickle period, 200 µs, after the falling edge of a PWM Command signal pulse. Figure 3-6 illustrates tickle pulse parameters.

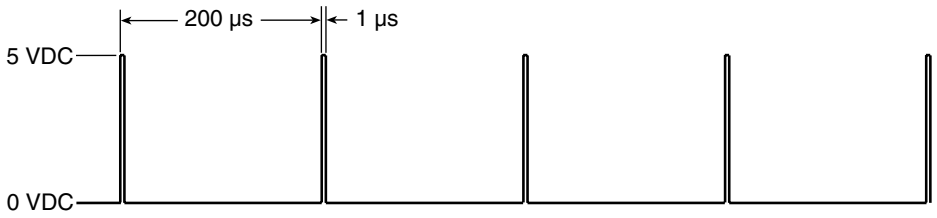

Figure 3-6 Tickle pulse waveform

Series 48 lasers are designed to operate at a tickle frequency of 5 kHz, which allows the laser to meet published specifications. Tickle frequencies lower than 4.5 kHz may compromise laser performance, particularly optical rise times, and stress the RF electronics thereby reducing long term reliability while tickle frequencies greater than 5 kHz may cause unintended lasing. Special care must be taken to maintain plasma ionization without lasing at tickle frequencies greater than 5 kHz. When sending 1 µs tickle pulses at 5 kHz, PWM signals can be sent at an independent, higher frequency but must go to near zero (< 1%) duty cycle to ensure laser turn-off.

Pulse width modulation (PWM)

Pulse Width Modulation, or PWM, controls laser power by varying the duty cycle of the laser's RF amplifiers, which in turn control the time-averaged RF power applied to the laser. Because laser output follows PWM input with a rise and fall time constant of ~100 µs, the laser cannot precisely follow Command signal frequencies over 5 kHz with duty cycles greater than 50%. Typically, the depth of modulation for a 50% duty cycle is 90 to 100% at 2 kHz and 60 to 80% at 5 kHz. Figure 3-7 shows Series 48 optical waveforms at two different modulation frequencies.

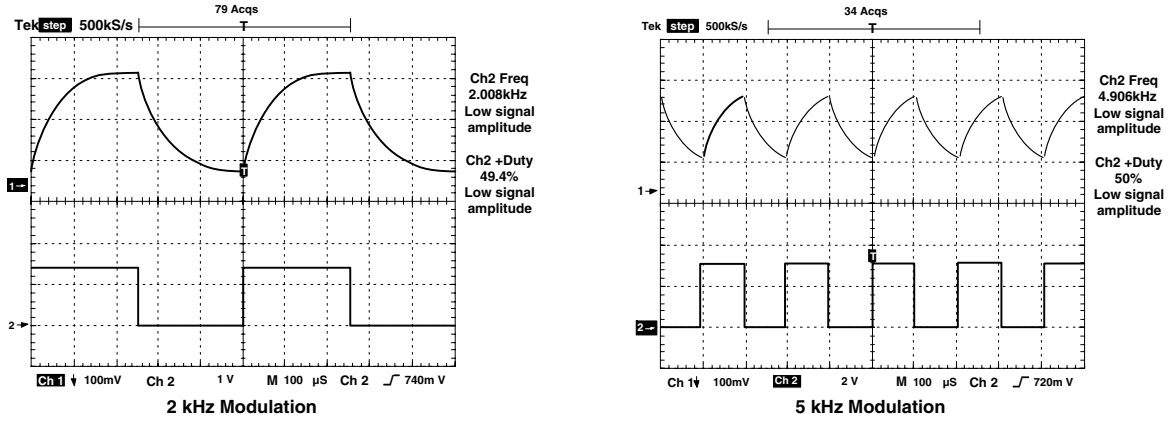

Figure 3-7 Series 48 waveforms

Controlling laser power

Series 48 lasers are designed to operate at Command signal base frequencies up to 20 kHz; however, the choice of PWM frequency depends on the user's specific application. In the majority of laser applications, the UC-2000's default Command signal frequency of 5 kHz has proven to work well. When considering Command frequencies at 5 kHz or below, please review *Marking/engraving operation* later in this section.

For high-speed motion applications that cannot tolerate any ripple in the optical beam response but still need adjustable power levels, we recommend the use of higher PWM frequencies, up to 20 kHz maximum. At 20 kHz, the laser's optical beam response no longer follows the Command input and is very nearly a DC value with just a small amount of ripple present.

Command signal

Warning
serious personal injury

Always use shielded cable when connecting your PWM Command signal source to the laser's *CTRL* connections. In electrically-noisy environments, long lengths of unshielded wire act like an antenna and may generate enough voltage to trigger uncommanded lasing.

The modulated Command signal applied to Series 48 lasers has three parameters: signal amplitude, base frequency, and PWM duty cycle. By changing these parameters, you can command the beam to perform a variety of marking, cutting, welding, or drilling operations.

The first Command signal parameter, signal amplitude, is either logic low—corresponding to laser beam off, or logic high—corresponding to beam on. The laser off voltage, typically 0 V, can range from 0.0 V to +0.5 VDC while the laser on voltage, typically 5 V, can range from +3.5 V to 10.0 VDC.

Base frequency, the second parameter, is the rate at which the amplitude is switched between its low and high logic states. The standard base frequency is 5 kHz, which has a period of 200 µs. Maximum PWM frequency is 20 kHz.

The third Command signal parameter, PWM duty cycle, is the percentage of the period that the Command signal is high. If the Command signal's amplitude (at 5 kHz) is high for 100 µs and low for 100 µs, it has a 50% duty cycle; if the amplitude is high for 190 µs and low for 10 µs, it has a 95% duty cycle. Figure 3-8 illustrates Command signal parameters while Table 3-4 lists PWM Command signal specifications.

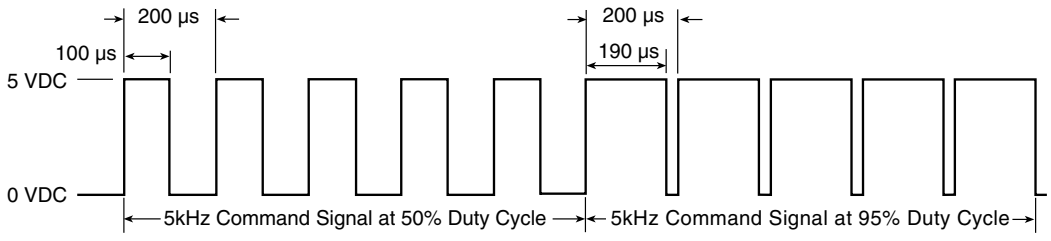

Figure 3-8 PWM Command signal waveform

Controlling laser power

Table 3-4 PWM Command signal specifications

Laser State	Minimum	Nominal	Maximum
Laser Off Voltage	0.0 VDC	0.0 VDC	+0.5 VDC
Laser On Voltage	+3.5 V	+5.0 VDC	+10.0 VDC
Current (@ 5 VDC)	— —	— —	6 mA (48-1/48-2) 12 mA (48-5)
Frequency Range	0 Hz (DC)	5 kHz	20 kHz
Duty Cycle	0%	— —	100%

Caution
possible equipment damage

Applying PWM Command pulses directly to the laser without first sending tickle pulses will cause unpredictable laser emission, degrade optical rise time, and may lead to RF Driver failure.

Operating modes

External control

In addition to controlling your Series 48 laser using a UC-2000 Controller, controlling the laser externally, without a UC-2000, is also possible. The two primary elements of laser control are gating, the ability to turn the laser on and off at the appropriate times, and power, the ability to control the laser's output energy. Both gating and power can be handled by a device such as a personal computer, Programmable Logic Controller (PLC), or a function generator capable of sending PWM pulses at the proper time (gating) and with the proper duty cycle (power).

Analog voltage or analog current control

Although Series 48 lasers cannot be controlled directly by analog voltage or current signals, this type of control is possible when using the UC-2000 Controller. The Controller is connected normally to the laser and analog voltage or current signals sent to the UC-2000's *ANV/C* connector then control both gating and power.

To generate the correct analog voltage from a computer or PLC, a Digital-to-Analog (D/A or DAC) card capable of generating 0 V (laser off) to 10 V (maximum laser power) must be installed. To generate the proper analog current, install a D/A card that can generate 4 mA (laser off) to 20 mA (maximum power). Software able to control your analog output card is required for both configurations.

Continuous wave (CW) operation

In some applications, such as high speed marking or cutting, the time constant of the laser and the PWM modulation causes a series of dots that may be visible on the marking surface instead of a "clean" line. Operating the laser in CW mode will prevent this behavior from occurring.

Controlling laser power

To operate the laser in CW mode, a constant +5 VDC signal is applied to the *CTRL* input(s) of the laser. This constant voltage source forces the internal switching electronics to remain on, providing continuous and uninterrupted laser output power.

Note: When operating in CW mode, laser power output cannot be adjusted. If you require an adjustable output power level, refer to the *Pulse width modulation (PWM)* section for information regarding high frequency operation.

Gated operation

In many marking and cutting applications, the laser is required to pulse, or gate, on and off in synchronization with an external control signal (typically from a computer or function generator operating in the range from DC to 1 kHz). To pulse or gate the laser, connect a signal providing +5.0 VDC pulses to the *Gate* connector on the rear panel of the UC-2000.

Users who intend to use a gating signal should set the UC-2000's gate input logic to internal Pull-Down (normally off) mode. This prevents the beam from being enabled unless a high level (+3.5 V to +5.0 VDC) signal is applied to the *Gate* input connector. In the pull-down (normally off) mode an asserted logic low state, short circuit to ground, or an open or disconnected *Gate* input locks the beam off.

⚠ Warning
serious personal injury

The UC-2000's default gate logic is factory set to internal Pull-Up (normally on) mode. A high level input signal OR an open (disconnected) gate connector will cause the beam to turn on. To gate the beam off, apply a logic low input, short circuit the *Gate* input connector, or reconfigure the Controller to Gate Pull-Down (normally off) operation. See the *UC-2000 Laser Controller Operator's Manual* for further information on configuring Gate logic.

Many CO_2 lasers operating in applications requiring short gating pulses at repetition rates below 500 Hz will exhibit some leading edge overshoot regardless of the PWM frequency. This occurs because a cooler lasing medium (the CO_2 gas) is more efficient than a hotter one. This overshoot is more pronounced at lower gating frequencies since the gas has a longer time to cool down between Command signal pulses.

Marking/engraving operation

When the delay between the end of one PWM Command signal pulse and the beginning of the next PWM pulse exceeds 200 µs (less than or equal to 5 kHz), the UC-2000 Controller or FH Series marking head sends a tickle pulse to maintain plasma ionization in the tube. Because the Controller can not anticipate when the next PWM Command pulse will arrive, the tickle pulse can effectively merge with a PWM signal that follows closely afterwards. When the PWM pulse that follows is short, causing the tickle pulse to become a significant fraction of the PWM pulse duration, then the tickle pulse effectively substantially increases the length of the PWM pulse it has merged with. For subtle marking applications on sensitive, low threshold materials this lengthened PWM pulse may affect mark quality.

While this situation can occur when using PWM Command signal frequencies of 5 kHz and less, it is important to note that it isn't the Command signal frequency itself that is the determining factor but rather this behavior happens only when the off time between PWM pulses exceeds 200 µs.

DB9 connections

Series 48 lasers are equipped with a female DB9 connector mounted to the sidewall of the laser. This connector provides the user with a convenient method for monitoring fault conditions (over temperature, control/RF circuitry failure) and adds remote interlock, remote keyswitch (relay or switch), message output, and remote LED indicator capability. DB9 pin assignments and functions are fully described in Table 3-6 on the following page.

A factory-installed jumper plug is attached to the *DB9 Connector* on each laser to enable normal operation. Two jumpers (see Figure 3-9) are wired to the plug. One jumper between pins 6 and 7 closes the *Remote Keyswitch* function, and the other jumper between pins 3 and 4 closes the *Remote Interlock*. If this jumper plug is removed, it is essential that pin 3 be jumpered to pin 4 (or pin 2) or be connected to external "remote interlock" circuitry in order to enable lasing. To take advantage of the DB9 functions described in Table 3-6, you must manufacture a connecting cable and configure DB9 connections for proper operation in your integrated system. A spare DB9 male connector and cover is included with each laser to facilitate easy cable manufacture.

Note: On lasers manufactured as OEM (-S) version lasers, i.e. without a *Keyswitch*, the *Remote Interlock* function is bypassed internally. For OEM customers wishing to access the *Remote Interlock* feature via the DB9 connector, please consult the factory for details.

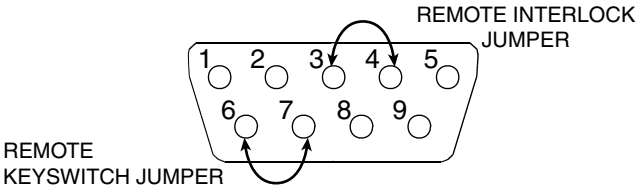

Figure 3-9 Factory-installed DB9 jumper plug wiring

Table 3-5 provides "dry circuit" (zero voltage) specifications for the Remote Keyswitch signal, pin 6 and pin 7 and the Remote Interlock signal on pin 3.

Table 3-5 Remote Keyswitch and Remote Interlock signal specifications

Signal State	Specification
ON (Contact Closed)	≤ 10 Ohms
OFF (Open Circuit)	≥ 100 kOhms
	Contact rating = 50 VDC, < 2 mA minimum (dry circuit)

DB9 connections

Table 3-6 DB9 pin assignments

Pin #	Signal Name	Description / Purpose
1	Fault Shutdown Output	Indicates failure of internal control/RF circuitry or existence of overtemperature (> 60 °C ±2 °C), overvoltage, or undervoltage fault. This active low signal (in reference to pin 2 or pin 4) transitions from +15 V to 0 VDC when a fault occurs. Provides user with control signal to disable external systems in the event of a fault. **See Note 1**.
2	Signal Ground	Signal/chassis ground for pins 1, 3, 5, 8, and 9.
3	Remote Interlock Connection	Disables laser when opened by a remote door or housing safety interlock. As shipped, pins 3 and 4 are jumpered to disable the *Remote Interlock* function. Allows an open external interlock switch to shut down the laser. Ground pin 3 only; do not apply voltage to this pin. **See Note 2**. This feature is internally bypassed on OEM models.
4	Signal Ground	Signal/chassis ground for pins 1, 3, 5, 8, and 9.
5	Message Output	Message Output goes low (in reference to pin 2 or pin 4) when laser tube temperature reaches 54 °C ±2 °C and remains low until temperature falls 2 °C. Provides user with a pre-shutdown temperature warning. Does not shut down the laser. **See Note 1**.
6	Remote Keyswitch Input	For connecting a remote relay or switch in series with the laser *Keyswitch*. Allows user to control laser on/off /reset from a remote location. Connect pin 6 to pin 7 to run; open this circuit to stop or reset faults. As shipped, pins 6 and 7 are jumpered to disable the *Remote Keyswitch* function. **See Note 2 and Note 3**.
7	Remote Keyswitch Output	See pin 6 description above. Pin 7 is at DC line potential (+30 VDC) when the *Keyswitch* is on or bypassed. Allows user to control laser on/off /reset functions from a remote location. **See Note 3 and Note 4**.
8	Remote Lase LED Output	Current and voltage limited output for direct connection to LED or LED-input optoisolator. Allows user to connect a remote *LASE* LED indicator. **See Note 5 and Note 6**.
9	Remote Ready LED Output	Current and voltage limited output for direct connection to LED or LED-input optoisolator. Allows user to connect a remote Ready (*PWR*) LED indicator. **See Note 5**.

1 Allen-Bradley (A-B) compatible outputs (pins 1 and 5) are Active Low.
Specifications: OFF: +15 VDC, 5 mA into 3 kOhm. ON: < 1 VDC, sinking 100 mA.

2 "Dry-circuit" (zero voltage) external switches are required since current into remote interlock and debounced remote keyswitch pins is negligible.

3 Connecting an LED to pins 6 or 7 to indicate keyswitch status requires an external current-limiting resistor.

4 The remote keyswitch output pin is not current-limited or fused.

5 Pins 8 and 9 can be directly connected to the anodes of LEDs or LED-input optoisolators without external current limiting devices. Connect LED cathodes to pin 2 or 4. Current is limited internally to 20 mA at 3.3 V maximum.

6 The output of Pin 8, the Remote Lase LED Output, is a Pulse Width Modulated (PWM) signal based on the PWM Command input signal. It is not a steady state (on/off) output.

technical reference

Integrating Series 48 safety features

The *Integrating Series 48 safety features* section includes subsections:

- Keyswitch functions
- Remote Interlock functions

The Series 48 *DB9 Connector* allows system integrators or end-users to integrate Series 48 laser safety features into their control system. In particular, the Series 48 *Remote Keyswitch* and *Remote Interlock* functions serve to disable DC power to the laser's RF driver. Without power, the RF driver cannot supply PWM Command or tickle signals to the resonator, causing the CO_2 gas to remain in a zero-energy state.

Keyswitch functions

Keyswitch lasers

After DC power-up, or after a fault or open interlock condition, the *Keyswitch* must be toggled to reset the laser, which enables the *PWR* LED and signals that DC power is applied to the RF driver. Over temperature faults are reset by removing, then reapplying DC power after the laser has cooled.

For *Keyswitch* lasers in automated control systems, this reset function is provided by the Remote Keyswitch signal via pins 6 and 7 on the *DB9 Connector*. To use this "remote keyswitch" functionality, first place the *Keyswitch* in the ON position. To reset a fault condition, open and then close a "dry-circuit" (zero voltage) switch or relay contact between pin 6, Remote Keyswitch Input, and pin 7, Remote Keyswitch Output. Reconnecting pin 6 to pin 7 applies power to the RF driver and begins a five-second delay after which lasing is enabled. The RF driver is disabled when the remote keyswitch circuit is open.

Your control system can monitor the laser's power-on status through the *DB9 Connector* by connecting your system's input between pin 9, Remote Ready LED Output, and pin 2 or pin 4, Signal Ground. The Remote Ready LED Output goes active when the laser is enabled (*PWR* LED turns On), indicating that lasing is possible after the five-second delay. The output is inactive (*PWR* LED off) when lasing is disabled. Refer back to Table 3-6, *DB9 pin assignments* for specific details.

Important Note: Pin 9, the Remote Ready LED Output, is a current- and voltage-limited output meant only for direct connection to an LED or LED-input optoisolator.

OEM lasers

On OEM lasers, the *PWR* LED illuminates on DC power-up and five seconds later DC power is applied to the RF driver. To reset a fault condition, remove DC power for 30 seconds and then reapply power to the laser or toggle (open, then close) the Remote Keyswitch signal via pins 6 and 7 on the *DB9 Connector*. To use this "remote reset" functionality, open and then close a "dry-circuit" (zero voltage) switch or relay contact between pin 6, Remote Keyswitch Input, and pin 7, Remote Keyswitch Output. Reconnecting pin 6 to pin 7 applies power to the RF driver and begins a five-second delay after which lasing is enabled.

Your control system can monitor the laser's power-on status through the *DB9 Connector* by connecting your system's input between pin 9, Remote Ready LED Output, and pin 2 or pin 4, Signal Ground. The Remote Ready LED Output goes active when the laser is enabled (*PWR* LED turns On), indicating that lasing is possible after the five-second delay. The output is inactive (*PWR* LED off) when lasing is disabled. Refer back to Table 3-6, *DB9 pin assignments* for specific details.

Important Note: Pin 9, the Remote Ready LED Output, is a current- and voltage-limited output meant only for direct connection to an LED or LED-input optoisolator.

Integrating Series 48 safety features

Remote interlock functions

Keyswitch lasers

Interlock circuits are often used to disable machinery when a shield, panel, or door is opened. The Series 48 remote interlock connects directly into an external, zero-voltage remote interlock circuit to prevent lasing by removing DC power from the laser's RF driver boards when the circuit is electrically "open".

Remote interlock functionality is provided by the Remote Interlock Connection via pin 3 on the *DB9 Connector*. Lasing is enabled when the Remote Interlock Connection signal is closed and disabled when the Remote Interlock Connection signal is electrically "open". DC power is applied to the RF driver only when the Remote Interlock Connection signal is closed (*PWR* LED is illuminated). When the Remote Interlock Connection is opened and then closed, you must toggle the *Keyswitch* or Remote Keyswitch Input to reset the laser.

To use the Series 48 remote interlock feature, connect pin 3, Remote Interlock Connection, through your "dry-circuit" (zero-voltage) interlock circuit and then ground the circuit to pin 2 or pin 4, Signal Ground.

Caution possible equipment damage	Do not apply a voltage to pin 3, Remote Interlock Connection on the *DB9 Connector*—the laser will be damaged. This input is a "dry-circuit" (zero voltage) input and must be grounded to either pin 2 or pin 4 to complete the interlock circuit.

Lasing is enabled when pin 3 is grounded (when the external interlock circuit is closed). If the external interlock circuit opens, then pin 3 opens and lasing is disabled. To enable lasing again, you must close the interlock circuit and toggle the *Keyswitch* or Remote Keyswitch Input. This resets the laser and begins a five-second delay after which lasing is enabled.

Your control system can monitor the laser's power-on status through the *DB9 Connector* by connecting your system's input between pin 9, Remote Ready LED Output, and pin 2 or pin 4, Signal Ground. The Remote Ready LED Output goes active when the laser is enabled (*PWR* LED turns On), indicating that lasing is possible after the five-second delay. The output is inactive (*PWR* LED off) when lasing is disabled. Refer back to Table 3-6, *DB9 pin assignments* for specific details.

Important Note: Pin 9, the Remote Ready LED Output, is a current- and voltage-limited output meant only for direct connection to an LED or LED-input optoisolator.

OEM lasers

The remote interlock function is internally bypassed on OEM lasers; to enable this feature, please consult the factory for details.

technical reference

Series 48 general specifications

Table 3-7 Series 48 general specifications

Parameter	Model 48-1	Model 48-2	Model 48-5
Output Specifications			
Wavelength (microns)	10.57–10.63	10.57–10.63	10.57–10.63
Power Output[1, 2]	10 W	25 W	50 W
Power Stability[3]	±10%	±5%	±5%
Mode Quality (at $1/e^2$)	TEM_{00}, 95% purity $M^2 < 1.2$	TEM_{00}, 95% purity $M^2 < 1.2$	TEM_{00}, 95% purity $M^2 < 1.2$
Beam Waist Size	3.5 mm	3.5 mm	3.5 mm
Beam Divergence	4 mrad	4 mrad	4 mrad
Ellipticity	< 1.2	< 1.2	< 1.2
Polarization	Linear, vertical	Linear, vertical	Random
Extinction ratio	50:1 minimum	50:1 minimum	N/A
Rise Time	< 150 µs	< 150 µs	< 150 µs
Modulation (Optical response)	up to 20 kHz	up to 20 kHz	up to 20 kHz
Electrical Specifications			
Power Supply Output			
Voltage	30 VDC	30 VDC	30 VDC
Maximum Current	7 A	14 A	28 A
Control (CTRL) Input			
Logic Low (Off State)	0.0 V to +0.5 VDC; 0.0 V nominal		
Logic High (On State)	+3.5 V to +10.0 VDC; +5.0 V nominal		
Maximum Current Load	6 mA @ +5.0 VDC (48-1, 48-2) 12 mA @ +5.0 VDC (48-5)		
Tickle Pulse Signal			
Tickle Frequency[4]	5 kHz		
Pulse Length	1.0 µs ± 0.2 µs		
Pulse Rise/Fall Time	≤ 100 ns between +0.5 V to +3.5 VDC		
PWM Command Input Signal			
PWM Frequency[5]	DC to 20 kHz		
PWM Duty Cycle	0% to 100%		

Cooling Specifications[6, 7]		
Model 48-1	(Air-cooled)	(Water-cooled)
Maximum Heat Load, laser	300 W	300 W
Minimum Flow Rate	250 CFM × 2 fans	0.5 GPM, < 60 PSI
Coolant Temperature	≤ 40 °C, ambient	18 °C to 22 °C

* Specifications subject to change without notice.

1 This power level is guaranteed for 12 months regardless of operating hours.

2 Minimum 30 VDC input voltage to obtain guaranteed output power.

3 From cold start (guaranteed).

Series 48 general specifications

Parameter

Cooling Specifications (cont.)[6, 7]

Model 48-2	(Air-cooled)	(Water-cooled)
Maximum Heat Load, laser	500 W	500 W
Minimum Flow Rate	250 CFM × 4 fans	0.8 GPM, < 60 PSI
Coolant Temperature	≤ 40 °C, ambient	18 °C to 22 °C

Model 48-5	(Water-cooled)
Maximum Heat Load, laser	800 W
Minimum Flow Rate	1.5 GPM, < 60 PSI
Coolant Temperature	18 °C to 22 °C

Environmental Specifications

Operating Temperature[8]	15 °C to 40 °C
Humidity	0% to 95%, non-condensing

Physical Specifications

48-1

Length	16.9 in	(42.9 cm)
(incl. cooling tubes)	18.1 in	(46.0 cm)
Width	2.8 in	(7.1 cm)
Height	4.2 in	(10.7 cm)
Weight	9.0 lbs	(4.1 kg)

48-2

Length	31.9 in	(81.0 cm)
(incl. cooling tubes)	33.1 in	(84.1 cm)
Width	2.8 in	(7.1 cm)
Height	4.2 in	(10.7 cm)
Weight	18.0 lbs	(8.2 kg)

48-5

Length	34.9 in	(88.6 cm)
(incl. cooling tubes)	36.4 in	(92.5 cm)
Width	5.3 in	(13.5 cm)
Height	4.5 in	(11.4 cm)
Weight	44.0 lbs	(20.0 kg)

* Specifications subject to change without notice.

4 48 Series lasers are designed to operate at a tickle frequency of 5 kHz, which allows the laser to meet published specifications. Tickle frequencies lower than 4.5 kHz may compromise laser performance, particularly optical rise times, and stress the RF electronics thereby reducing long term reliability while tickle frequencies greater than 5 kHz may cause laser emission.

5 FCC and CE tested at 5 kHz.

6 Lasers with output power ≥ 50 W must be water-cooled. Lasers with output < 50 W can be water- or air-cooled although water-cooling is strongly recommended for duty cycles > 50%. Water-cooling improves power stability at any duty cycle.

7 Inlet cooling water temperature should always be maintained above the dew point to avoid condensation and water damage to the laser.

8 Published specifications guaranteed at a cooling temperature of 22 °C.

Model 48-1 package outline drawing

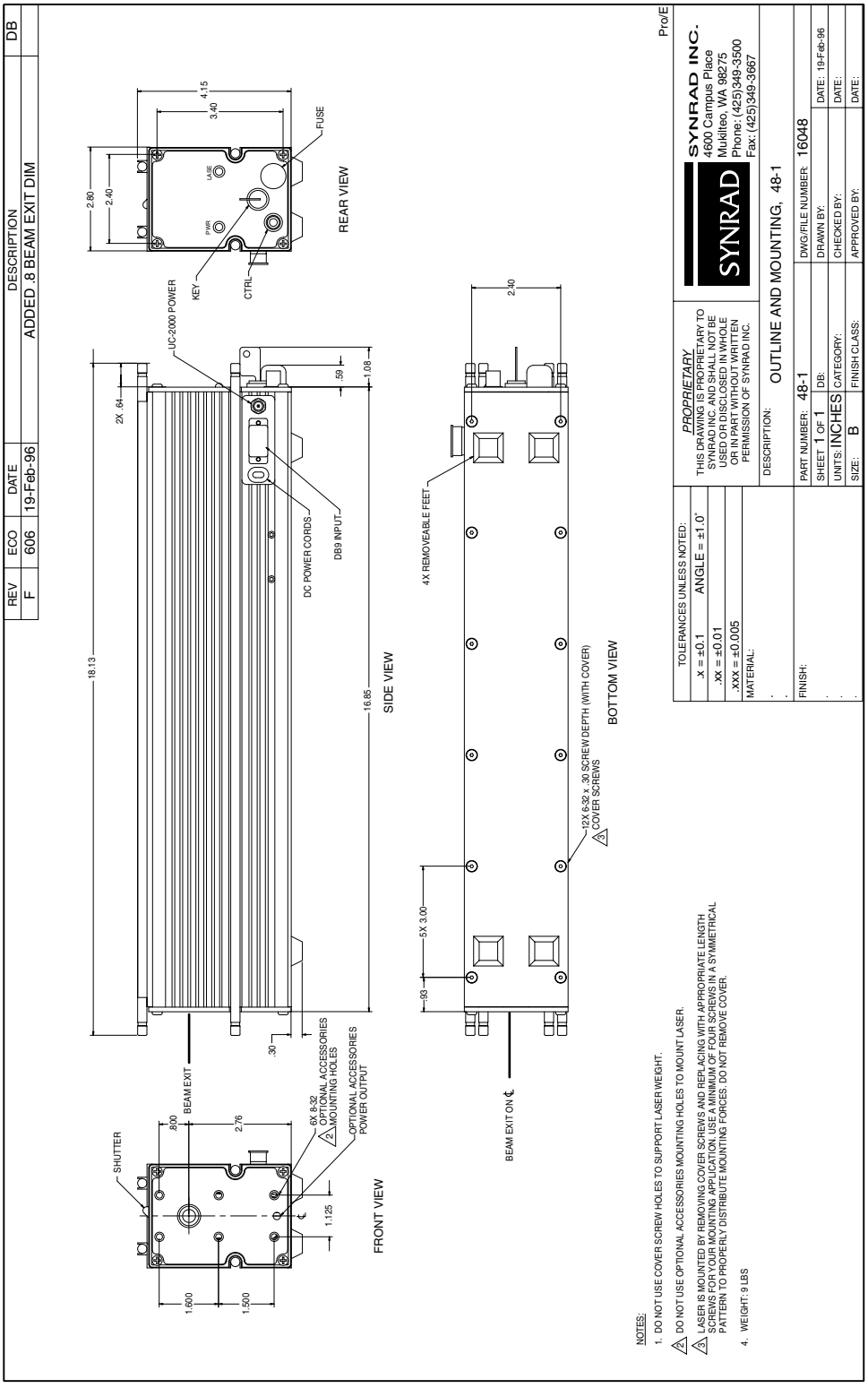

Figure 3-10 Model 48-1 package outline and mounting dimensions

Model 48-2 package outline drawing

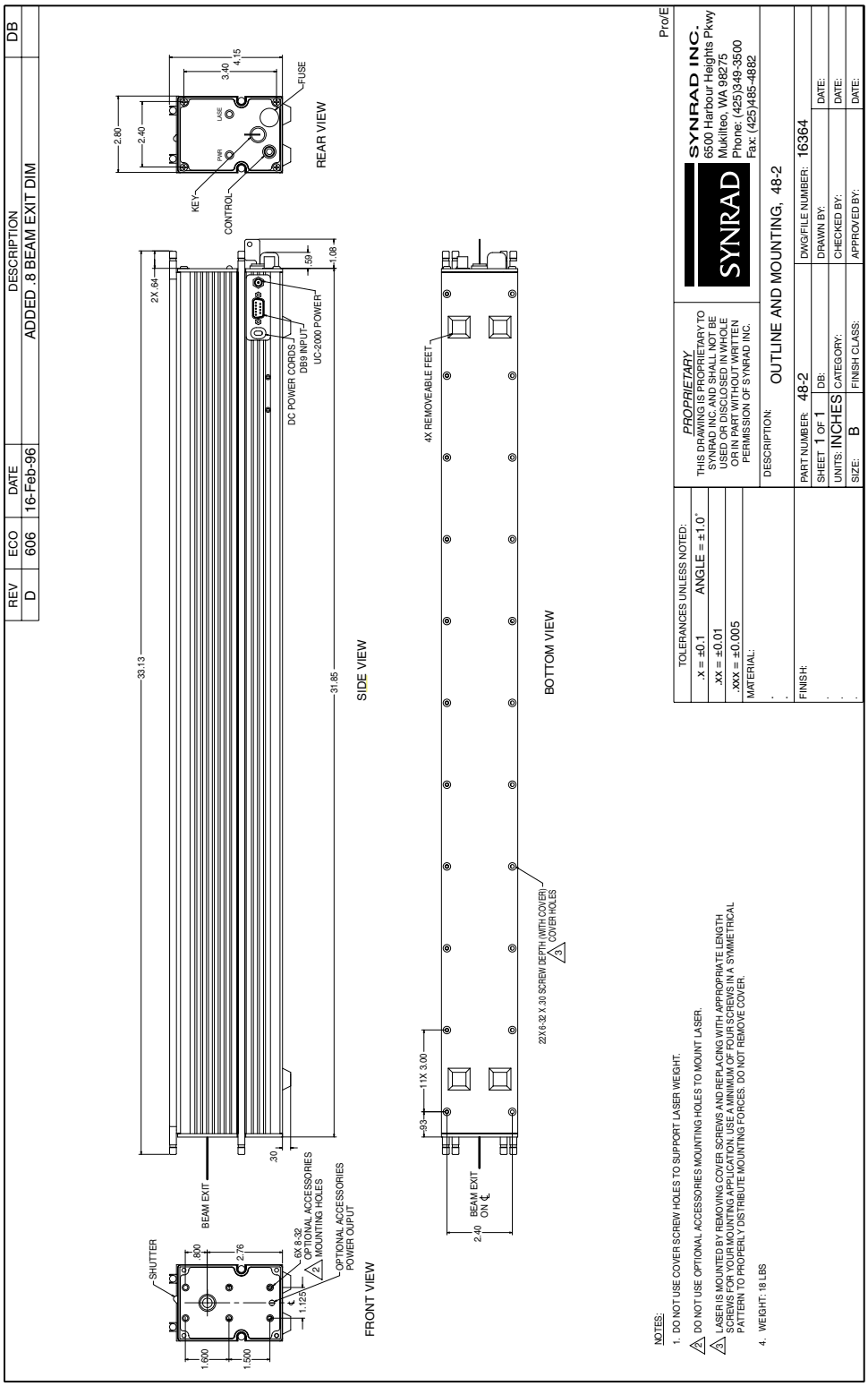

Figure 3-11 Model 48-2 package outline and mounting dimensions

Model 48-5 package outline drawing

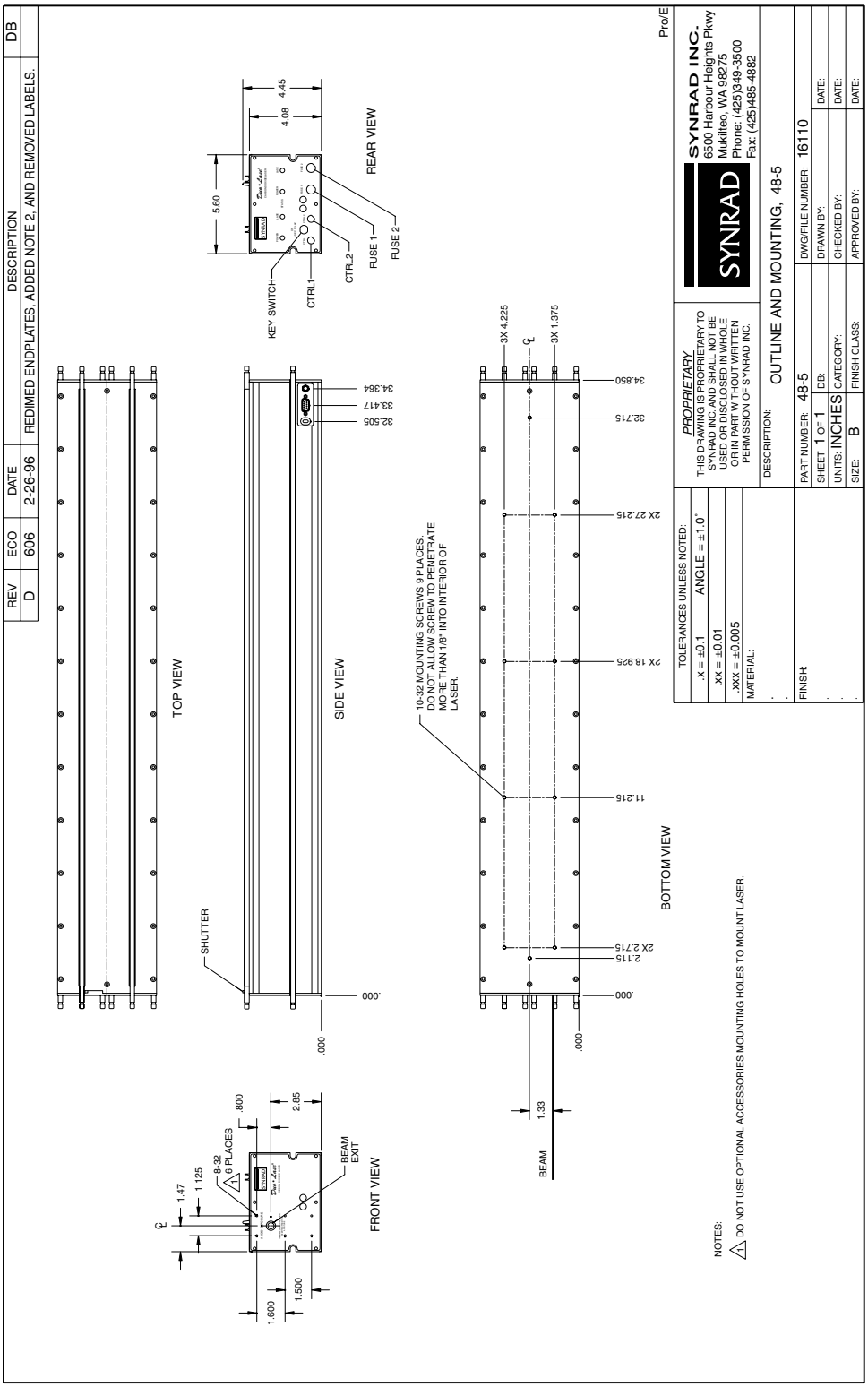

Figure 3-12 Model 48-5 package outline and mounting dimensions

4 maintenance/ troubleshooting

Use information in this section to perform maintenance or troubleshoot your SYNRAD Series 48 laser.

This section contains the following information:

- Maintenance – describes typical Series 48 maintenance procedures.
- Troubleshooting – explains how to troubleshoot common Series 48 problems.

maintenance/ troubleshooting

Maintenance

The *Maintenance* section includes subsections:

- Disabling the laser
- Daily inspections
- Storage/shipping
- Cleaning optical components

Disabling the laser

Before performing any maintenance on your SYNRAD Series 48 laser, be sure to completely disable the laser by disconnecting the laser from its DC power source.

Daily inspections

Perform the following steps daily to keep your Series 48 laser in optimum operating condition. Except for the procedures described below, no other service is required or should be attempted.

Caution possible equipment damage	If you operate your laser or marking head in a dirty or dusty environment, contact SYNRAD about the risks of doing so and the precautions you can take to increase the longevity of your laser, marking head, and associated optical components.

1. For water-cooled lasers, inspect all cooling tubing connections for signs of leakage. Check for signs of condensation that may indicate the cooling water temperature has been set below the dew point temperature. Condensation will damage electrical and optical components inside the laser. See *Setting coolant temperature* in the "Getting Started" section for information on preventing condensation.
2. Inspect beam delivery components for signs of dust or debris and clean as required. When cleaning the optical surfaces of beam delivery components, carefully follow the manufacturer's instructions.

Caution possible personal injury	A risk of exposure to toxic elements may result when certain optical or beam delivery components are damaged. In the event of damage to laser or marking head optics, contact SYNRAD, Inc. or the optics manufacturer for handling instructions.

maintenance/ troubleshooting

Maintenance

3 Visually inspect the laser's exterior housing to ensure that all warning labels are present. Refer to hazard label drawings in the "Laser Safety" section for label types and locations.

Storage/shipping

When preparing your water-cooled Series 48 laser for storage or shipping, remember to drain cooling water from the laser. In cold climates any water left in the cooling system may freeze, which could damage internal components. After draining thoroughly, use compressed shop air at no more than 29 PSI (while wearing safety glasses!) to remove any residual water. When finished, cap all cooling connectors to prevent debris from entering the cooling system.

Cleaning optical components

Debris or contaminants on the laser's output coupler or external beam delivery components may affect laser processing and lead to damage or failure of the optics and/or the laser. Carefully follow the steps below to inspect and clean the optical components in the beam path. Before beginning the cleaning process, read this entire section thoroughly to ensure that all cleaning materials are available and that each step is completely understood.

Danger
serious personal injury

Ensure that DC power to the laser is turned off and locked out before inspecting optical components in the beam path. ***Invisible*** CO_2 laser radiation is emitted through the lens. Corneal damage or blindness may result from exposure to laser radiation.

Caution
possible equipment damage

A small amount of contamination on the laser's output window (or on any optic in the beam path) can absorb enough energy to damage the optic. Inspect the output window and other beam delivery optics periodically for signs of contaminants and carefully clean as required.

In dirty environments, purge laser optics using filtered air or nitrogen to prevent vapor and debris from accumulating on optical surfaces.

Important Note: Exercise great care when handling infrared optics; they are much more fragile than common glass materials. Optical surfaces and coatings are easily damaged by rough handling and improper cleaning methods.

maintenance/ troubleshooting

Maintenance

Cleaning guidelines

- Wear finger cots or rubber gloves to prevent contamination of the optics by dirt and skin oils.
- Always place optical components on lens tissue for protection; never place optics on hard or rough surfaces.
- It may be necessary to use fluffed cotton swabs instead of cotton balls to uniformly clean the entire surface of small-diameter mounted optics.
- Before using any cleaning agents, read their Material Safety Data Sheets (MSDS) and observe all necessary safety precautions.

Required cleaning materials

Table 4-1 lists the type and grade of materials required to properly clean optical surfaces.

Table 4-1 Required cleaning materials

Cleaning Material	Requirements
Finger cots or rubber gloves	Powder free
Air bulb	Clean air bulb
Ethyl alcohol	Spectroscopic or reagent grade
Acetone	Spectroscopic or reagent grade
Lens tissue	Optical quality
Cotton balls or cotton swabs	High-quality surgical cotton/high-quality paper-bodied

Cleaning optics

1. Shut off and lock out all power to the laser. You must verify that the laser is in a zero-energy state before continuing with the optical inspection!
2. Visually inspect all optical surfaces in the beam path, including the laser's output coupler, for contaminants.
3. Remove loose contaminants from the optic by holding a clean air bulb at an angle to the optic and blow a stream of air at a glancing angle across the lens surface. Repeat as necessary.
4. Dampen a cotton ball or fluffed cotton swab with the selected cleaning agent. Ethyl alcohol (least aggressive) is best for initial surface cleaning. Acetone (moderately aggressive) is best for oily residue or minor baked-on vapors and debris.

Note: If acetone is used as a cleaning solvent, a second follow-up cleaning of the optical surface using ethyl alcohol is required.

Maintenance

5 Gently wipe the optical surface with the damp cotton beginning in the center of the optic and working outward in a spiral pattern. ***Do not rub hard or apply any pressure***, especially when using a cotton swab. Drag the cotton ball or swab without applying any downward pressure.

Note: Use a clean cotton ball or fluffed swab on each pass. The cotton will pick up and carry surface contaminants that may scratch optical surfaces if reused.

6 Carefully examine the optic under a good light. Certain contaminants or damage such as pitting cannot be removed. In these cases the optic must be replaced to prevent catastrophic failure.

7 Repeat Steps 4 through 6 as required, removing all traces of contaminants and deposits.

maintenance/ troubleshooting

Troubleshooting

The *Troubleshooting* section includes subsections:

- Introduction
- L48 interconnect schematic
- L48 control board schematic
- Resetting faults
- Laser faults
- Beam delivery optics

Introduction

This section is designed to help isolate problems to the module level only. Problems on circuit boards or the laser tube are not within the scope of this guide because they are not user-serviceable assemblies; do not attempt to repair them. Contact SYNRAD or a SYNRAD Authorized Distributor for repair or replacement information.

To quickly troubleshoot the Series 48 laser, it is necessary to understand the sequence of events that must happen before the laser can turn on and operate. Before you attempt to perform any service, we advise you to read the entire troubleshooting guide and review the relevant schematic diagrams. Symptoms and possible causes are highlighted by dark print and bullet points throughout this section. Information about each symptom and cause can be found in the paragraphs following each heading.

Danger
serious personal injury

This Class IV laser product emits ***invisible*** infrared laser radiation at the 10.6 µm CO_2 wavelength. Direct or diffuse laser radiation can inflict severe corneal injuries and can seriously burn human or animal tissue. Service personnel troubleshooting Series 48 lasers should be thoroughly trained in laser safety practices and electronic service techniques before attempting repairs.

Caution
possible equipment damage

Attempting repair of a SYNRAD Series 48 laser without the express authorization of SYNRAD, Inc. will void the product warranty. If troubleshooting or service assistance is required, please contact the SYNRAD Service Department.

maintenance/ troubleshooting

L48 interconnect schematic

Figure 4-1 shows Series 48 interconnections for all Model L48 Series lasers.

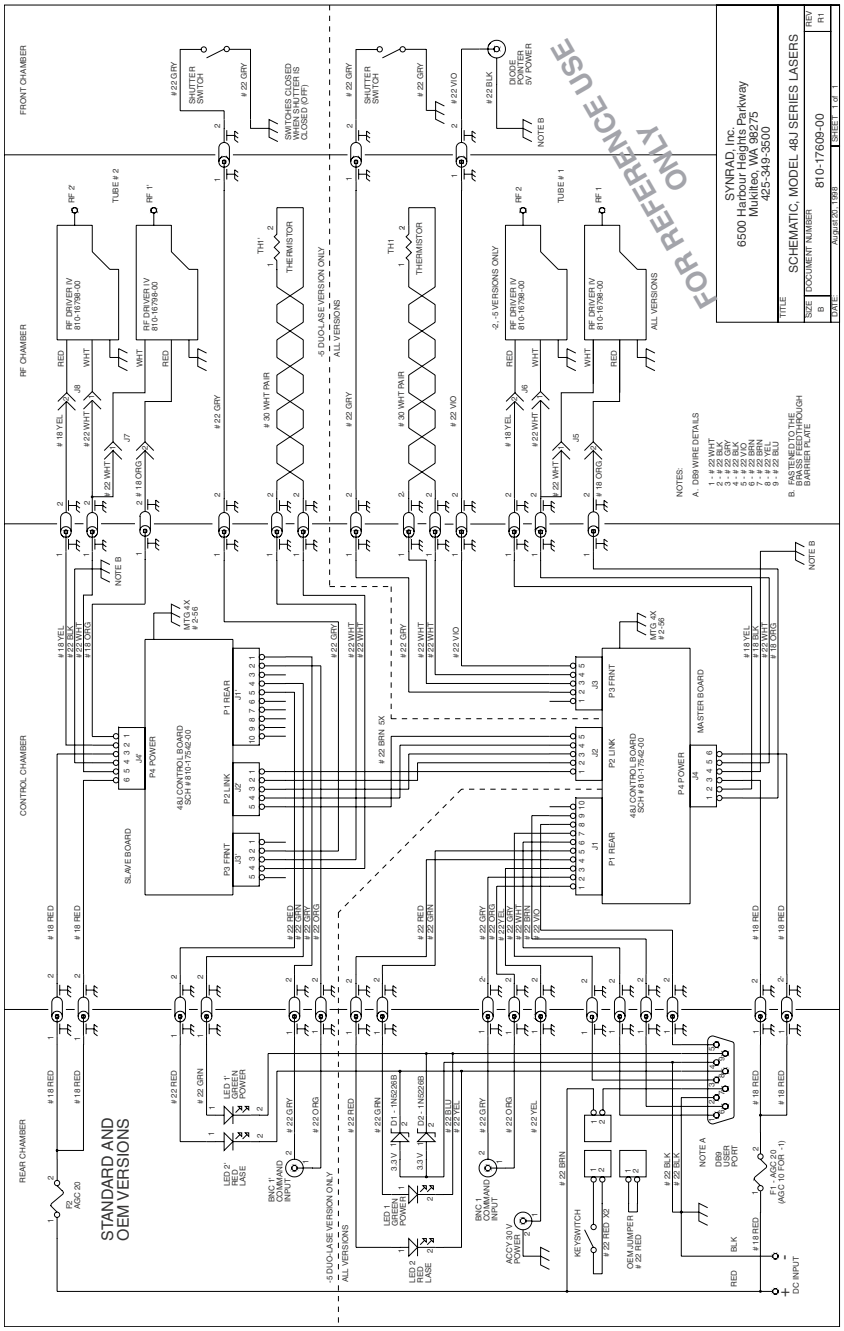

Figure 4-1 Model L48 Series interconnect schematic

maintenance/ troubleshooting

Troubleshooting

L48 control board schematic

Figure 4-2 schematically illustrates the layout of L version control boards.

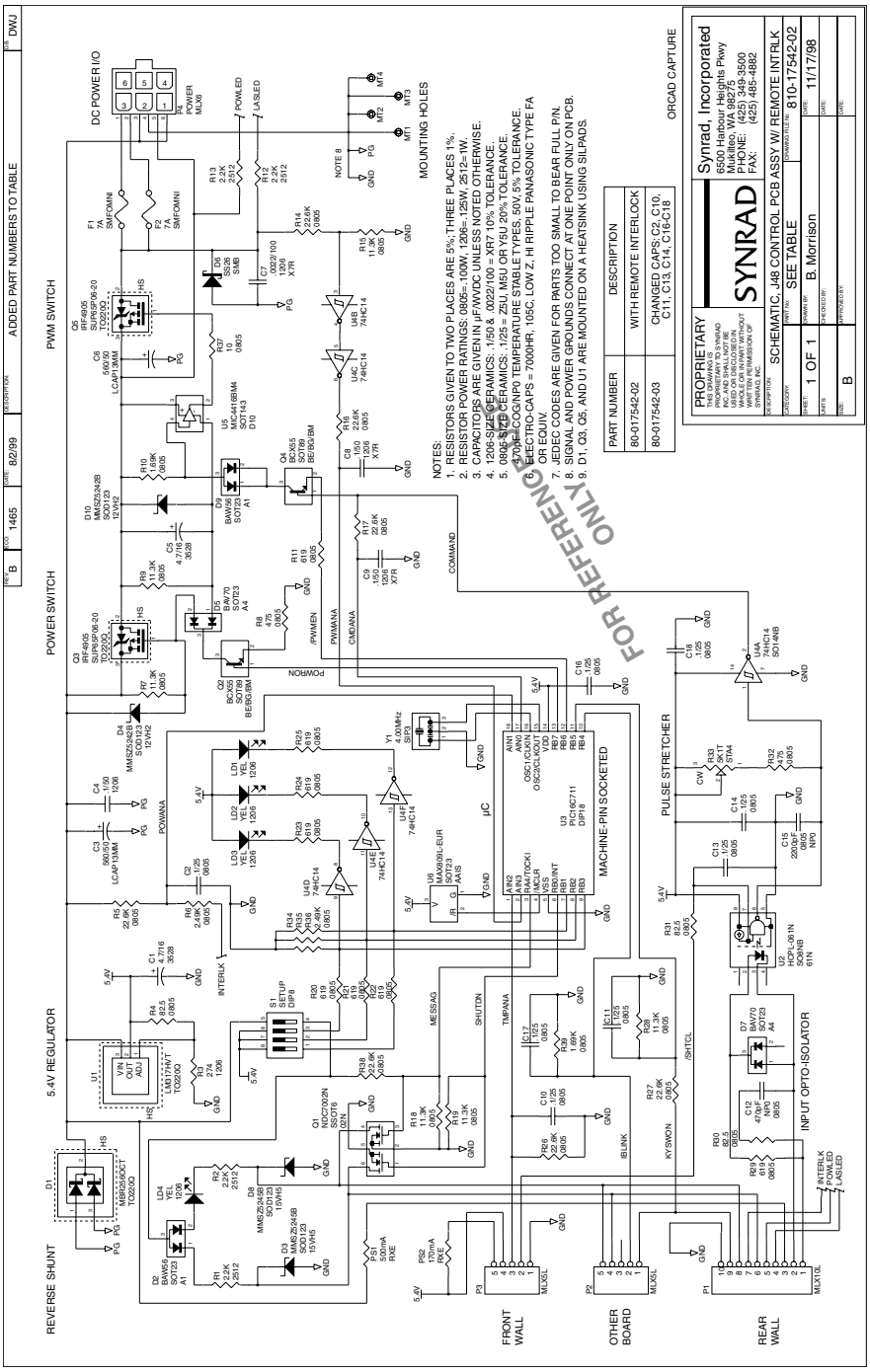

Figure 4-2 L version control board schematic

maintenance/ troubleshooting

Resetting faults

Keyswitch lasers

On *Keyswitch* lasers, the *PWR* indicator illuminates green only when the *Remote Interlock* input is closed and the *Keyswitch* is cycled from OFF to the ON position (or the *Remote Keyswitch* input is opened and then closed). After the *PWR* indicator illuminates, a five-second delay occurs before the laser is permitted to lase. The *LASE* LED illuminates dimly when tickle pulses are applied to the laser and when PWM Command pulses are applied (and are long enough to produce laser output) the *LASE* LED illuminates and appears to brighten in relation to an increasing PWM duty cycle.

To reset a remote interlock fault after the fault condition has been cleared, the *Keyswitch* must be cycled from OFF to ON (or with the *Keyswitch* ON, cycle the *Remote Keyswitch* input open and then closed). When the *PWR* indicator illuminates, lasing is enabled after the five-second delay.

To reset an over temperature fault, lower coolant temperature below 22 °C (water-cooled) or below 40 °C (air-cooled). When the laser cools sufficiently, remove DC power for 30 seconds and then reapply power to the laser or cycle the *Keyswitch* from OFF to ON (or with the *Keyswitch* ON, cycle the *Remote Keyswitch* input open and then closed). When the *PWR* indicator illuminates, lasing is enabled after the five-second delay.

A closed shutter is not considered a fault condition; when the shutter is opened, lasing is enabled after a five-second delay provided that the *PWR* indicator is illuminated green.

After a power failure or shutdown has occurred, the Power-On Reset feature will not allow lasing to restart until the *Keyswitch* or *Remote Keyswitch* is first cycled off (open circuit condition) and then back on (closed circuit).

During any fault shutdown, the Fault Shutdown Output (pin 1 on the *DB9 Connector*), which is normally at +15 VDC, latches to a low state (0 VDC) until a keyswitched reset occurs.

OEM lasers

On OEM lasers, the *PWR* lamp illuminates on DC power-up. After the *PWR* indicator illuminates, a five-second delay occurs before the laser is permitted to lase. The *LASE* LED illuminates dimly when tickle pulses are applied to the laser and when PWM Command pulses are applied (and are long enough to produce laser output) the *LASE* LED illuminates and appears to brighten in relation to an increasing PWM duty cycle.

To reset an over temperature fault, the coolant temperature must be lowered below 22 °C (water-cooled) or below 40 °C (air-cooled). When the laser cools sufficiently, remove DC power for 30 seconds and then reapply power to the laser or toggle (open, then close) the Remote Keyswitch signal via pin 6 and pin 7 on the *DB9 Connector*. When the *PWR* indicator illuminates, lasing is enabled after the five-second delay.

The Power-On Reset feature is not available on OEM models; OEM customers must provide this required safety feature as part of their equipment integration.

During any fault shutdown, the Fault Shutdown Output (pin 1 on the *DB9 Connector*), which is normally at +15 VDC, latches to a low state (0 VDC) until the laser is reset by removing DC power for 30 seconds and then reapplying power to the laser.

maintenance/ troubleshooting

Troubleshooting

Laser faults

Each Symptom listed below describes a particular fault condition. For each Symptom, specific causes and solutions are described in the Possible Causes section.

Symptom:

- There is no output laser beam; *PWR* and *LASE* indicators are off.

Possible Causes:

- No DC voltage is applied or the voltage level is out of specification.

Check that +30 VDC is available on the power supply output terminals and ensure that *DC Power* cable terminal connections are tight.

Check the fuse(s) on the rear of the laser. Replace with fast-blow 10 Amp (48-1) or 20 Amp (48-2/48-5) AGC/3AG fuses as required.

If your DC-2 or DC-5 power supply is operating at an input voltage of 120 VAC, ensure that a jumper wire is connected between pins 1 and 2 on the input terminal strip. Refer to *Connecting* in the "Getting Started" section for details.

Possible Causes:

- A reverse DC voltage was applied to the laser.

Replace the fuse(s) with a fast-blow 10 Amp (48-1) or 20 Amp (48-2/48-5) AGC/3AG fuse as required.

Possible Causes:

- The laser's *DB9 Connector* is not configured correctly.

Ensure that the factory-wired DB9 jumper plug is firmly plugged into the laser's *DB9 Connector*.

If the laser is connected through the *DB9 Connector* to external circuits, check that field wiring is correct. The remote interlock connection (pin 3) must be grounded through your external interlock circuit to pin 2 or pin 4. Pin 6 must be connected to pin 7 through your external keyswitch circuitry. Refer to *Connecting* in the "Getting Started" section and *DB9 connections* in the "Technical Reference" section for details. A quick method to isolate the problem to either the laser or the field wiring is to disconnect field wiring and plug in the factory-wired jumper plug; if the lasers operates normally with the jumper plug installed, verify external wiring and circuit devices.

Possible Causes:

- The laser's *Keyswitch* or aperture shutter are not set properly.

Cycle the *Keyswitch* to the OFF position for a few seconds, then cycle back to ON.

Close and then re-open the *Shutter Switch*.

Troubleshooting

Possible Causes:

- The laser is in an over temperature condition.

Allow the laser to cool. Verify that the laser is receiving the proper air or water flow per Table 4-2 below. On air-cooled lasers, verify fan operation and check for at least 2.25" of unobstructed clearance around the fan housing. To restart the laser, disconnect DC power, wait 30 seconds, and then reapply DC power.

Table 4-2 Series 48 cooling specifications

Model	Air-cooled	Water-cooled
48-1	250 CFM × 2 fans (1 per side)	0.5 GPM, < 60 PSI
48-2	250 CFM × 4 fans (2 per side)	0.8 GPM, < 60 PSI
48-5	N/A	1.5 GPM, < 60 PSI

Symptom:

- No output beam and the *PWR* and *LASE* LEDs are Off, but +30 VDC is applied.

Possible Causes:

- A fault shutdown has occurred. Pin 1 on the *DB9 Connector* is at 0 VDC in reference to pin 2 or pin 4 (Pin 1 is at +15 VDC during normal operation).

An overtemperature, overvoltage/undervoltage, or RF circuitry failure has occurred.

Correct the problem(s), then remove power from the laser for 30 seconds. Re-apply power (on *Keyswitch* lasers, cycle the *Keyswitch* or *Remote Keyswitch*).

Symptom:

- No output beam, but the *PWR* LED is On. The *LASE* indicator is dim and does not brighten.

Possible Causes:

- A PWM Command input signal is not present.

Verify that a PWM Command signal is present on the *CTRL* input. On 48-5 dual-tube lasers, a Command signal must be applied to both *CTRL1* and *CTRL2* inputs simultaneously. See *Controlling laser power* in the "Technical Reference" section for PWM Command signal details.

Symptom:

- Laser power varies or responds intermittently to input PWM Command pulses.

maintenance/ troubleshooting

Troubleshooting

Possible Causes:

- Verify that your UC-2000 or equivalent PWM controller is delivering tickle pulses of the proper duration. See *Controlling laser power* in the "Technical Reference" section for tickle pulse details.

Beam delivery optics

Symptom:

- The laser appears to slowly lose power over time; laser output power must be increased to maintain previous performance.

Possible Causes:

- Beam delivery optics are coated by vapor residue or debris.

Danger
serious personal injury

Ensure that DC power to the laser is turned off and locked out before inspecting optical components in the beam path. ***Invisible*** CO_2 laser radiation is emitted through the lens. Corneal damage or blindness may result from exposure to laser radiation.

Shut down the laser and carefully inspect each optic in the beam delivery path, including the laser's output coupler. Remember that optics are fragile and must be handled carefully; preferably by the mounting ring only. If the optic requires cleaning, then refer back to *Maintenance* for cleaning instructions. Use only recommended cleaning materials (see Table 4-1) to prevent scratching delicate optical surfaces.

If the focusing optic is pitted, it must be replaced immediately. The laser's high power density will cause pits or debris on the lens to absorb enough energy that the lens may crack. If this happens, other optics in the beam path may be contaminated or damaged as well.

When the application requires air (instead of nitrogen or argon) as an assist gas, we recommend the use of breathing quality air available in cylinders from a welding supply company. Because compressed shop air contains minute particles of oil and other contaminants that will damage optical surfaces, it must be carefully filtered and dried before use as a purge or assist gas. Refer to Table 3-1, G*as purity specifications*, in the "Technical Reference" section for filtering specifications.

appendix a

Use information in this section to connect and operate your Closed Loop (C/L) Stabilization Kit.

This section contains the following information:

- Introduction – explains how the closed loop kit functions.
- Safety precautions – lists laser safety precautions.
- Connecting – describes how to connect the closed loop kit to your laser and UC-2000 Controller.
- Operation – describes closed loop operation.
- Closed loop specifications – provides technical specifications for the Closed Loop Stabilization Kit.

appendix a

Closed Loop Stabilization Kit

Introduction

The Closed Loop (C/L) Stabilization Kit, available for 10 W and 25 W Series 48 lasers, must be installed and calibrated at the factory. The closed loop kit provides an effective, reliable method of stabilizing laser power output by optically sampling the beam and providing feedback to adjust the PWM duty cycle percentage of the UC-2000's output PWM Command signal.

After installation, the beam passes through an optical sampler (which replaces the standard front plate) before it exits the closed loop housing. Optical beam transmission is 92% since the sampler diverts approximately 8% of the output beam to a diffuser and thermopile detector. The detector signal is amplified and sent to the UC-2000 where the Controller generates a variable duty cycle signal to maintain constant average laser output power.

Note: Once installed and aligned on the laser, the Closed Loop Stabilization Kit becomes part of the loop response/gain parameter and must NOT be moved or adjusted. Any user modifications or adjustments will void the product warranty.

Safety precautions

⚠ Danger
possible personal injury

Please read these instructions carefully before using your Series 48 laser with a Closed Loop Stabilization Kit. To prevent injury to personnel or damage to your laser or CL Kit, follow all safety precautions and setup instructions as described here and in your laser's *Operator's Manual*. Safe operating practices should be exercised at all times when actively lasing to prevent exposure to direct or scattered laser radiation. Improper handling or operation may result in exposure to hazardous ***invisible*** laser radiation, damage to, or malfunction of the laser or Closed Loop Stabilization Kit. Severe burns will result from exposure to the laser beam. Always wear safety glasses with side shields to reduce the risk of damage to the eyes when operating the laser.

appendix a

Closed Loop Stabilization Kit

Connecting

Refer to Figure A-1 for an illustration showing a typical closed loop system and then perform the following steps:

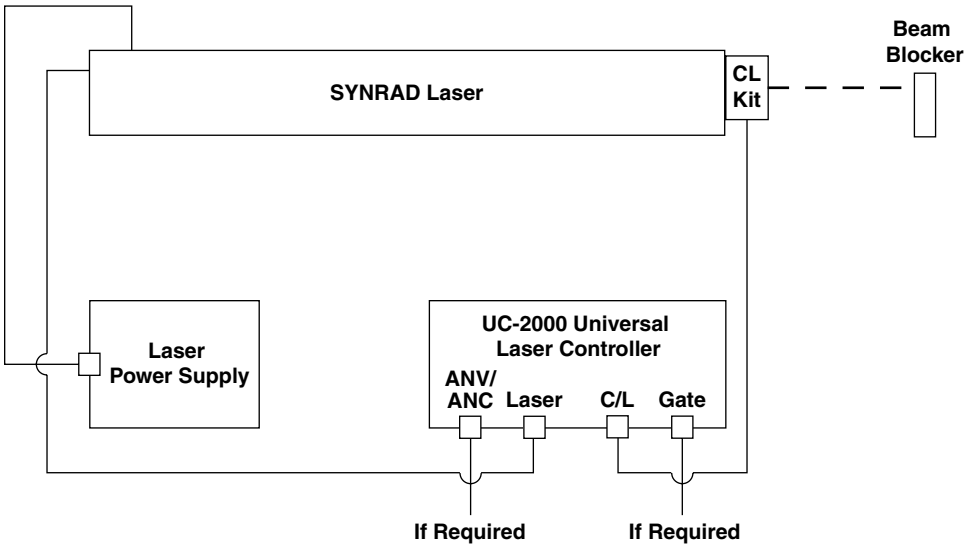

Figure A-1 Typical closed loop setup

1. Disconnect power from your laser and the UC-2000 Controller.
2. Connect one end of the *CL Interconnect* cable to the laser-mounted closed loop assembly and the other end to the UC-2000's 8-pin mini-DIN *C/L* connector.
3. If required, connect a gating signal to the UC-2000's *Gate* BNC connector.
4. If required, connect an ANV signal from your analog voltage source to the UC-2000's *ANV/ANC* BNC connector.
5. Set the UC-2000 to MAN. CLOSED or ANV CLOSED mode.
6. Apply power to both the laser and UC-2000 and then verify proper system operation.

appendix a

Closed Loop Stabilization Kit

Operation

Set the UC-2000 to MAN. CLOSED or ANV CLOSED mode. Adjust the regulated setpoint to provide a laser power output between approximately 20% and 80% of full power. This 20% window on either side of the range allows the Controller to maintain full dynamic power regulation. Within the dynamic response time of the system, the UC-2000 Controller can be gated from an external, low-frequency signal source through the *Gate* connector.

Note: When operating in either closed loop mode, power output is no longer a curve of laser output versus PWM duty cycle but instead, laser power output becomes a linear function of the desired setpoint percentage.

For the closed loop kit, servo settling time to 90% of final value occurs within approximately 2 ms. Output power regulation is typically ±2%, even when the beam "line hops" between 10.57 and 10.63 µm.

Closed loop specifications

Table A-1 Closed loop general specifications

Parameter	Specification
Optical Transmission	92%, ±1%
Power Input, optical	150 W maximum
Power Input, electrical	12 VDC @ 3 mA (provided by UC-2000)
Power Stability, five minutes after cold start	±2%
Control Range	20%–80% of rated output power
Control Frequency[1]	5 kHz
Servo Settling Time, typical	2 ms

* Specifications subject to change without notice.

1 The Closed Loop Stabilization Kit is calibrated for operation at a PWM Command frequency of 5 kHz.

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