firestar series ti

ti-Series operator's manual

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firestar series ti

Firestar® ti-Series Operator's Manual

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ti80 version C
ti100 version B

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Trademark/copyright information

SYNRAD, Firestar, and Power Wizard are registered trademarks of SYNRAD, Inc.

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

Warranty information

This is to certify that Firestar® ti-Series lasers are guaranteed by SYNRAD, Inc. to be free of all defects in materials and workmanship for a period of two years 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.

We request that you examine each shipment within 10 days of receipt and inform SYNRAD, Inc. of any shortage or damage. If no discrepancies are reported, SYNRAD shall assume the shipment was delivered complete and defect-free.

If, within two years from the date of purchase, any part of the Firestar ti-Series 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 Firestar ti-Series 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 Firestar ti-Series 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.

Contact information

Worldwide headquarters

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

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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

For assistance in Europe, contact SYNRAD's European subsidiary, Synrad Europe, at:

Synrad Europe
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D-82152 Planegg, Germany

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Fax:	+49 (0) 89 31 707-222
E-mail:	info@synrad-europe.com

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 4 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.

Important Note: Important information or recommendations concerning the subject under discussion.

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 4 laser product emits ***invisible*** infrared laser radiation in the 9.3–10.6 µm CO_2 wavelength band depending on model.

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 9.3–10.6 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.

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

laser safety

Hazard information

⚠ Warning
serious personal injury

For laser systems being used or sold within the U.S.A., customers should refer to and follow the laser safety precautions described in the American National Standards Institute (ANSI) document, Z136.1-2007, *Safe Use of Lasers*.

For laser systems being used or sold outside the U.S.A., customers should refer to and follow the laser safety precautions described in European Normative and International Electrotechnical Commission documents EN 60825-1:2007, – *Safety of Laser Products – Part 1: Equipment Classification and Requirements* and IEC/TR 60825-14:2004, *Safety of Laser Products – Part 14: A User's Guide*.

⚠ 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 Z136.1-2007, *Safe Use of Lasers*, section 7.3.

U.S. 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.

⚠ Warning
serious personal injury

The use of aerosol dusters containing difluoroethane causes "blooming", a condition that ***significantly*** expands and scatters the laser beam. This beam expansion can effect mode quality and/or cause laser energy to extend beyond the confines of optical elements in the system, possibly damaging acrylic safety shielding. Do not use air dusters containing difluoroethane in any area adjacent to CO_2 laser systems because difluoroethane persists for long time periods over wide areas.

laser safety

Hazard information

Firestar® ti-Series 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. To prevent exposure to direct or scattered laser radiation, follow all safety precautions specified throughout this manual and exercise safe operating practices per ANSI Z136.1-2007 or IEC/TR 60825-14:2004 at all times when actively lasing.

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

This product contains components that are considered hazardous industrial waste. If a situation occurs where the laser is rendered non-functional and cannot be repaired, it may be returned to SYNRAD, Inc. who, for a fee, 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.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

Firestar ti60 label locations

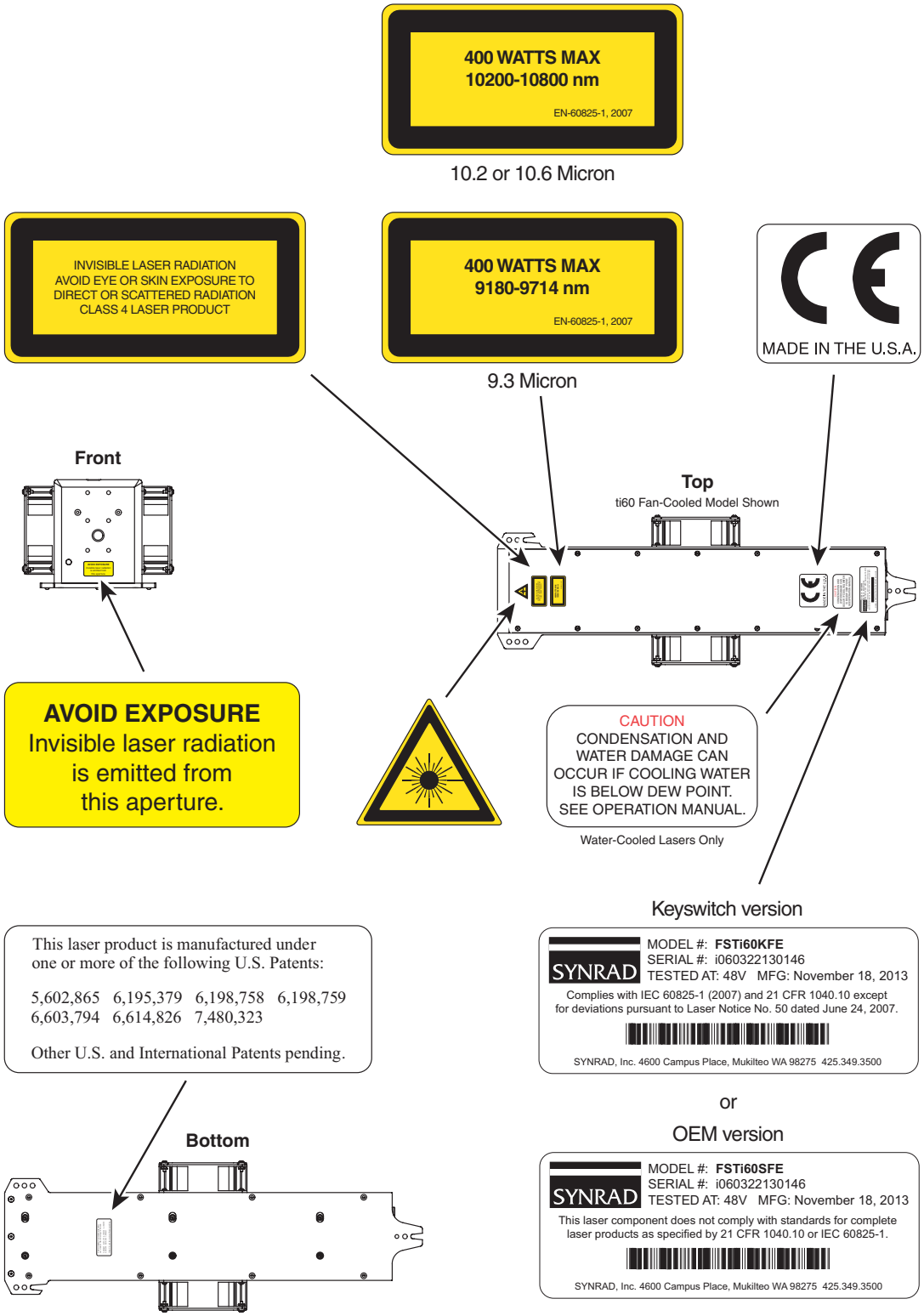


Figure 1 Firestar ti60 hazard label and CE label locations

laser safety

Firestar ti80 label locations

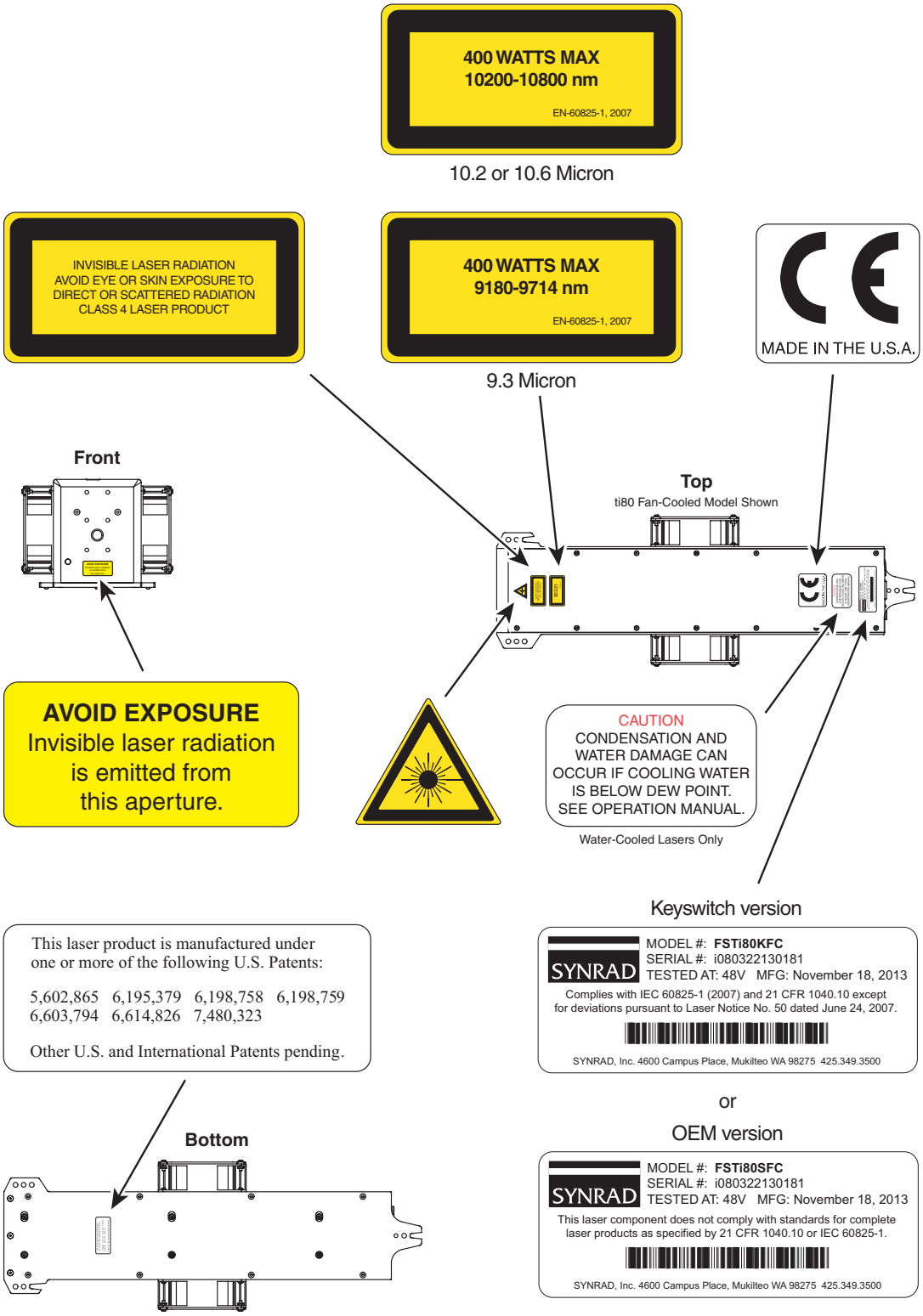


Figure 2 Firestar ti80 hazard label and CE label locations

laser safety

Firestar ti100 label locations

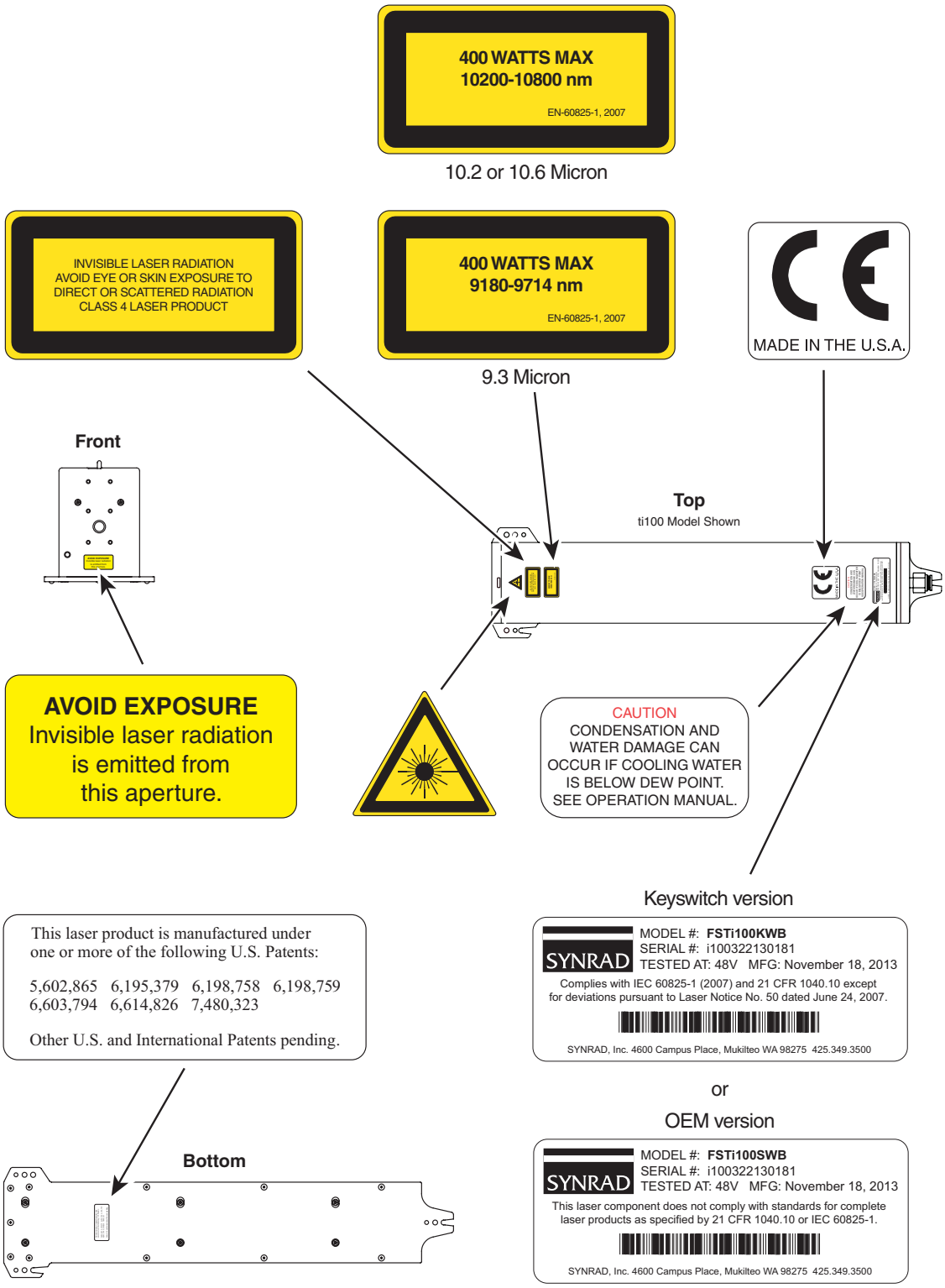


Figure 3 Firestar ti100 hazard label and CE label locations

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 Firestar ti-Series 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

Note: Firestar ti-Series lasers are available in either Keyswitch or OEM versions.

Keyswitch models

Firestar ti-Series Keyswitch model lasers comply with requirements for Class 4 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 Firestar ti-Series 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), laser ready indicator, 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 4 safety features*, indicates which features are available on ti-Series lasers, the type and description of the feature, and if the feature is required by CDRH regulations.

laser safety

Agency compliance

OEM models

Firestar ti-Series 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. Table 1, *Class 4 safety features*, indicates which features are available on ti-Series lasers, the type and description of the feature, and if the feature is required by CDRH regulations.

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 Firestar ti-Series lasers have been tested and found to comply by demonstrating performance characteristics that have met or exceeded the requirements of 47 CFR, Part 18, Conducted and Radiated 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 Firestar ti-Series lasers.

System Maintenance

Ensure that all exterior covers are properly fastened in position.

Measures to Correct Interference

If you suspect that your Firestar 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 Firestar laser is properly grounded to the same electrical potential as the equipment or system it is connected to.

laser safety

Agency compliance

FCC caution to the user

The FCC 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

Note: Firestar ti-Series lasers are available in either Keyswitch or OEM versions.

RoHS compliance

SYNRAD Firestar ti-Series lasers meet the requirements of the European Parliament and Council Directive 2011/65/EU on the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment that establishes maximum concentration values for certain hazardous substances in electrical and electronic equipment.

Laser safety standards

Under the Low Voltage Directive, 2006/95/EC, the European Norm (EN) document EN 60825-1:2007 was developed to provide laser safety guidance and includes clauses on Engineering Specifications, Labeling, Other Informational Requirements, Additional Requirements for Specific Laser Products, Classification, and Determination of the Accessible Emission Level. To develop a risk assessment plan/laser safety program for users, see IEC/TR 60825-14:2004 that includes clauses on Administrative Policies, Laser Radiation Hazards, Determining the MPE, Associated Hazards, Evaluating Risk, Control Measures, Maintenance of Safe Operation, Incident Reporting and Accident Investigation, and Medical Surveillance.

Keyswitch models

Firestar ti-Series Keyswitch models are designed to comply with the requirements imposed by EN 60825-1 for Class 4 laser products. Table 1, *Class 4 safety features*, summarizes ti-Series product features, indicating the type and description of features and whether those features are required by European Union regulations.

OEM models

Firestar ti-Series 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 60825-1; EN 60204-1, *Safety of Machinery*; the Machinery Directive EN 2006/42/EC; and/or any other applicable Standards and in cases where the system is being imported into the U.S., it must also comply with CDRH regulations.

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. Table 1, *Class 4 safety features*, indicates which features are available on ti-Series lasers, the type and description of the feature, and if the feature is required by European Union regulations.

laser safety

Agency compliance

Table 1 Class 4 safety features

Feature	Location/Description	Required by: CDRH	Required by: EN60825-1	Available on: ti-Series
Keyswitch	Rear panel control On/Off/Reset Keyswitch controls power to laser electronics. Key can not be removed from switch in the "On" position.	Yes	Yes	Yes[1]
Shutter function	Laser control Functions as a beam attenuator to disable RF driver/laser output when closed.	Yes	Yes	Yes[1]
Shutter (SHT) indicator	Rear panel indicator (Blue) Illuminates blue to indicate shutter is open.	No	No	Yes
Ready (RDY) indicator	Rear panel indicator (Yellow) Indicates that laser has power applied and is capable of lasing.	Yes	Yes	Yes
Lase (LASE) indicator	Rear panel indicator (Red) Indicates the laser is actively lasing. Lase LED illuminates when the duty cycle of the Command signal is long enough to produce laser output.	No	No	Yes
Five second delay[2]	Firestar circuit element Disables RF driver/laser output for five seconds after Keyswitch is turned to "On" or remote reset/start pulse is applied when Keyswitch is in "On" position.	Yes	No	Yes[1]
Power fail lockout	Firestar circuit element Disables RF driver/laser output if input power is removed then later reapplied (AC power failure or remote interlock actuation) while Keyswitch is in "On" position.	Yes	Yes	Yes[1]
Remote Interlock	Rear panel connection Disables RF driver/laser output when a remote interlock switch on an equipment door or panel is opened.	Yes	Yes	Yes
Remote Interlock (INT) indicator	Rear panel indicator (Green/Red) Illuminates green when Remote Interlock circuitry is closed. Illuminates red when interlock circuitry is open.	No	No	Yes
Over temperature protection	Firestar circuit element Temperature shutdown occurs if temperature of the laser tube rises above safe operating limits.	No	No	Yes
Temp (TMP) indicator	Rear panel indicator (Green/Red) Illuminates green when laser temperature is within operating limits, changing to red when thermal limits are exceeded.	No	No	Yes
Warning labels	Firestar exterior Labels attached to various external housing locations to warn personnel of potential laser hazards.	Yes	Yes	Yes

1 Keyswitch versions only

2 Five-second delay disabled on all OEM (Sxx) lasers beginning August 2011.

laser safety

Agency compliance

Electromagnetic interference standards

The European Union's Electromagnetic Compatibility (EMC) Directive, 2004/108/EC, 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 Firestar ti-Series lasers, EN 61000-6-4 defines radiated and conducted RF emission limits while EN 61000-6-2 defines immunity requirements for industrial environments.

SYNRAD's Firestar ti-Series lasers have been tested and found to comply by demonstrating performance characteristics that have met or exceeded the requirements of EMC Directive 2004/108/EC.

When integrating SYNRAD's Firestar ti-Series 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 Firestar ti-Series lasers comply with the relevant requirements of 2004/108/EC, the Electromagnetic Compatibility Directive, as summarized in Table 2 below.

Table 2 European Union Directives

Applicable Standards / Norms	
2004/108/EC	Electromagnetic Compatibility Directive
2006/95/EC	Low Voltage Directive
2011/65/EU	RoHS Directive
EN 60825-1:2007	Safety of Laser Products (Keyswitch models only)
EN 61010-1:2001	Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use - Part 1 : General Requirements
EN 61000-6-4:2007	Radiated Emissions, Group 1, Class A
EN 61000-6-4:2007	Conducted Emissions, Group 1, Class A
EN 61000-6-2:2005	Electrostatic Discharge Immunity
EN 61000-6-2:2005	RF Electromagnetic Field Immunity
EN 61000-6-2:2005	Electrical Fast Transient/Burst Immunity
EN 61000-6-2:2005	Conducted RF Disturbances Immunity

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.

Figure 4 European compliance mark

laser safety

Declaration of Conformity

Declaration of Conformity

in accordance with ISO/IEC 17050-2:2004

We,

Manufacturer's Name: SYNRAD, Inc.

Manufacturer's Address: 4600 Campus Place
Mukilteo, WA 98275
U.S.A.

hereby declare under our sole responsibility that the following equipment:

Product Name: Firestar ti-Series Laser

Model Number: FSTi60KxD; FSTi80KxB; FSTi100KWB (Keyswitch)
FSTi60SxD; FSTi80SxB; FSTi100SWB (OEM*)

conforms to the following Directive(s) and Standard(s):

Applicable Directive(s):	2004/108/EC	Electromagnetic Compatibility Directive
	2006/95/EC	Low Voltage Directive
	2011/65/EU	RoHS Directive
Applicable Standard(s):	EN 61010-1:2001	Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use - Part 1: General Requirements
	EN 60825-1:2007	Safety of Laser Products (Keyswitch only)
	EN 61000-6-4:2007	Radiated Emissions, Group 1, Class A
	EN 61000-6-4:2007	Conducted Emissions, Group 1, Class A
	EN 61000-6-2:2005	Electrostatic Discharge Immunity
	EN 61000-6-2:2005	RF Electromagnetic Fields Immunity
	EN 61000-6-2:2005	Electrical Fast Transient/Burst Immunity
	EN 61000-6-2:2005	Conducted RF Disturbances Immunity

*OEM lasers do not comply with EN 60825-1:2007, *Safety of Laser Products*. Buyers of OEM laser products are solely responsible for meeting applicable Directives and Standards for CE compliance and marking.

Corporate Officer:

Dave Clarke, President of SYNRAD, Inc.

Dated 25 July 2012

European Contact:

Synrad Europe
Münchener Straße 2A
D-82152 Planegg
Germany

CE

MADE IN U.S.A.

1 getting started

Use information in this chapter to prepare your Firestar ti-Series laser for operation. The order of information presented in this chapter is the same as the order of tasks that you will 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 chapter contains the following information:

- Introduction – introduces the Firestar ti-Series laser, lists important features, and describes Firestar nomenclature.
- Unpacking – provides important information about shipping your ti-Series laser.
- Inventory – displays and describes all components shipped with your laser.
- Mounting – describes how to attach the ti-Series laser 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

The *Introduction* section includes subsections:

- ti-Series features
- Firestar nomenclature
- Model numbers

ti-Series features

Firestar® ti-Series lasers are part of a new series of small-footprint lasers from SYNRAD featuring high power and excellent beam quality. The circular beam provides more accurate cutting and faster processing speeds than competing technologies. With an integrated RF power supply, meaning no external RF supply or cables, our compact ti-Series lasers mount easily to flatbed cutters, robotic arms, or gantry systems making integration into your production line simple and fast. Firestar ti-Series features include:

- Fully integrated RF power supply
- Excellent pulsing characteristics
- Fast rise/fall times (< 75 µs)
- Operates at frequencies from DC–160 kHz
- Built-in "tickle" generator
- Color-coded status LEDs mirror user outputs
- "Industrial-strength" ±5–24 VDC inputs and outputs
- 9.3 µm, 10.2 µm, and 10.6 µm wavelengths available
- Keyswitch or OEM models available

Firestar nomenclature

Firestar ti-Series 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 larger processing systems by the Original Equipment Manufacturer (OEM) or System Integrator who bears the responsibility for meeting the appropriate laser safety requirements for Class 4 laser systems.

Model numbers

The last three characters in the Firestar model number serve to designate the functional category, cooling method, and model version. The functional category is indicated by either a "K" for Keyswitch or "S" (Switch-less) for OEM models. The next letter indicates the cooling method: "W" for water-cooled units, "F" for fan-cooled units, and "A" for air-cooled lasers (where the customer must provide the proper cooling via fans or blowers). The last letter in the model number indicates the current model version beginning with "B". For example, the model number FSTi100KWB designates that particular Firestar ti100 laser as a Keyswitch, water-cooled model. FSTi60SAE indicates an OEM, air-cooled ti60 laser.

getting started

Unpacking

The *Unpacking* section includes subsections:

- Incoming inspection
- Packaging guidelines

Incoming inspection

Upon arrival, 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, Inc.

The shipping carrier is responsible for any damage occurring during transportation from SYNRAD, Inc. to your receiving dock.

Packaging guidelines

- To prevent equipment damage or loss of small components, use care when removing packaging materials.
- After unpacking, review the *Inventory* section and verify that all components are on hand.
- Do not lift or support the laser using the cooling fittings; lift the laser by the mounting feet or baseplate only.
- Save all shipping containers and packaging materials, including covers and plugs. Use these specialized packing materials when shipping the laser to another location.
- 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.
- Refer to *Firestar ti-Series packaging instructions* drawings in the Technical Reference chapter for details on packaging the laser using SYNRAD-supplied shipping materials.
- When shipping water-cooled lasers, remember to drain all cooling water from the laser and then cap open fittings to prevent debris from entering the coolant path.

getting started

Inventory

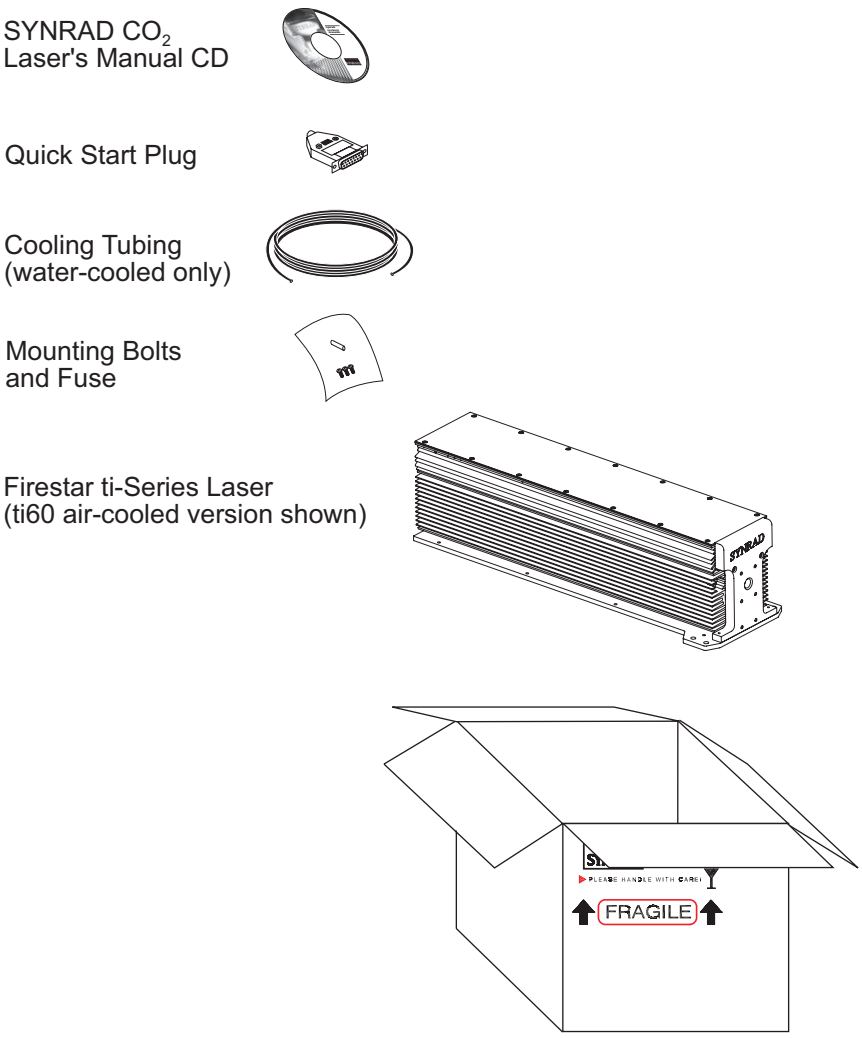


Figure 1-1 Firestar ti-Series shipping box contents

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

Table 1-1 Ship kit contents

Shipping Box Contents	Qty	Shipping Box Contents	Qty
SYNRAD Firestar ti-Series Laser	1	Cooling Kit (water-cooled only)	1
SYNRAD CO_2 Lasers Manual CD	1	Mounting Bolts	3
Quick Start Plug (except SA models)	1	Spare Fuse	2
Cooling Tubing (water-cooled only)	1	Final Test Report (not shown)	1

Inventory

Contents description

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

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

SYNRAD CO_2 Lasers Manual CD – contains a Firestar ti-Series manual that provides setup, operation, and maintenance information for your ti-Series laser.

Quick Start Plug (except SA models) – connects to Firestar's *User I/O* connector. Jumpers are built into the plug to enable Firestar's shutter and remote interlock circuits for initial start-up and testing.

Cooling Tubing (water-cooled only) – carries cooling water from the chiller to the laser and back. This black polyethylene tubing is 1/2-inch O.D. by 30 feet and must be cut to length.

Cooling Kit (water-cooled only) – adapts the laser's straight 1/2-inch coolant fittings to 90° adaptor fittings for either 1/2-inch standard or 12-mm metric cooling tubing.

Mounting Bolts – Three each 1/4–20 × 5/8" UNC capscrews are provided for fastening the Firestar ti-Series laser to your mounting surface.

Spare Fuse – fast-acting mini ATO-type fuse protects Firestar's internal circuitry.

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

getting started

Mounting

The *Mounting* section includes subsections:

- Fasten from above
- Fasten from below

Firestar's base plate is designed so that the laser is easily mounted to either vertical or horizontal surfaces using only three fasteners. Three ball bearing "feet" pressed into Firestar's base plate eliminate any possible distortion of the laser tube caused by variations in the flatness of the surface on which the laser is mounted. Refer to the Firestar ti-Series package outline drawings in the Technical Reference chapter for laser mounting locations and dimensions. Read through the mounting sections below to determine which set of mounting holes are required for your application. When mounting Firestar ti-Series lasers, you can choose to fasten from above, into your mounting surface, or from below, into the laser's base plate.

Note: For proper airflow, air- or fan-cooled units must have at least 57.2 mm (2.25") of unobstructed clearance between the outside edge of the cooling fan and any enclosure or mounting surface.

Caution
possible equipment damage

SYNRAD does not recommend mounting lasers in a vertical "head-down" or "tail-down" orientation. If you must mount your laser in this manner, please contact the factory for limitations as a vertical orientation increases the risk of damage to the laser's output optic.

Fasten from above (ISO/UNC fasteners)

To fasten your Firestar ti-Series laser to a mounting surface from above, perform the following steps:

1 Refer to the appropriate outline and mounting drawing for dimensions and then drill and tap three M6 × 1 ISO or 1/4–20 UNC holes into your mounting surface. These hole locations should correspond to the two slots labeled "A" and the thru hole labeled "B" shown in Figure 1-2.

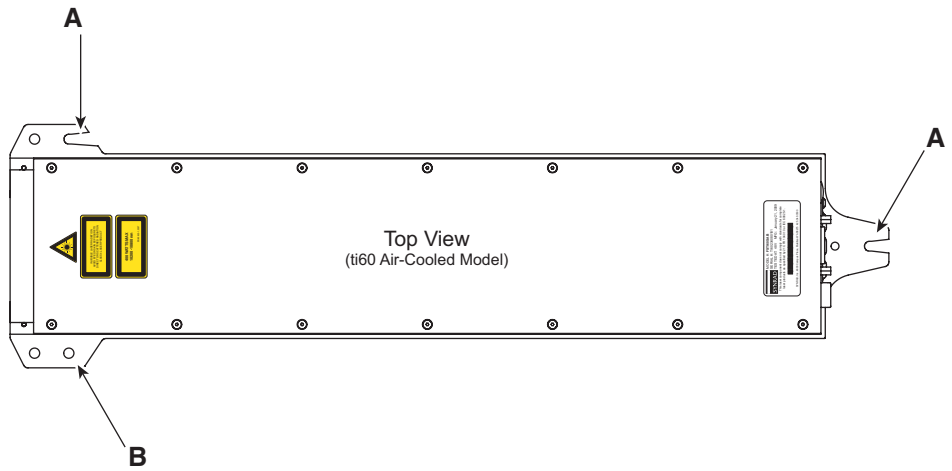


Figure 1-2 Fasten from above

2 Place Firestar on the mounting surface so that slots “A” and hole “B” on the base plate line up with the tapped holes in the mounting surface.

3 Insert M6 × 1 × 16 mm or 1/4–20 × 5/8" UNC capscrews through Firestar’s base plate into the threaded holes of the mounting surface. Turn the screws by hand until the threads engage.

4 Evenly tighten all three capscrews to a maximum torque of 6.1 N m (54 in lb).

Fasten from below (UNC fasteners only)

To fasten your Firestar ti-Series laser to a mounting surface from below, perform the following steps:

1 Refer to the appropriate outline and mounting drawing for dimensions and then drill three 0.261" diameter holes into your mounting surface. Hole locations should correspond to the 1/4–20 UNC threaded holes labeled “C” shown in Figure 1-3.

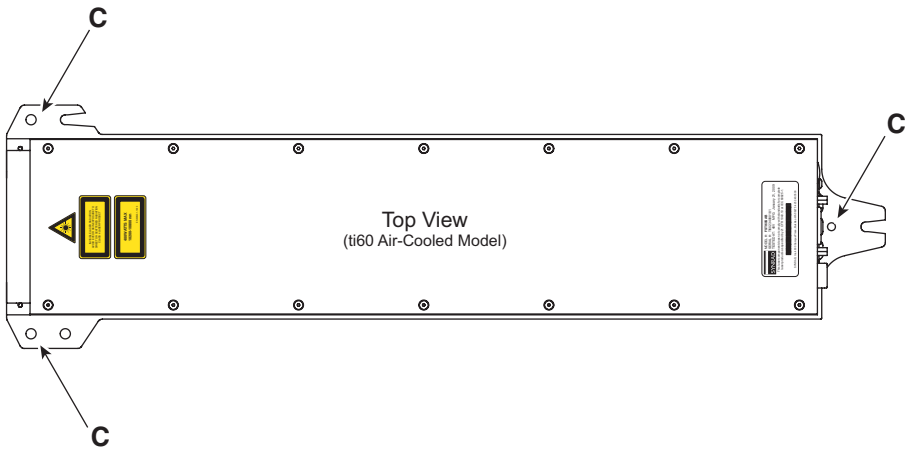


Figure 1-3 Fasten from below

2 Place Firestar on the mounting surface so that the threaded holes on the base plate (labeled “C” in Figure 1-3) line up with the 0.261" holes drilled through the mounting surface.

3 Insert 1/4–20 × 5/8" UNC capscrews (included in ship kit) through the mounting surface into the threaded holes of Firestar’s base plate. Turn the screws by hand until the threads engage.

4 Evenly tighten all three capscrews to a maximum torque of 6.1 N m (54 in lb).

getting started

Connecting

The *Connecting* section includes subsections:

- Water-cooled connections
- OEM air-cooled connections
- Electrical connections
- Control connections

Note: If your laser is fan-cooled, then skip to the *Electrical connections* section. For air-cooled lasers, go to the *OEM air-cooled connections* section.

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.

Laser cooling fitting adaptors

If your integrated laser application uses metric cooling tubing, you should install tubing adaptors to convert the laser's *WATER IN* and *WATER OUT* fittings from 1/2-inch tubing to 12-mm metric tubing. The ship kit sent with ti-Series lasers includes a Cooling Kit containing two each 1/2-inch male to 12-mm female 90° adaptors and two each 1/2-inch male to 1/2-inch female 90° adaptors. If required for your application, many tubing and fitting manufacturers can supply 1/2-inch to 12-mm straight fittings.

Caution possible equipment damage	Do not overtighten the WATER IN/WATER OUT cooling fittings. Overtightening the cooling fittings may crack the cooling manifold, causing coolant leakage, or partially block the cooling channel, leading to reduced coolant flow and premature laser failure. If you must install new fittings, wrap the threads with teflon tape and carefully tighten the fittings, making sure **the maximum insertion depth is no more than 6.6 mm (0.26") into the cooling manifold**.

Guidelines for cutting and installing tubing

- Cut tubing squarely; diagonal cuts may not seal properly. Carefully trim any burrs if the cut is "ragged".
- Avoid excessive stress on fittings; create gentle bends when routing tubing close to connectors. Excessive stress from sharp bends 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.
- 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 12.7 mm (1/2") from its end before reconnecting. Trimming the end of the tubing before reconnecting the fitting provides an undisturbed sealing surface.

Chiller preparation guidelines

- You must provide fittings to adapt the laser's 1/2-inch O.D. polyethylene cooling tubing to your chiller's Inlet and Outlet ports. These fittings can be "quick disconnect" or compression type fittings.
- Because Firestar's cooling tubing is specified in inch sizes, do not use metric tubing fittings 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 the pressurized tubing to blow-off the fitting.

Coolants

SYNRAD recommends that the laser's cooling fluid contain at least 90% distilled water by volume. In closed-loop systems, use a corrosion inhibitor/algaecide such as Optishield® Plus or equivalent as required. 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. If tap water is used, chloride levels should not exceed a concentration of 25 parts per million (PPM) and total hardness should be below 100 PPM. Install a filter on the chiller's return line and inspect frequently. Firestar ti-Series lasers incorporate the following wetted materials in the coolant path—nickel-plated brass, copper, acetal, PBT, polyethylene, stainless steel, and Viton®.

Note: DO NOT use de-ionized (DI) water as a coolant. DI water is unusually corrosive and is not recommended for mixed material cooling systems.

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 the laser is 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.

- Air-condition the room or the enclosure containing the laser.
- Install a dehumidifier to reduce the humidity of the enclosure containing the laser.
- Stop coolant flow when the laser is shut down.
- Increase coolant flow by an additional 3.8 lpm (1.0 GPM). Do not exceed a coolant pressure of 414 kPa (60 PSI).
- Refer to Table 1-2 and gradually increase coolant temperature until it is above the dew point temperature and condensation disappears. Do not exceed a coolant temperature of 30 °C (86 °F).

Note: Water-cooled ti-Series lasers can be operated at coolant temperatures up to 30 °C to reduce condensation; however, this may result in decreased laser performance and/or reduced laser lifetime.

Connecting

Table 1-2 provides dew point temperatures for a range of air temperature and relative humidity values. The laser's coolant temperature must be set ***above*** the dew point temperatures shown in the chart; ***however, for best results and performance, use a coolant temperature in the range of 18–22 °C (64–72 °F)***.

Table 1-2 Dew point temperatures

Dew Point Temperature Chart °F (°C)

	Relative Humidity (%)															
	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
Air Temp °F (°C)																
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.

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.

Cooling tubing connections

To connect cooling tubing to your ti-Series laser, refer to Figure 1-4 and perform the following steps.

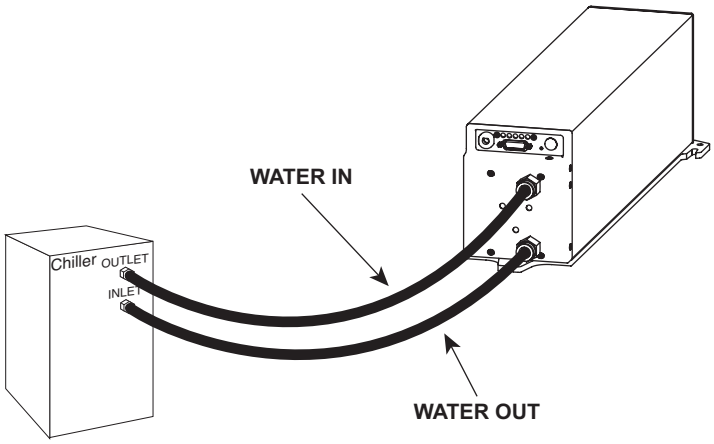


Figure 1-4 Firestar ti-Series cooling connections

1 Locate the 1/2-inch O.D. polyethylene cooling tubing in the ship kit.

Note: If your system uses metric cooling tubing, locate the two 1/2-inch male to 12-mm female 90° adaptors in the cooling kit and install them into the laser's *WATER IN* and *WATER OUT* ports.

2 Cut and connect a length of tubing to fit between the chiller's Outlet port and the upper *WATER IN* port on the rear of the Firestar ti-Series laser.

3 Cut and connect a length of tubing to fit between the lower *WATER OUT* port on the rear of the laser and the chiller's Inlet port.

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

4 Turn on the chiller and adjust the temperature setpoint to 18 °C to 22 °C. Regulate coolant flow between 3.8–7.6 lpm (1.0–2.0 GPM) at less than 414 kPa (60 PSI) of pressure.

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

getting started

Connecting

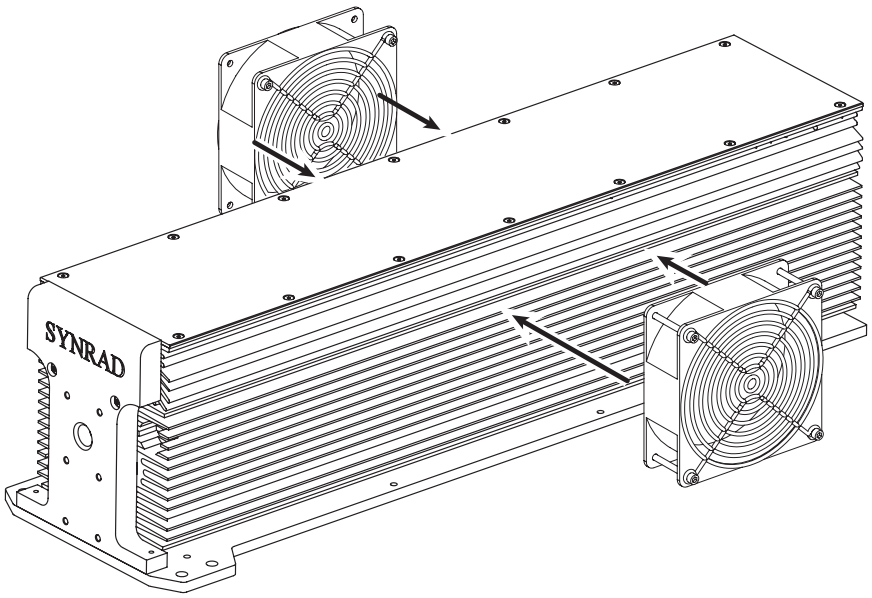
OEM air-cooled connections (SA models)

OEM air-cooled lasers are shipped without cooling fans so customers must provide some type of air cooling to prevent the laser from overheating.

For ti60 lasers, SYNRAD recommends using two cooling fans (as seen in Figure 1-5) with a rating of at least 4.0 m^3/min (140 CFM) at a static air pressure of 9.1 mm H_2O (0.36 in H_2O).

For ti80 lasers, you must provide two cooling fans (Figure 1-5) with a rating of at least 5.4 m^3/min (190 CFM) at a static air pressure of 17.8 mm H_2O (0.70 in H_2O).

Figure 1-5 shows the fan placement necessary to keep the ti60/ti80 heat sink temperatures below 50 °C (122 °F). To provide proper airflow, cooling fans should have a diameter of approximately 114–127 mm (4.5–5 inches) and have at least 57.2 mm (2.25") of unobstructed clearance between the outside edge of the fan housing and any mounting surface or enclosure.



Mount cooling fans so they are centered horizontally and vertically on each side of OEM ti60/ti80 lasers

Figure 1-5 Recommended ti60/ti80 cooling fan locations

A +48 VDC output to power customer-supplied cooling fans is available from the SA model's side-mounted DB-9 connector. Internal circuitry allows the laser to control fan speed based on the laser's output power and chassis temperature. Refer to *DB-9 connections* in the Technical Reference chapter for details.

Electrical connections

The following procedures describe how to complete electrical connections to ti-Series lasers. Firestar ti-Series DC power cables are manufactured from #10 AWG wire and measure 1 meter (42 inches) in length.

DC power supply

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.

Caution
possible equipment damage

Do not reverse polarity when connecting DC power cables to your DC power source. Reversed DC polarity will damage the ti-Series's internal RF and control board circuitry. Carefully follow the directions below to ensure that DC cable leads are properly connected to the correct DC output terminals.

The Firestar ti60 laser requires a DC power supply capable of providing 48 VDC at 18 A minimum. The ti80 requires 48 VDC at 22 A and the ti100 requires 48 VDC at 35 A minimum.

For ti-Series lasers, we recommend the SYNRAD PS-48 DC power supply, which can provide a maximum of 50 A at 48 VDC. AC input requirements for the PS-48 supply are 180–264 VAC, single-phase (1Ø), 9.4 A max (@ 208 VAC), 47–63 Hz.

To connect the PS-48 supply, refer to Figure 1-6 and perform the following steps:

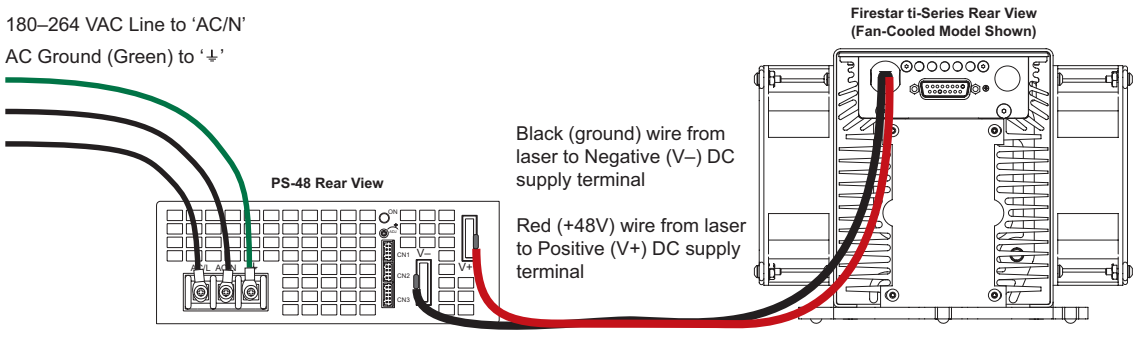


Figure 1-6 PS-48 DC power supply

1. Verify that input AC power to the DC power supply is physically locked out or disconnected.
2. Locate the 48 VDC output terminals on the PS-48 power supply's output section and connect the black (–) DC power cable from the laser to the Negative (V–) output terminal.
3. Connect the red (+) DC power cable from the laser to the Positive (V+) 48 VDC output terminal.

getting started

Connecting

Note: Because AC input connections and requirements vary from facility to facility, customers must provide the AC power cable or wiring.

4 Connect one side of the 180–264V AC line to the input terminal labeled "AC/L".

5 Connect the other side of the AC line to the input terminal labeled "AC/N".

6 On the AC input section of the PS-48 power supply, connect the ground wire, typically green, to the input terminal labeled with the ground symbol.

Control connections

All control connections to Firestar ti-Series lasers are made through the 15-pin *User I/O* connector on the laser's rear panel. The *User I/O* port receives power commands from SYNRAD's UC-2000 Universal Laser Controller, or FH Flyer marking head, and also serves as the connection point for auxiliary signals between the laser and any parts handling, automation, or monitoring equipment.

Caution
possible equipment damage

Turn off DC power before installing or removing any plug or cable from the *User I/O* connector. Ensure that user connections are made to the appropriate pins and that the appropriate signal levels are applied. Failure to do so may damage the laser.

Quick Start Plug

Note: The *Quick Start Plug* is not included with SA models, but may be ordered separately.

⚠ Warning
serious personal injury

The use of the *Quick Start Plug* bypasses the laser's safety interlock function, potentially exposing personnel in the area to ***invisible*** infrared laser radiation.

Because this plug jumpers Remote Interlock and Shutter Open Request signals, the laser will fire immediately on application of a PWM Command signal. Your integrated control system should provide interlock and shutter signals directly to the DB-15 *User I/O* connector only after safe operating conditions are established.

The *Quick Start Plug* is intended only for initial testing and trouble-shooting by qualified personnel. In normal operation, the laser's Remote Interlock input should be connected to the machine's safety interlock circuitry.

Connecting

In order for your Firestar ti-Series laser to properly operate, several input signals must be applied to the DB-15 *User I/O* connector before lasing is enabled. Voltage must be applied to Remote Interlock (Pin 3) and Shutter Open Request (Pin 10) inputs before the laser will fire. In applications where Firestar is integrated into an automated system and safety interlocks are required, these input signals must be provided by the customer's control system. The *Quick Start Plug* included in the ship kit has factory-installed shorting jumpers wired into it to enable these inputs. Connect the *Quick Start Plug* to the *User I/O* connector when performing initial start-up and testing of your Firestar laser.

For further information about the *User I/O* connector, see *User I/O connections* in the Technical Reference chapter for *User I/O* pinouts and signal descriptions. See *Integrating Firestar safety features*, also in the Technical Reference chapter, for detailed instructions on integrating Firestar's keyswitch, shutter, and remote interlock functions with automated control systems. Figure 3-7, *Quick Start Plug wiring diagram*, in the Technical Reference chapter shows the *Quick Start Plug* wiring diagram.

UC-2000 Universal Laser Controller

⚠ **Warning** serious personal injury	Always use shielded cable when connecting your PWM Command signal source to PWM Input/PWM Return inputs. In electrically-noisy environments, long lengths of unshielded wire act like an antenna and may generate enough voltage to trigger uncommanded lasing.

SYNRAD recommends using a UC-2000 Universal Laser Controller to generate pulse width modulated (PWM) Command signals to control the laser's output power. To connect a UC-2000 Controller (available separately from SYNRAD), perform the following steps:

1. Remove DC power from the laser.
2. Locate the *Quick Start Plug* in the ship kit.

Note: The *Quick Start Plug* is not included with SA models, but may be ordered separately.

3. Connect the *Quick Start Plug* to the *User I/O* connector on the rear of the laser.
4. Attach the BNC connector on the end of the UC-2000's *Power/Control* cable to the BNC connector on the rear of the *Quick Start Plug*.
5. Connect the miniature DC power plug on the UC-2000's *Power/Control* cable to the miniature connector on the wall plug transformer cable.
6. Connect the mini-DIN connector on the other end of the UC-2000's *Power/Control* cable to the *Laser* connector on the UC-2000's rear panel.
7. Plug the compact transformer into any 100–240 VAC, 50–60 Hz outlet.

Note: Firestar ti-Series lasers can also be controlled from an alternate user-supplied Command signal source. Refer to *Controlling laser power* in the Technical Reference chapter for control signal descriptions and refer to *User I/O connections*, also in the Technical Reference chapter, for signal specifications and connection details.

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operation 2

Use information in this chapter to familiarize yourself with Firestar's controls and indicators and to begin operating the laser.

This chapter contains the following information:

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

operation

Controls and indicators

The *Controls and indicators* section includes subsections:

- ti-Series front panel
- ti-Series rear panel
- OEM ti-Series side panel (SA models)

ti-Series front panel

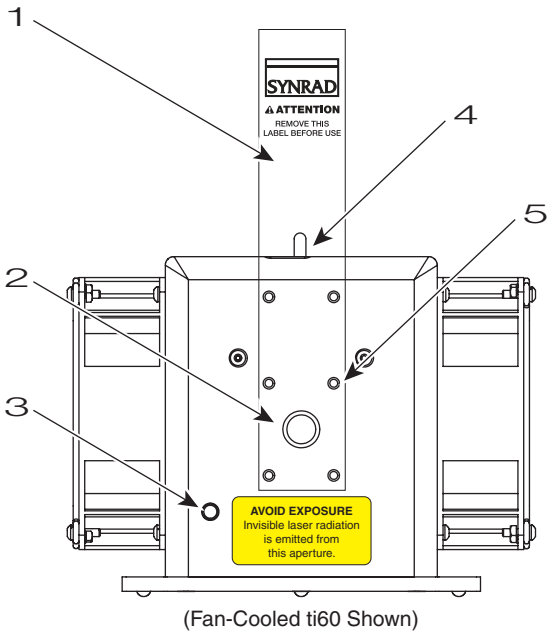


Figure 2-1 ti-Series front panel controls and indicators

1 Aperture Seal – prevents dust from damaging the output coupler during shipping. Remove the red self-adhesive label before applying power to the laser.

2 Laser Aperture – provides an opening in Firestar's faceplate from which the beam exits.

3 *DP POWER* Connector (except SA models) – provides a convenient +5 VDC, 50 mA receptacle to power a visible red diode pointer (available from SYNRAD as an optional accessory).

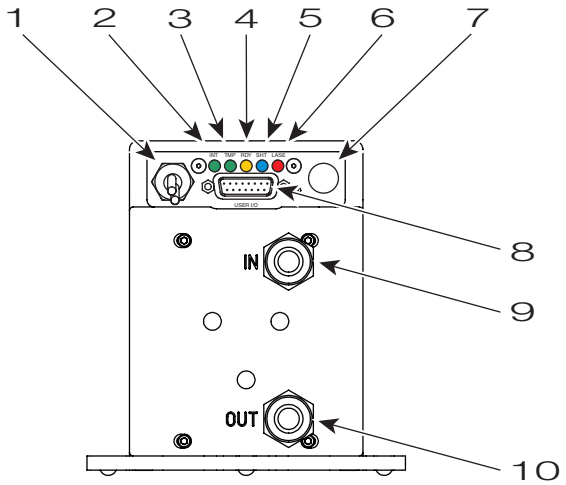
4 *Shutter Switch* (Keyswitch models only) – activates a mechanical shutter that opens or closes the laser aperture. Closing the shutter also interrupts RF power to the laser. There is a five-second delay imposed from the time the shutter is opened to the time that PWM signals are accepted.

5 Optical Accessories Mounting – provides six threaded holes (8–32 UNC) for mounting optional beam delivery components Because excessive weight may damage the laser, consult SYNRAD before mounting components not specifically designed as Firestar options. Refer to *Firestar ti-Series package outline drawings* in the Technical Reference chapter for mounting hole dimensions.

Note: When mounting optical components to ti-Series lasers, the 8–32 UNC fasteners must extend no further than 4.8 mm (0.19") into the laser's faceplate.

Controls and indicators

ti-Series rear panel



(Water-Cooled ti100 Shown)

Figure 2-2 ti-Series rear panel controls and indicators

1 DC Power Cables – receives +48 VDC from the DC power supply. Firestar ti-Series DC power cables are manufactured from #10 AWG wire and measure 1 meter (42 inches) in length.

2 *INT* (Remote Interlock) Indicator – illuminates green to indicate that a remote interlock circuit is closed and that lasing may be enabled (on *Keyswitch* lasers, a five-second delay occurs when the interlock circuit closes). The *INT* indicator is red and lasing is disabled if the interlock input is open.

3 *TMP* (Temperature) Indicator – illuminates green to indicate that laser temperature is within limits and that lasing may be enabled. The *TMP* indicator is red and lasing is disabled if the laser's temperature rises above safe operating limits.

4 *RDY* (Ready) Indicator – illuminates yellow when the laser is enabled, indicating that, after a five-second delay, lasing will begin when a PWM Command signal is applied.

5 *SHT* (Shutter) Indicator – illuminates blue to indicate that a Shutter Open Request signal is connected to the *User I/O* port and lasing may be enabled. On *Keyswitch* lasers, a five-second delay occurs when a Shutter Open Request signal is applied.

6 *LASE* Indicator – illuminates red to indicate that the laser is actively lasing. The *LASE* indicator is off when tickle pulses are being generated and illuminates red when PWM Command signal pulses are long enough to produce laser output.

7 *Keyswitch* (Keyswitch models only) – enables/disables operation of the laser. Firestar is enabled when the *Keyswitch* is turned to the ON position. Turn the *Keyswitch* OFF to disable lasing.

8 *USER I/O* Connector – provides a connection point for auxiliary output power as well as input and output signals. Refer to *User I/O connections* in the Technical Reference chapter for pinouts and signal descriptions.

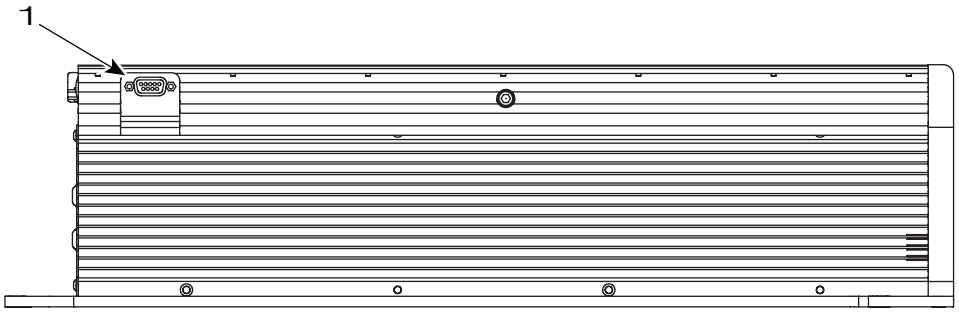
9 *WATER IN* Port (water-cooled models only) – labeled IN, this connection provides the cooling water inlet to Firestar's water-cooling system.

10 *WATER OUT* Port (water-cooled models only) – labeled OUT, this connection provides the cooling water outlet from Firestar's water-cooling system.

operation

Controls and indicators

OEM ti-Series side panel (SA models)



(Air-Cooled ti60 OEM Shown)

Figure 2-3 OEM ti-Series side panel controls and indicators

1 *DB-9* connector – provides an auxiliary +5 V power source as well as +48 VDC for powering 48 V cooling fans. The +5 VDC output is protected by a 0.5 A self-resetting fuse while both +48 VDC outputs are sourced directly from the user's 48 V DC power supply and protected by internal 1.1 A self-resetting fuses. Refer to *DB-9 connections* in the Technical Reference chapter for pinouts and signal descriptions.

Important Note: The pinout and functionality of the side-mounted DB-9 connector on ti-Series SA model lasers is ***not*** the same as the DB-9 connector on t-Series or t70i SA model lasers.

operation

Initial start-up

The *Initial start-up* section includes subsections:

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

⚠ Danger
serious personal injury

This Class 4 laser product emits ***invisible*** infrared laser radiation in the 9.3– 10.6 µm CO_2 wavelength band depending on model. Because 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 contact the laser beam. 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.

⚠ Warning
serious personal injury

On ti-Series OEM lasers, remote interlock (*INT*) faults are not latched. Clearing the fault condition enables the *RDY* indicator and the laser will fire immediately provided the *SHT* indicator is lit and a PWM Command signal is applied. Because exposure to 9.3–10.6 µm CO_2 laser radiation can inflict severe corneal injuries and seriously burn human tissue, the OEM or System Integrator must ensure that appropriate safeguards are in place to prevent unintended lasing.

⚠ Warning
serious personal injury

The use of the *Quick Start Plug* bypasses the laser's safety interlock function, potentially exposing personnel in the area to ***invisible*** infrared laser radiation.

The *Quick Start Plug* is intended only for initial testing and trouble-shooting by qualified personnel. In normal operation, the laser's Remote Interlock input should be connected to the machine's safety interlock circuitry.

Caution
possible equipment damage

Because of their smaller beam diameter, Firestar ti-Series lasers have significantly higher power densities than other SYNRAD lasers. This means that any contaminants on the laser's output coupler (or on any beam delivery optic) can absorb enough energy to damage one of more optics in the beam path. Periodically inspect the laser's output coupler and all other beam delivery optics for signs of contaminants, and then 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.

operation

Initial start-up

With a UC-2000 Controller

Before your Firestar® 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.

Note: When performing the initial start-up, you must first connect the *Quick Start Plug* or provide the required Remote Interlock and Shutter Open Request input signals to the *User I/O* connector. See *User I/O connections* in the Technical Reference chapter for pinouts and signal descriptions.

Starting auxiliary equipment

1 Ensure that all personnel in the area are wearing protective eyewear.

Caution possible equipment damage	Remove the aperture seal before firing the laser. The self-adhesive seal is installed to prevent dust from entering the laser housing during shipment and installation and must be removed before operation.

2 Remove the red self-adhesive aperture seal from the laser faceplate.

3 Place a power meter, or appropriate beam block, 61 cm (24 in) from the laser aperture to prevent the beam from traveling beyond the work area.

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

4 On water-cooled systems, turn on the chiller (set in the range of 18–22 °C) and verify it is delivering between 3.8–7.6 lpm (1.0–2.0 GPM) at less than 414 kPa (60 PSI) of pressure.

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.

5 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.

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

7 Turn on the DC power supply.

Initial start-up

If the *Quick Start Plug* is installed, the *INT* (Remote Interlock) indicator will illuminate green and the *SHT* (Shutter) indicator will illuminate blue. The *TMP* (Temperature) indicator will illuminate green if laser temperature is within safe operating limits.

Note: On cold starts, provide five to ten seconds of tickle before sending PWM Commands to the laser.

Starting your Firestar ti-Series laser

Note: Firestar *RDY* and *SHT* LEDs denote separate control functions. Although the *RDY* lamp may light while the *SHT* LED is Off (*Shutter Switch* Closed or Shutter Open Request signal missing), no power is applied to the RF boards until both *RDY* and *SHT* indicators are illuminated.

1. If the laser has a Diode Pointer installed, remove its aperture dust cover.
2. Place the *Shutter Switch* (if equipped) in the Open position. The blue *SHT* (Shutter) indicator on the laser's rear panel will illuminate.
3. Rotate the *Keyswitch* (if equipped) to the ON position. Verify that the *RDY* (Ready) indicator on the laser's rear panel is illuminated.

Note: Each time a *Keyswitch*-equipped laser is powered up or cycled OFF/ON, a five-second delay occurs between the time that *RDY* and/or *SHT* indicators illuminate and the laser is permitted to lase.

Note: For remote keyswitch operation (keyswitch versions), you can set the *Keyswitch* to the ON position and use the Remote Reset/Start Request input (on the *User I/O* connector) as a remote keyswitch similar to other SYNRAD laser models.

⚠ Warning
serious personal injury

Because of phase differences, external tickle pulses may combine with the internally-generated tickle signal causing the *LASE* LED to flicker during the transition from tickle to lasing. Laser output may occur if the *LASE* LED flickers.

4. Press the UC-2000's *Lase On/Off* button. The *Lase* indicator on the UC-2000 should illuminate.
5. Use the UC-2000's *PWM Adj Knob* to slowly increase power. The laser's *LASE* indicator illuminates red when PWM signal pulses are long enough to produce laser output (typically 3–6 µs at 5 kHz). The spot where the beam hits the beam block increases in brightness to indicate increased power output.
6. Press the UC-2000's *Lase On/Off* button to stop lasing. *LASE* indicators on the UC-2000 and the laser should turn off.
7. Place the laser's *Shutter Switch* (if equipped) in the Closed position.
8. On water-cooled lasers, shut off the chiller or otherwise stop coolant flow through the laser.

operation

Initial start-up

Caution possible equipment damage	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 Firestar ti-Series laser fails to lase, refer to *Troubleshooting* in the Maintenance/Troubleshooting chapter for troubleshooting information.

Without a UC-2000 Controller

If you are not using a UC-2000 to control the laser, follow the steps below to verify laser operation. Although a tickle signal is not required, you will need to provide PWM Command signals to Firestar's *User I/O* connector. Refer to *User I/O connections* in the Technical Reference chapter for connector pinouts and see *Controlling laser power* in the Technical Reference chapter for Command signal descriptions.

Note: When performing the initial start-up, you must first connect the *Quick Start Plug* or provide the required Remote Interlock and Shutter Open Request input signals to the *User I/O* connector. See *User I/O connections* in the Technical Reference chapter for pinouts and signal descriptions.

Starting auxiliary equipment

1 Ensure that all personnel in the area are wearing protective eyewear.

Caution possible equipment damage	Remove the aperture seal before firing the laser. The self-adhesive seal is installed to prevent dust from entering the laser housing during shipment and installation and must be removed before operation.

2 Remove the red self-adhesive aperture seal from the laser faceplate.

3 Place a power meter, or appropriate beam block, 61 cm (24 in) from the laser aperture to prevent the beam from traveling beyond the work area.

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

Initial start-up

4 On water-cooled systems, turn on the chiller (set in the range of 18–22 °C) and verify it is delivering between 3.8–7.6 lpm (1.0–2.0 GPM) at less than 414 kPa (60 PSI) of pressure.

5 Connect the output of your PWM controller to PWM Input (Pin 9) on the laser's *User I/O* connector and connect the ground or return of the Controller to PWM Return (Pin 1).

6 Set your PWM controller to a frequency of 5 kHz @ +5 VDC and ensure that the controller's duty cycle is set to zero percent output (0.0%).

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

8 Turn on the DC power supply.

If the *Quick Start Plug* is installed, the *INT* (Remote Interlock) indicator will illuminate green and the *SHT* (Shutter) indicator will illuminate blue. The *TMP* (Temperature) indicator will illuminate green if laser temperature is within safe operating limits.

Note: On cold starts, provide five to ten seconds of tickle before sending PWM Commands to the laser.

Starting your Firestar ti-Series laser

Note: Firestar *RDY* and *SHT* LEDs denote separate control functions. Although the *RDY* lamp may light while the *SHT* LED is Off (*Shutter Switch* Closed or Shutter Open Request signal missing), no power is applied to the RF boards until both *RDY* and *SHT* indicators are illuminated.

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

2 Place the *Shutter Switch* (if equipped) in the Open position. The blue *SHT* (Shutter) indicator on the laser's rear panel will illuminate.

3 Rotate the *Keyswitch* (if equipped) to the ON position. Verify that the *RDY* (Ready) indicator on the laser's rear panel is illuminated.

Note: Each time a *Keyswitch*-equipped laser is powered up or cycled OFF/ON, a five-second delay occurs between the time that *RDY* and/or *SHT* indicators illuminate and the laser is permitted to lase.

Note: For remote keyswitch operation (keyswitch versions), you can set the *Keyswitch* to the ON position and use the Remote Reset/Start Request input (on the *User I/O* connector) as a remote keyswitch similar to other SYNRAD laser models.

⚠ Warning
serious personal injury

Because of phase differences, external tickle pulses may combine with the internally-generated tickle signal causing the *LASE* LED to flicker during the transition from tickle to lasing. Laser output may occur if the *LASE* LED flickers.

4 Using your PWM controller, slowly increase the duty cycle of the square wave. The *LASE* indicator illuminates red when PWM pulses are long enough to produce laser output (typically between 3–6 µs at 5 kHz). The spot where the beam hits the beam block increases in brightness to indicate increased power output.

operation

Initial start-up

5 Remove the PWM Command signal from the *User I/O* connector. The *LASE* indicator on the laser should turn off.

6 Place the laser's *Shutter Switch* (if equipped) in the Closed position.

Caution possible equipment damage	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.

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

If your Firestar ti-Series laser fails to lase, refer to *Troubleshooting* in the Maintenance/Troubleshooting chapter for troubleshooting information.

technical reference

3

Use information in this chapter as a technical reference for your Firestar ti-Series laser.

This chapter contains the following information:

- Technical overview – briefly describes Firestar's technology and basic optical setup.
- Controlling laser power – explains various aspects of Firestar control signals.
- User I/O (Input/Output) connections – describes signals and specifications for the laser's User I/O connector.
- DB-9 connections (SA models only) – describes pin configuration and specifications for the SA model's side-mounted DB-9 connector.
- Integrating Firestar safety features – describes how to integrate Firestar ti-Series safety features into your automated control system.
- Firestar ti60 general specifications – provides specifications for Firestar ti60 lasers.
- Firestar ti80 general specifications – provides specifications for Firestar ti80 lasers.
- Firestar ti100 general specifications – provides specifications for Firestar ti100 lasers.
- Firestar ti-Series package outline drawings – illustrates laser package and mounting dimensions for Keyswitch and OEM ti60/ti80/ti100 lasers.
- Firestar ti-Series packaging instructions – illustrates how to package ti-Series lasers for shipment using SYNRAD-supplied packaging materials.

technical reference

Technical overview

The *Technical overview* section includes subsections:

- ti-Series laser
- Optical setup

ti-Series laser

Laser tube

Firestar® ti-Series lasers were developed using new technology patented by SYNRAD, Inc. Firestar's patented "t" technology, based on a combination of free-space and waveguide resonator designs, enables SYNRAD to economically produce a symmetrical laser beam from a small but powerful laser capable of operating for many years with virtually no maintenance. Firestar's unique extruded aluminum envelope offers excellent heat transfer, long gas life, and low operating costs in contrast to other laser tube technologies. In addition to being the vessel that maintains the lasing environment, the aluminum tube is also the structural platform that integrates the laser's optical, electrical, and cooling components.

Optical resonator

The optical resonator, in conjunction with the electrodes and the gas mixture, generates the laser beam. Firestar ti-Series optical resonators are comprised of three optical elements: a front mirror, a rear mirror, and an output window. These optical elements are fastened to the tube's exterior and are exposed to its interior through holes in the end caps. O-rings are sandwiched between optical elements and the end cap to form a gas seal and to provide a flexible cushion that allows the slight movement necessary for alignment. All optical elements are aligned and locked into place by factory technicians before the laser is shipped.

Caution
possible equipment damage

Because of their smaller beam diameter, Firestar ti-Series lasers have significantly higher power densities than other SYNRAD lasers. This means that any contaminants on the laser's output coupler (or on any beam delivery optic) can absorb enough energy to damage one or more optics in the beam path. Periodically inspect the laser's output coupler and all other beam delivery optics for signs of contaminants, and then 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.

The output beam, roughly circular as it exits the resonator, transitions to a Gaussian-like mode in five to ten Raleigh ranges, which is approximately 1.6–3.3 m (5.2–10.8 ft). The internal structure and optics of the resonator combine to produce a Gaussian-like mode quality (M^2 factor) of $\leq 1.2^*$. As shown in Figure 3-1, beam waist diameter is 2.0 mm ±0.3 mm at the output aperture and full angle divergence due to diffraction is less than 7 milliradians (a 7 mrad full angle divergence means that beam diameter increases 7 mm over every one meter distance traveled).

* $M^2 < 1.3$ for 9.3 µm and 10.2 µm models.

Technical overview

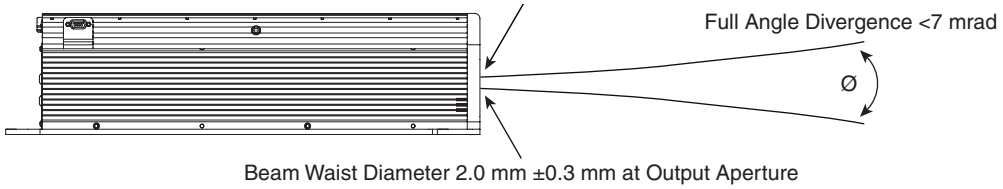


Figure 3-1 Firestar ti-Series beam characteristics

Internal RF power supply

Firestar ti-Series lasers are driven by a compact radio frequency (RF) power supply mounted internally in the laser chassis. The 48 VDC input voltage is converted into a high-power RF signal using an RF power oscillator. The output from the RF oscillator (nominally at 83.5 MHz) drives the laser directly by exciting carbon dioxide (CO_2) gas in the tube to produce lasing.

Control circuit

Switches and sensors built into the ti-Series control board monitor the laser for conditions like under/over voltage, over temperature, and No-Strike faults that pose a risk of damage to the laser. Additionally, laser operation is controlled by the following: a manual *Shutter Switch* and manual *Keyswitch* (on Keyswitch-equipped lasers); the Shutter Open Request input; the Remote Interlock input; and the Remote Reset/Start Request input.

Optical setup

After selecting a laser for a CO_2 laser processing system, the two most important elements to consider are: (1) beam 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 the same careful attention to detail.

Beam delivery optics

Divergence, or expansion, of the laser beam is important in materials processing since a larger beam entering the focusing optic produces a smaller focused spot. Because the ti-Series laser beam diverges by 7 mm over each meter of distance traveled, the laser should be mounted a distance of 1.0–1.5 m (40–60 in) away from the work area and no closer than 0.75 m (30 in) for optimum performance. Right angle turning mirrors (beam benders) are often used in conjunction with the laser mounting position to obtain this distance.

Expander/collimators are optical devices that reduce laser divergence while at the same time increasing beam diameter by a selectable magnification factor. Adding an expander/collimator substantially reduces beam divergence and any variance in beam diameter caused by the changing optical path length in an XY ("flying optics") table application. 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.

Note: Optical components in the beam path must always be aligned to the actual beam path, not the laser faceplate. Because of slight variations in laser construction, the beam path may not always be centered in, or perpendicular to, the aperture in the faceplate.

technical reference

Technical overview

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 being processed.

Caution
possible equipment damage

Any 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. Be careful to select optics that are thick enough to withstand the maximum assist gas pressure available for the process. This is especially important in metal cutting applications using high-pressure assist gases.

Cleanliness is another important issue affecting performance and becomes increasingly important as laser power increases. Dirty or scratched lenses will under perform, exhibit a vastly shortened lifetime, and may fail catastrophically.

When the application requires air (instead of nitrogen) as an assist 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 and dried to ISO 8573-1:2010 Class 1, 2, 1 specifications shown in Table 3-1.

Table 3-1 Assist gas purity specifications

Assist Gas	Typical Purpose	Specification	
Air	Cutting/Drilling	Breathing Grade	≥ 99.9996% purity; filtered to ISO Class 1 particulate level
Air	Cutting/Drilling	Compressed	Instrument-grade air filtered and dried to ISO 8573-1:2010 Class 1, 2, 1 (≤ 10 1.0–5.0 µm particles/m^3; ≤ –40 °F dew point; ≤ 0.01 mg/m^3 oil vapor)
Argon	Welding	High Purity Grade	≥ 99.998% purity; filtered to ISO Class 1 particulate level
Helium	Welding	High Purity Grade	≥ 99.997% purity; filtered to ISO Class 1 particulate level
Nitrogen	Cutting/Drilling	High Purity Grade	≥ 99.9500% purity; filtered to ISO Class 1 particulate level
Oxygen	Cutting/Drilling	Ultra Pure Grade	≥ 99.9998% purity; filtered to ISO Class 1 particulate level

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 PWM Command signals to the ti-Series laser. If using an alternate method of laser control, thoroughly review this section, *Controlling laser power*, as well as the following section, *User I/O connections*, for an understanding of the signal requirements necessary to control Firestar lasers. For more information about the UC-2000, please consult the *UC-2000 Laser Controller Operator's Manual*.

Tickle pulse

⚠ **Warning** serious personal injury	Because of phase differences, external tickle pulses may combine with the internally-generated tickle signal causing the *LASE* LED to flicker during the transition from tickle to lasing. Laser output may occur if the *LASE* LED flickers.

Tickle pulses pre-ionize the laser gas to just below the lasing threshold so that a further increase in pulse width adds enough energy to the plasma to cause laser emission. Tickle pulses cause 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. All Firestar ti-Series lasers incorporate a built-in tickle generator, freeing customers from the need to supply external tickle pulses between lasing commands.

Internal circuitry monitors the incoming PWM signal and determines the amount of time the laser was on (lasing) during the last 200 microsecond (µs) interval. If the laser's on time was greater than the preset tickle value, then no tickle pulse is generated, because the PWM signal was sufficient to maintain a plasma state. If no PWM signal was applied during the 200-µs measurement period (or was *shorter* than the preset tickle value), internal circuitry generates a tickle pulse such that the laser always receives a pre-set amount of RF drive averaged over any 200-µs interval.

Pulse Width Modulation (PWM)

Pulse Width Modulation, or PWM, controls laser power by varying the duty cycle of Firestar's RF amplifiers, which in turn control the time-averaged RF power applied to the laser. Typically, laser output follows the PWM input with a rise and fall time constant of ~75 µs; however, the laser cannot precisely follow PWM input signals if the "On" pulse is less than 75 µs in duration. At a constant 50% duty cycle, ti-Series lasers typically reach 90–100% of full optical output when operated at a frequency of 5 kHz. The percentage of optical output increases as duty cycle increases (at a constant PWM frequency) or as PWM frequency decreases (at a constant duty cycle). Figure 3-2 on the following page shows representative ti-Series optical output waveforms at two different duty cycles with the same PWM frequency.

Controlling laser power

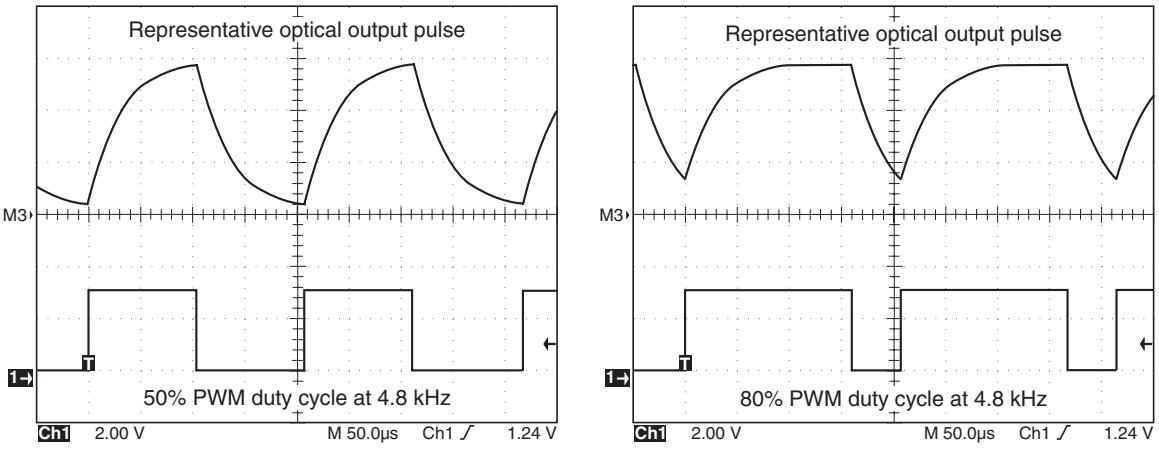


Figure 3-2 Representative Firestar ti-Series waveforms

Firestar ti-Series lasers are designed to operate at Command signal base frequencies up to 160 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 160 kHz maximum.

Command signal

⚠ Warning
serious personal injury

Always use shielded cable when connecting your PWM Command signal source to PWM Input/PWM Return inputs. 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 between Pin 9, PWM Input, and Pin 1, PWM Return, of the *User I/O* connector on the Firestar ti-Series laser has three basic 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 +0.8 VDC while the laser on voltage, typically 5 V, can range from +3.5 V to +6.7 VDC.

Base frequency, the second parameter, is the repetition rate of the PWM input signal. The standard base frequency is 5 kHz, which has a period of 200 µs. Maximum PWM frequency is 160 kHz.

Controlling laser power

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 3-3 illustrates PWM Command signal parameters while Table 3-2 lists PWM signal specifications.

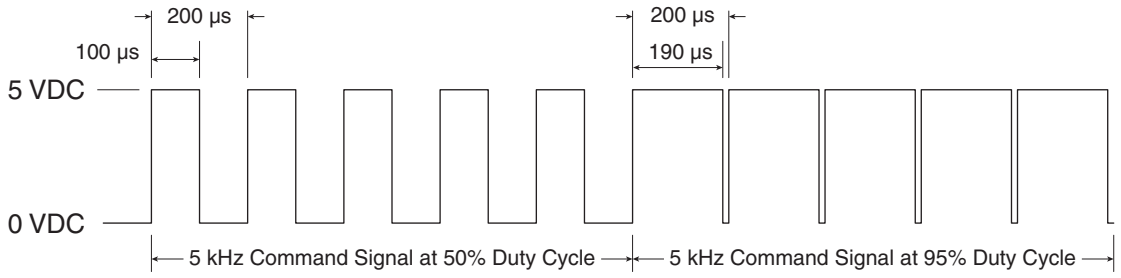


Figure 3-3 PWM Command signal waveform

Firestar's *User I/O* PWM input consists of a high-speed optoisolator LED with a forward voltage drop (Vf) of 1.5 VDC. The PWM input frequency can range from DC (0 Hz) to 160 kHz. Table 3-2 provides minimum, maximum, and nominal PWM signal specifications.

Table 3-2 PWM Command signal levels

Laser State	Minimum	Nominal	Maximum
Laser Off	0.0 VDC	0.0 VDC	+0.8 VDC
Laser On	+3.5 VDC (3 mA)	+5.0 VDC (6 mA)	+6.7 VDC (10 mA), continuous
Frequency Range	0 Hz (DC)	5 kHz	160 kHz
Duty Cycle	0%	— —	100%

Operating modes

External control

In addition to controlling the Firestar laser using a UC-2000 Controller, control of Firestar 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 function generator capable of sending PWM pulses at the proper time (gating) and with the proper duty cycle (power).

Analog voltage or current control

Although Firestar ti-Series 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 laser gating and power.

technical reference

Controlling laser 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 either configuration.

Continuous wave (CW)

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.

To operate the laser in CW mode, apply a constant +5 VDC signal to Pin 9, PWM Input, and Pin 1, PWM Return, on the *User I/O* connector. This constant voltage source forces the internal switching electronics to remain on, providing continuous and uninterrupted laser output power. During CW operation, output power cannot be changed. To adjust output power, refer back to the *Pulse Width Modulation (PWM)* section for information regarding high frequency operation.

Note: SYNRAD lasers are designed for maximum performance using a 95% duty cycle. Increasing the maximum PWM percentage beyond 95% greatly increases the laser's heat load with little or no corresponding increase in laser output power.

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 signal, short circuit to ground, or an open or disconnected *Gate* input locks the beam off.

⚠ Warning
serious personal injury

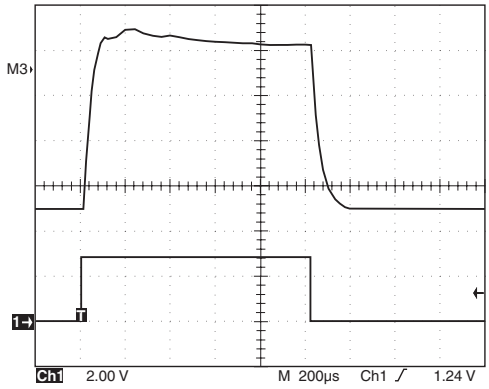
The UC-2000's default gate logic is factory set to internal Pull-Up (normally on) mode so that an open (disconnected) *Gate* input causes the laser to turn on. This functionality allows the user to easily test and verify laser operation prior to integration.

In an integrated system, you should configure 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 signal, short circuit to ground, or an open or disconnected *Gate* inputs locks the beam off.

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. The overshoot effect is more pronounced at lower gating frequencies since the gas has a longer time to cool down between Command signal pulses.

Controlling laser power

SYNRAD's Firestar ti-Series lasers produce an optical output pulse that is almost exactly square (see Figure 3-4), meaning that there is no leading edge overshoot and virtually no power variation across the actual pulse. The square output pulse of the ti-Series laser coupled with its shorter rise times (~75 µs) means that material processing is more efficient since a greater amount of laser energy is absorbed, which is especially desirable when working with high threshold materials.



Optical output pulse (10% duty cycle at 100 Hz)

Figure 3-4 Representative ti-Series optical output pulse

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 microseconds (less than or equal to 5 kHz), Firestar's on-board tickle generator sends a tickle pulse to maintain plasma ionization in the tube. Because the on-board tickle generator can not anticipate when the next PWM Command pulse will arrive, the tickle pulse (which typically lasts for 2–6 µs depending on the laser) 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 microseconds.

technical reference

User I/O connections

The *User I/O connections* section includes subsections:

- User I/O connection summary
- Input/output signals
- Sample I/O circuits

User I/O connection summary

Table 3-3 below provides a quick reference summary for Firestar ti-Series *User I/O* connections.

Table 3-3 User I/O pin descriptions

Pin	Function	Description
1	PWM Return	Use this input pin as the return side of the PWM Command signal.
2	Remote Reset/Start Request input	Apply a positive or negative voltage (±5–24 VDC) with respect to Pin 11, Input Common, to reset or remote keyswitch the laser. The laser remains disabled while voltage is applied. Removing voltage from the Remote Reset/Start Request pin causes the laser's *RDY* indicator to illuminate. On *Keyswitch* lasers, a five-second delay occurs before lasing is enabled. **Note:** When connecting field wiring to the Remote Reset/Start Request input, use twisted pair and/or shielded cabling. Refer to *SYNRAD Technical Bulletin #21* for details.
3	Remote Interlock input	Apply a positive or negative voltage (±5–24 VDC) with respect to Pin 11, Input Common, to enable lasing. If your system does not use an interlock, connect this pin to a ±5–24 VDC source (Figure 3-7 shows how the Remote Interlock input is factory-jumpered on the *Quick Start Plug*). On *Keyswitch* lasers, a five-second delay occurs after the interlock is enabled.
4	+ 5 VDC Auxiliary Power	This connection provides +5 VDC for driving external inputs or outputs. The +5 VDC Auxiliary Power output can source up to 0.5 A and is protected by a 0.5 A self-resetting fuse. The return (ground) path must be through Pin 12, Auxiliary DC Power Ground.
5	+ 24 VDC Auxiliary Power	This connection provides +24 VDC for driving external inputs or outputs. The +24 VDC Auxiliary Power output can source up to 0.5 A and is protected by a 0.5 A self-resetting fuse. The return (ground) path must be through Pin 12, Auxiliary DC Power Ground.
6	Laser Active output	This bi-directional switched output is internally connected to Pin 13, Output Common, when the laser is actively lasing (*LASE* indicator illuminated red). This output is open, in a high-impedance state, when no beam is being emitted (*LASE* indicator Off).

User I/O connections

Pin	Function	Description
7	Fault Detected output	This bi-directional switched output is internally connected to Pin 13, Output Common, when an over temperature fault (*TMP* LED is red) or other improper operating condition (*SHT* indicator is flashing) exists. The output is open, in a high-impedance state, when laser operation is within limits (*TMP* LED green and *SHT* LED blue).
8	Laser Ready output	This bi-directional switched output is internally connected to Pin 13, Output Common, when the laser is enabled (*RDY* indicator illuminated yellow), indicating that lasing will occur when a PWM Command signal is applied to Pin 9 and Pin 1. This output is open, in a high-impedance state, when the laser is disabled (*RDY* indicator Off).
9	PWM Input	Connect your PWM Command signal (+5 VDC, 5 kHz nominal, 160 kHz max, pulse width modulated) to this input pin to control laser output power. Refer back to *Controlling laser power* for further information on laser control signals.
10	Shutter Open Request input	Apply a positive or negative voltage (±5–24 VDC) with respect to Pin 11, Input Common to enable lasing. If your system does not use a shutter, connect this pin to a ±5–24 VDC source (Figure 3-7 shows how the Shutter Open Request input is factory-jumpered on the *Quick Start Plug*). On *Keyswitch* lasers, a five-second delay occurs after this input is enabled.
11	Input Common	Use this input pin to connect return lines for Remote Interlock, Shutter Open Request, and Remote Reset/Start Request lines.
12	Auxiliary DC Power Ground	This connection provides a ground (earth) connection for +5 and +24 VDC auxiliary power outputs. This pin is the only *User I/O* pin that is connected to chassis ground. Do not use this pin for grounding if DC power to external I/O circuits is supplied from an external customer-supplied DC power source.
13	Output Common	Use this pin to complete the return path for output connections (Pin 6, 7, 8, 14, or 15). The Output Common line is protected by a 0.25 A self-resetting fuse.
14	Shutter Open output	This bi-directional switched output is internally connected to Pin 13, Output Common, when the *Shutter Switch* is Open (*Keyswitch*-equipped lasers) and a Shutter Open Request signal is present (*SHT* indicator illuminated blue), indicating that lasing may be enabled if other operating conditions are met. This output is open, in a high-impedance state, when the laser is disabled (*SHT* indicator Off).
15	Interlock Open output	This bi-directional switched output is internally connected to Pin 13, Output Common, when remote interlock circuitry is open (*INT* indicator illuminated red), indicating that lasing is disabled. The output is open, in a high-impedance state, when lasing is enabled (*INT* indicator green).

technical reference

User I/O connections

Input/output signals

Firestar's input/output signals are divided into three categories: auxiliary DC power, input signals, and output signals. Signals in each category are fully described in the section below. Figure 3-5 illustrates the pin arrangement of the *User I/O* (15 pin female D-type subminiature) connector on the laser's rear panel.

Note: See *DB-9 connections* later in this section for signal descriptions and pinouts of the SA model's side-mounted DB-9 connector.

Caution
possible equipment damage

Turn off DC power before installing or removing any plug or cable from the *User I/O* connector. Ensure that user connections are made to the appropriate pins and that the appropriate signal levels are applied. Failure to do so may damage the laser.

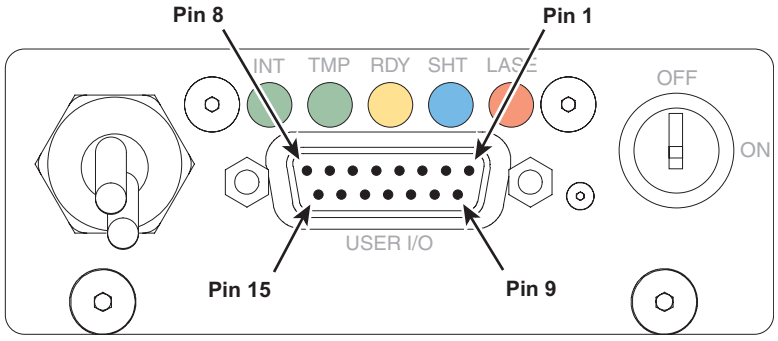


Figure 3-5 User I/O connector pinouts

User I/O connections

Auxiliary DC power

Firestar's *User I/O* connector provides auxiliary DC power for driving external inputs or outputs connected to the *User I/O* port. Pin 4, +5 VDC Auxiliary Power, and Pin 5, +24 VDC Auxiliary Power, are protected by self-resetting fuses rated at 0.5 A. Pin 12, Auxiliary DC Power Ground, is connected to chassis ground while all other *User I/O* pins are floating with respect to chassis ground. Figure 3-6 illustrates Firestar's internal DC supply wiring.

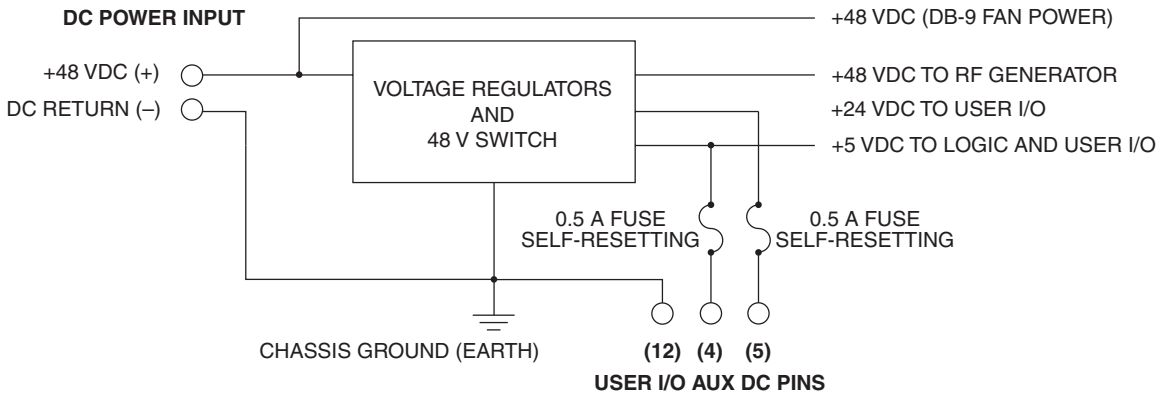


Figure 3-6 Auxiliary DC power supply wiring

Pin 4 + 5 VDC Auxiliary Power

This connection provides +5 VDC for driving external inputs or outputs. The +5 VDC Auxiliary Power output can source up to 0.5 A and is protected by a 0.5 A self-resetting fuse. The return (ground) path must be through Pin 12, Auxiliary DC Power Ground.

Pin 5 + 24 VDC Auxiliary Power

This connection provides +24 VDC for driving external inputs or outputs. The +24 VDC Auxiliary Power output can source up to 0.5 A and is protected by a 0.5 A self-resetting fuse. The return (ground) path must be through Pin 12, Auxiliary DC Power Ground.

Pin 12 Auxiliary DC Power Ground

This connection provides a ground (earth) connection for +5 and +24 VDC auxiliary power outputs. This pin is the only *User I/O* pin that is connected to the laser's chassis ground. Do not use this pin for grounding if I/O circuits are powered from an external customer-supplied DC power source.

technical reference

User I/O connections

Input signals

Four inputs allow control of ti-Series lasers. Remote Reset/Start Request, Remote Interlock, and Shutter Open Request inputs are optoisolated and bi-directional to allow positive or negative polarity inputs. These three signals share a common return, Input Common, which is separate from chassis ground to completely isolate control signals for optimal EMI performance. The fourth input, PWM Input, is optoisolated with a separate return line, PWM Return, to isolate PWM signals from the other three inputs.

Pin 1 PWM Return

Connect the return side of your PWM Command signal to this pin. Refer to Table 3-4 for input circuit specifications.

Pin 2 Remote Reset/Start Request input

Apply a positive or negative voltage (±5–24 VDC) with respect to Pin 11, Input Common, to disable the laser. The laser remains disabled while voltage is applied to this pin. Removing voltage from the Remote Reset/Start Request pin causes the laser's *RDY* indicator to illuminate. On *Keyswitch*-equipped lasers, a five-second delay occurs before lasing is enabled. Because all DC power is removed from the laser's RF driver when this input is active, no lasing can occur until voltage is removed from Pin 2. Refer to Table 3-4 for input circuit specifications.

Note: When connecting field wiring to the Remote Reset/Start Request input, use twisted pair and/or shielded cabling. Refer to *SYNRAD Technical Bulletin #21* for details.

For *Keyswitch*-equipped lasers in automated systems, the Remote Reset/Start Request input can operate as a remote keyswitch. To use this "remote keyswitch" functionality, first place the *Keyswitch* in the ON position. Then after each DC power-up cycle (or to reset a fault condition), apply a momentary voltage pulse in the range of ±5–24 VDC to Pin 2. This reset action initiates a five-second delay after which lasing is enabled.

Pin 3 Remote Interlock input

Apply a positive or negative voltage (±5–24 VDC) with respect to Pin 11, Input Common, to enable lasing. If your system does not use a remote interlock, this pin must be connected to a voltage source in the range of ±5–24 VDC. Refer to Figure 3-7 for a diagram showing how the Remote Interlock input is factory-jumpered on the *Quick Start Plug*. Because all DC power is removed from the laser's RF driver when this input is inactive, no lasing can occur until voltage is applied to Pin 3. Refer to Table 3-4 for input circuit specifications.

After voltage is removed and then re-applied to the Remote Interlock input on *Keyswitch*-equipped lasers, the *Keyswitch* or the Remote Reset/Start Request input must be toggled to restart the laser. This action initiates a five-second delay during which lasing is inhibited.

On OEM lasers, the Remote Interlock input is not latched. Re-applying a signal to Pin 3 enables laser output immediately, when the Shutter Open Request signal is present (*SHT* LED illuminated).

Pin 9 PWM Input

Connect your PWM Command signal (+5 VDC, 5 kHz nominal, 160 kHz max) to Pin 9. This pulse width modulated Command signal controls laser output so that a duty cycle of 50% corresponds to a laser output of approximately one-half rated output power and a duty cycle of 95% corresponds to approximately full output power. Refer to *Controlling laser power* in this chapter for further information on laser control signals. Connect the PWM signal source return to Pin 1, PWM Return. See Table 3-4 for input circuit specifications.

User I/O connections

Pin 10 Shutter Open Request input

Apply a positive or negative voltage (±5–24 VDC) with respect to Pin 11, Input Common, to enable lasing. If your system does not supply a Shutter Open Request signal, this pin must be connected to a voltage source in the range of ±5–24 VDC. Refer to Figure 3-7 for a diagram showing how the Shutter Open Request input is factory-jumpered on the *Quick Start Plug*. On *Keyswitch*-equipped lasers, a five-second delay occurs after the input is enabled. Because all DC power is removed from the laser's RF driver when this input is inactive, no lasing can occur until voltage is applied to Pin 10. See Table 3-4 for input circuit specifications.

To enable *Keyswitch*-equipped lasers, you must apply a voltage (in the range of ±5–24 VDC) to the Shutter Open Request input and move the manual *Shutter Switch* to the Open position. Lasing is inhibited when voltage is removed from Pin 10 or the manual *Shutter Switch* is Closed.

Pin 11 Input Common

Use this pin to connect return lines for Remote Interlock, Shutter Open Request, and Remote Reset/Start Request lines. Refer to Table 3-4 for input circuit specifications.

Figure 3-7 illustrates how Remote Interlock and Shutter Open Request inputs are factory-jumpered on the *Quick Start Plug* to enable lasing for initial testing and troubleshooting purposes.

⚠ Warning
serious personal injury

The use of the *Quick Start Plug* bypasses the laser's safety interlock function, potentially exposing personnel in the area to ***invisible*** infrared laser radiation.

The *Quick Start Plug* is intended only for initial testing and troubleshooting by qualified personnel. In normal operation, the laser's Remote Interlock input should be connected to the machine's safety interlock circuitry.

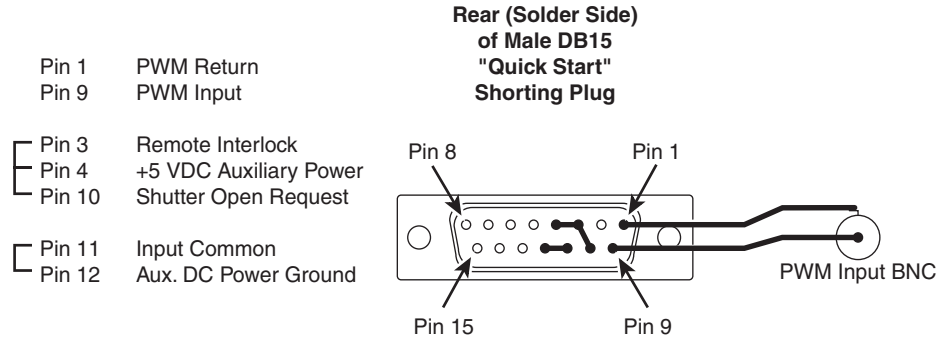


Figure 3-7 Quick Start Plug wiring diagram

User I/O connections

Figure 3-8 illustrates the input circuit's equivalent internal schematic while Table 3-4 provides Firestar ti-Series input circuit specifications.

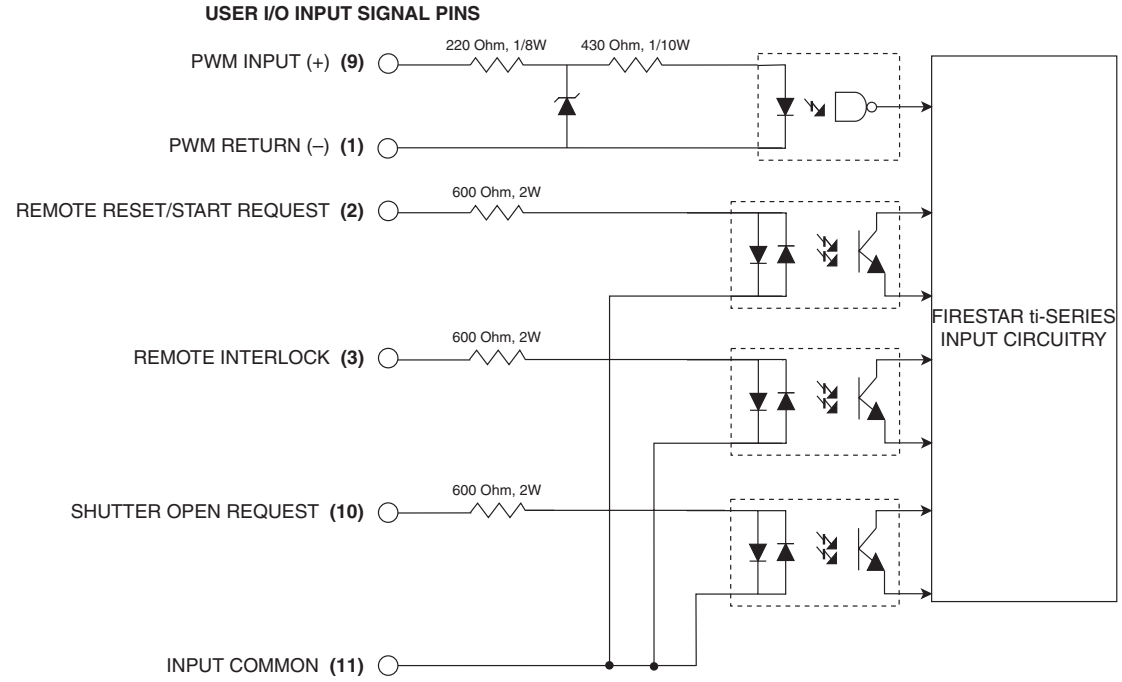


Figure 3-8 Input equivalent schematic

Table 3-4 Input circuit specifications

Input Signal Name	Input Device Type and Specifications
PWM Input	High-speed optoisolator LED, forward voltage drop (Vf) 1.5 VDC Off state Vmax +0.8 VDC On state Vmin +3.5 VDC @ 3 mA On state (continuous) Vmax +6.7 VDC @ 10 mA Frequency, max. 160 kHz
Remote Reset/Start Request Remote Interlock Shutter Open Request	Bi-directional optoisolator LED, forward voltage drop (Vf) 1.15 VDC Off state Vmax < 1.0 VDC On state Vmin ±5.0 VDC @ 7 mA On state (continuous) Vmax ±24.0 VDC @ 40 mA

Note: The Remote Reset/Start Request input must not be sent until Firestar's +5 VDC power supply has stabilized (approximately 200 ms after DC power-up).

User I/O connections

Output signals

Firestar's five user outputs correspond to the status functions described below. Outputs are optoisolated, bi-directional analog switches that allow for high-side or low-side switching. The shared connection, Output Common, is separate from the laser's chassis ground to allow high-side or low-side switching and to isolate control signals for optimum EMI performance.

Firestar's optically-isolated outputs are useful for sending laser status to a Programmable Logic Controller (PLC) or computerized control system. Each of the five outputs can source 50 mA at ±24 VDC maximum for a total load of 250 mA. For controlling larger loads, use these outputs to drive control relays.

Note: Laser Ready and Shutter Open outputs indicate separate functions. The RF driver is disabled until both Laser Ready and Shutter Open outputs are closed (both *RDY* and *SHT* LEDs On).

Pin 6 Laser Active output

This bi-directional switched output is internally connected to Pin 13, Output Common, when the laser is actively lasing (*LASE* indicator red). This output is open, in a high-impedance state, when no beam is being emitted (*LASE* indicator Off). Refer to Table 3-5 for output circuit specifications.

Pin 7 Fault Detected output

This bi-directional switched output is internally connected to Pin 13, Output Common, when an over temperature fault (*TMP* LED is red) or other improper operating condition (blue *SHT* indicator is flashing) exists. The output is open, in a high-impedance state, when laser operation is within limits (*TMP* LED green and *SHT* LED blue). Refer to Table 3-5 for output circuit specifications.

Pin 8 Laser Ready output

This bi-directional switched output is internally connected to Pin 13, Output Common, when the laser is enabled (*RDY* indicator yellow), indicating that lasing will occur when a PWM Command signal is applied to Pin 9 and Pin 1. This output is open, in a high-impedance state, when the laser is disabled (*RDY* indicator Off). Refer to Table 3-5 for output circuit specifications.

Pin 13 Output Common

Use this pin to complete the return (ground) path for any output connection (Pin 6, 7, 8, 14, or 15). The Output Common line is protected by a 0.3 A self-resetting fuse.

Pin 14 Shutter Open output

This bi-directional switched output is internally connected to Pin 13, Output Common, when the *Shutter Switch* is Open (*Keyswitch*-equipped lasers) and a Shutter Open Request signal is present (*SHT* indicator blue), indicating that lasing may be enabled if other operating conditions are met. The output is open, in a high-impedance state, when the laser is disabled (*SHT* indicator Off). Refer to Table 3-5 for output circuit specifications.

Pin 15 Interlock Open output

This bi-directional switched output is internally connected to Pin 13, Output Common, when remote interlock circuitry is open (*INT* indicator red), indicating that lasing is disabled. The output is open, in a high-impedance state,when lasing is enabled (*INT* indicator green). See Table 3-5 for output circuit specifications.

User I/O connections

Figure 3-9 illustrates the output circuit's equivalent internal schematic and Table 3-5 provides Firestar ti-Series output circuit specifications.

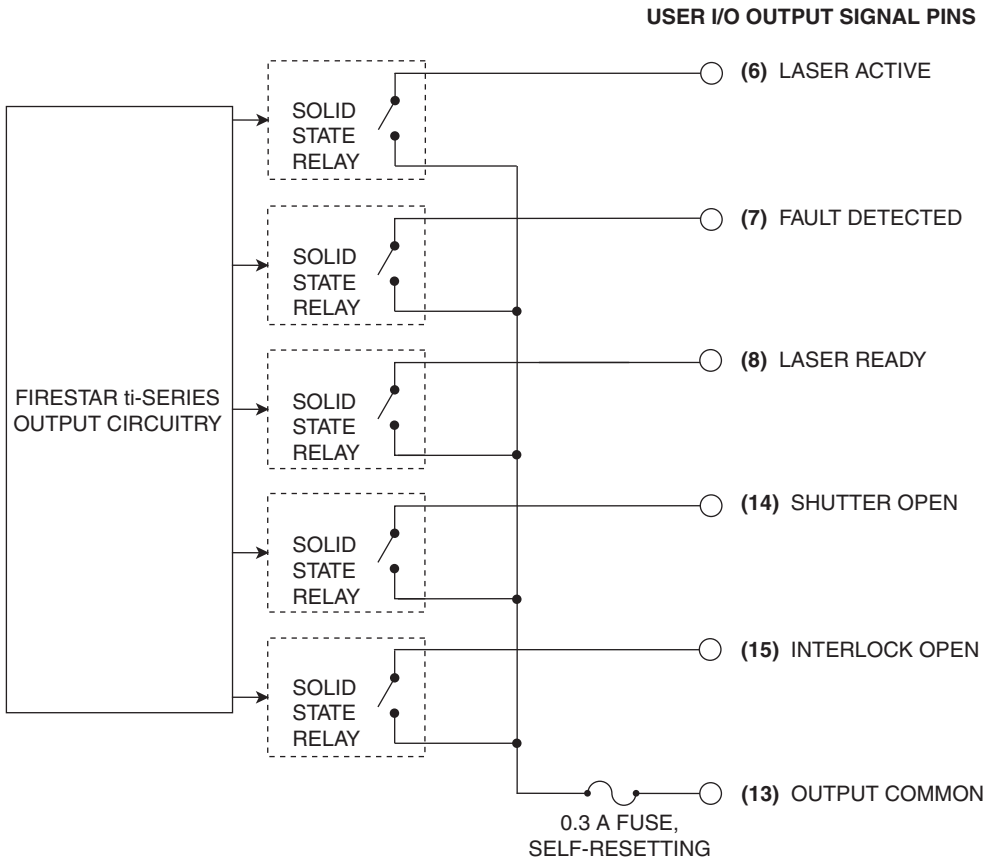


Figure 3-9 Output equivalent schematic

Table 3-5 Output circuit specifications

Output Device	Specifications
Bi-directional MOSFET	2.5 Ohms Rdson 10 MOhms Off Voltage ±24 VDC, max. Current 50 mA, max.

Sample I/O circuits

Sample inputs

Figure 3-10 illustrates one method of supplying a Remote Interlock signal using a customer-supplied limit switch. Firestar's +24 VDC Auxiliary Power output powers the circuit. Note that Pin 4, +5 VDC Auxiliary Power, could have been used to power the circuit instead, depending on circuit voltage requirements.

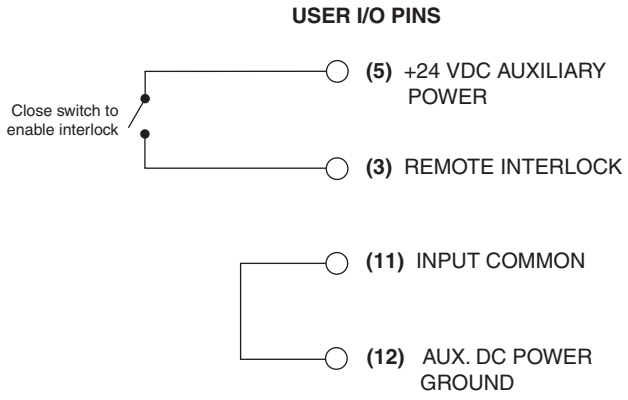


Figure 3-10 Customer-supplied interlock

Figure 3-11 shows another variation for supplying a Remote Interlock signal to the laser. In this case, the customer is using a switch and supplying a negative voltage to drive Firestar's input circuit.

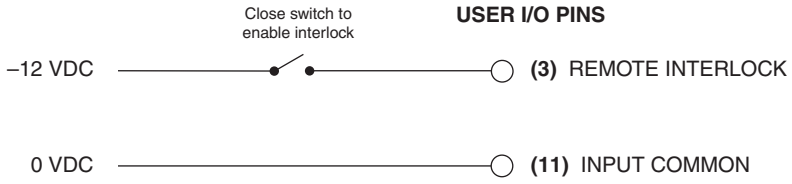


Figure 3-11 Customer-supplied interlock, negative voltage

User I/O connections

A Programmable Logic Controller (PLC) can also drive Firestar inputs. Figure 3-12 shows a typical method for connecting to a PLC input module when only one Firestar input is used.

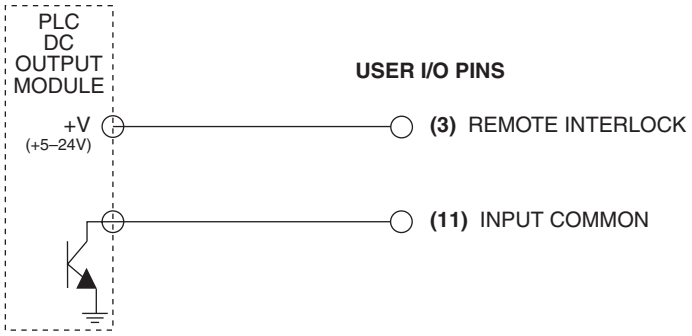


Figure 3-12 PLC driven interlock signal

When multiple PLC inputs are required, connect Firestar inputs to the PLC as shown in Figure 3-13. By supplying voltage (+VDC) to Pin 11, Input Common, and pulling individual inputs to ground, each input can be independently activated by the PLC's output module.

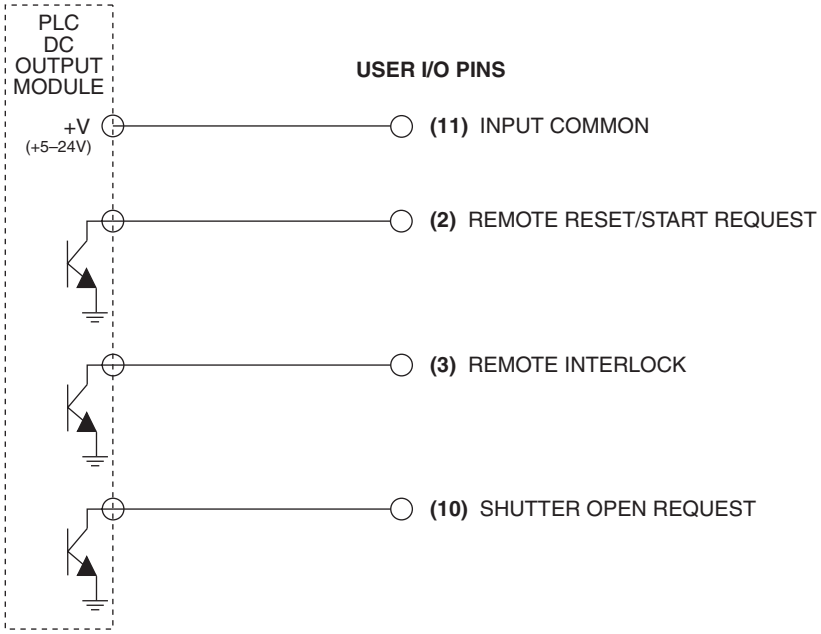


Figure 3-13 Multiple PLC driven inputs

User I/O connections

Sample outputs

Firestar's optoisolated, bi-directional switched outputs can drive small loads (50 mA max), PLC inputs, or relays that can control higher current loads. Figure 3-14 illustrates one method of controlling a remote warning lamp using power supplied by Firestar's +24 VDC Auxiliary Power output. Remember to size current-limiting resistor, R1, so that the current draw does not exceed 50 mA.

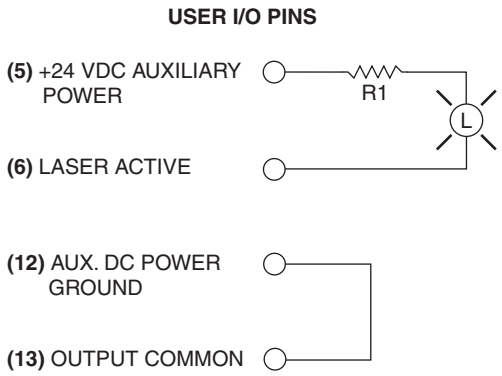


Figure 3-14 Firestar output driving warning lamp

Figure 3-15 illustrates a method for controlling a higher voltage, higher current load by using a 24 V control relay. Ensure that the relay coil's pull-in current does not exceed 50 mA. A diode or surge suppressor must be installed across the relay coil to prevent voltage spikes from damaging Firestar outputs.

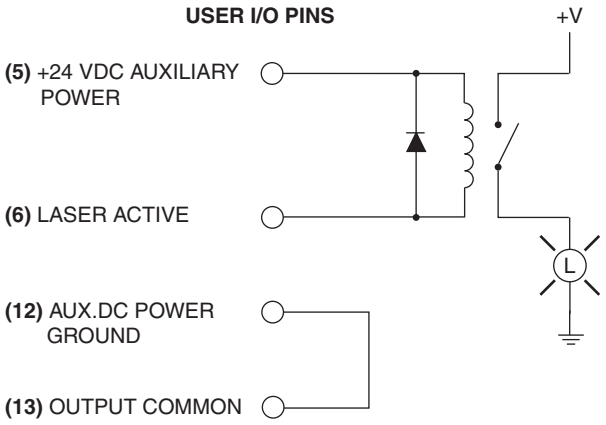


Figure 3-15 Firestar output driving relay

User I/O connections

Figure 3-16 illustrates how Firestar's outputs can drive the DC Input Module of a Programmable Logic Controller (PLC). By supplying voltage (+VDC) to Pin 13, Output Common, each Firestar output is independently switched to activate individual PLC inputs.

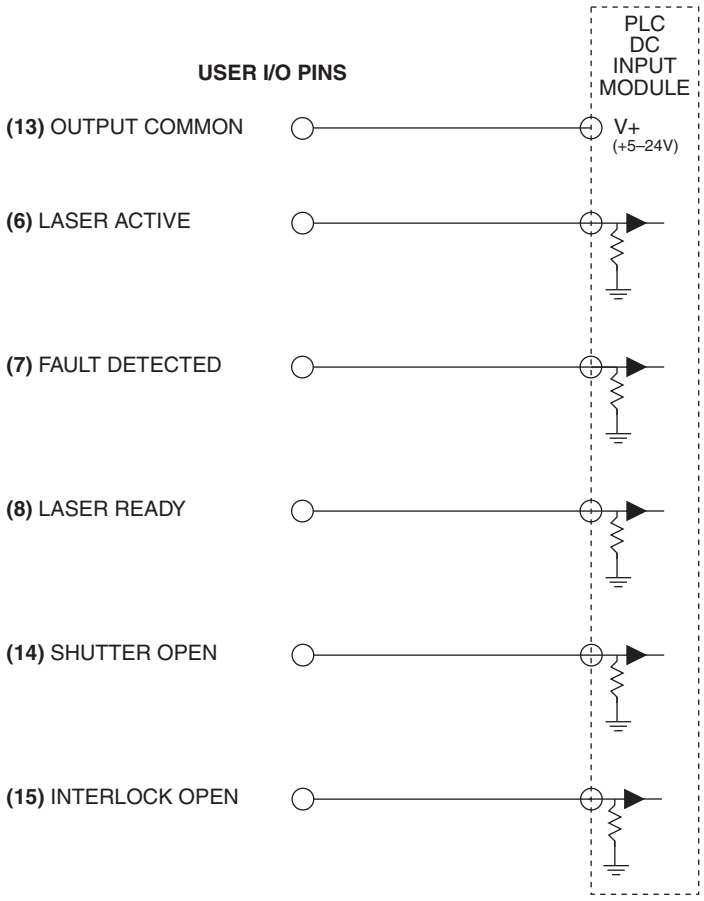


Figure 3-16 Firestar outputs driving PLC input module

DB-9 connections (SA models only)

The *DB-9 connections* section includes subsections:

- DB-9 pin descriptions
- 48 VDC fan speed control
- Isolated cooling fan connections

DB-9 pin descriptions

The side-mounted DB-9 connector on SA model lasers provides a *Shutter Switch* input, auxiliary +5 V power, and +48 VDC for powering user-supplied 48 V cooling fans. Figure 3-17 illustrates DB-9 pinouts and Table 3-6 describes the function of each pin on the DB-9 connector.

Important Note: The pinout and functionality of the side-mounted DB-9 connector on ti-Series SA model lasers is ***not*** the same as the connector on t-Series or t70i SA model lasers.

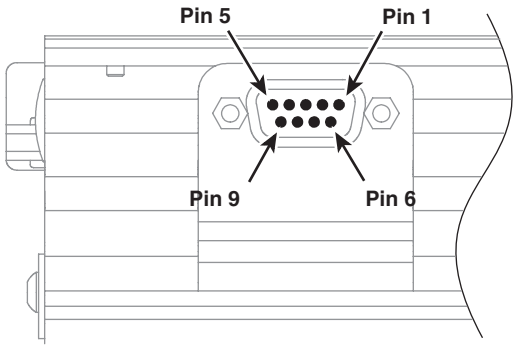


Figure 3-17 DB-9 connector pinouts

Table 3-6 Side-mounted DB-9 pin descriptions

Pin	Function	Description
1	PWM Control Output (ti80 laser only)	This optoisolated output provides a 0–5 V pulse-width modulated (PWM) signal to drive the PWM input on variable-speed DC fans. This output is not current-limited or fused. The PWM output is driven by internal circuitry based on the laser's output power and chassis temperature.
2	Shutter Switch Input	On *Keyswitch*-equipped models, this input connects to the physical *Shutter Switch*. Leave this input open to enable lasing. Grounding this pin indicates that the shutter is Closed, which disables lasing. If connecting an external shutter switch to Pin 2, the circuit path must be grounded to Pin 6 or Pin 7, Signal Ground. With *Keyswitch*-equipped lasers, there is a five-second delay imposed from the time the shutter input is opened to the time that PWM Command signals are accepted.
3	+ 5 VDC Auxiliary Power Output	This output provides +5 V for driving external inputs or outputs (like a diode pointer). The +5 VDC Auxiliary Power Output (Pin 3) is protected by a 0.5 A self-resetting fuse. The return (ground) path is through Pin 6 or Pin 7, Signal Ground.

technical reference

DB-9 connections (SA models only)

Pin	Function	Description
4	+ 48 VDC Fan Power Output	This output provides +48 V for powering a customer-supplied cooling fan. The + 48 VDC Fan Power Output (Pin 4) is sourced directly from the user's 48 V DC power supply and is protected by a 1.1 A self-resetting fuse. Pin 4 and Pin 8 can only source a ***combined*** current of 1.0 A total.
5	Fan Power Return	This connection provides a return (ground) path for Pin 4 and Pin 8 (+ 48 VDC Fan Power Output) when using internal PWM fan control. Pin 5 and Pin 9 (Fan Power Return) can only sink a ***combined*** current of 1.0 A total. Internal circuitry allows the laser to control fan speed based on the laser's output power and chassis temperature. See *48 VDC fan speed control* for detailed information.
6	Signal Ground	Pin 6 and Pin 7 provide a return (ground) path for Pin 2 (Shutter Switch Input), Pin 3 (+5 VDC Auxiliary Power Output), or Pin 4/Pin 8 (+ 48 VDC Fan Power Output) when fan speed control is ***not*** required. Pin 6 and Pin 7, Signal Ground, are the only DB-9 pins connected to chassis ground. Do not use these pins if DC power is provided by an external customer-supplied DC power source.
7	Signal Ground	Pin 6 and Pin 7 provide a return (ground) path for Pin 2 (Shutter Switch Input), Pin 3 (+5 VDC Auxiliary Power Output), or Pin 4/Pin 8 (+ 48 VDC Fan Power Output) when fan speed control is ***not*** required. Pin 6 and Pin 7, Signal Ground, are the only DB-9 pins connected to chassis ground. Do not use these pins if DC power is provided by an external customer-supplied DC power source.
8	+ 48 VDC Fan Power Output	This output provides +48 V for powering a customer-supplied cooling fan. The + 48 VDC Fan Power Output (Pin 8) is sourced directly from the user's 48 V DC power supply and is protected by a 1.1 A self-resetting fuse. Pin 4 and Pin 8 can only source a ***combined*** current of 1.0 A total.
9	Fan Power Return	This connection provides a return (ground) path for Pin 4 and Pin 8 (+ 48 VDC Fan Power Output) when using internal PWM fan control. Pin 5 and Pin 9 (Fan Power Return) can only sink a ***combined*** current of 1.0 A total. Internal circuitry allows the laser to control fan speed based on the laser's output power and chassis temperature. See *48 VDC fan speed control* for detailed information.

DB-9 connections (SA models only)

48 VDC fan speed control

When operating air-cooled (SA model) ti-Series lasers with customer-supplied cooling fans, you can choose to run fans continuously at full-speed (no fan speed control) or at a variable speed using internal or external fan speed control. Each option is described below.

No fan speed control

To operate 48 VDC cooling fans continuously at full-speed, connect the positive (+) fan leads to Pin 4 and Pin 8, + 48 VDC Fan Power Output, and connect the negative (–) fan leads to Pin 6 and Pin 7, Signal Ground as shown in Figure 3-18.

Important Note: The combined current draw of ***both*** fans must not exceed 1.0 A to prevent tripping the internal 1.1 A self-resetting fuse.

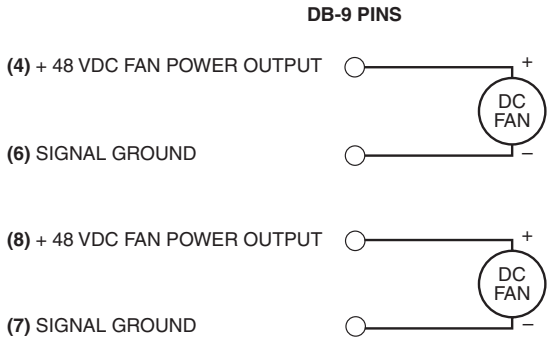


Figure 3-18 48 VDC fan connection – no speed control

Internal fan speed control

The side-mounted DB-9 connector on SA model lasers has internal circuitry that controls fan speed based on the laser's output power and chassis temperature. At tickle, or very low PWM duty cycles, cooling fans run at reduced speed to minimize noise; at higher PWM duty cycles, fan speed increases to match the cooling rate to power output. Fan speed is controlled by pulse width modulation (PWM) of the Fan Power Return lines (Pin 5/Pin 9) as shown in Figure 3-19.

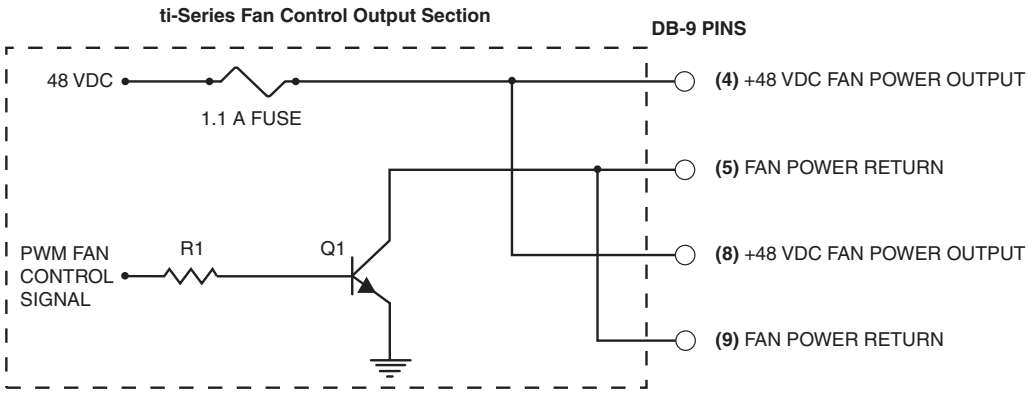


Figure 3-19 Internal fan speed control circuitry

DB-9 connections (SA models only)

Figure 3-20 illustrates the connections for internal fan speed control when using customer-supplied 48 VDC cooling fans. Connect the positive (+) fan leads to Pin 4 and Pin 8, +48 VDC Fan Power Output, and connect the negative (–) fan leads to Pin 5 and Pin 9, Fan Power Return.

Some types of cooling fans are not designed for PWM control and will stall at low speeds. SYNRAD has tested Delta EFB1248SHE cooling fans with good results.

Important Note: The combined current draw of ***both*** fans must not exceed 1.0 A to prevent tripping the internal 1.1 A self-resetting fuse.

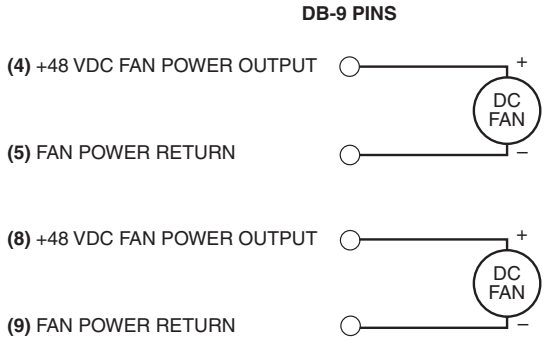


Figure 3-20 48 VDC fan connection – internal speed control

External fan speed control (ti80 only)

On Firestar ti80SA lasers only, the side-mounted DB-9 connector also provides an external PWM output, PWM Control Output, on Pin 1. This output provides a 5 V PWM signal for controlling the speed of PWM-enabled cooling fans based on the laser's output power and chassis temperature as shown in Figure 3-21. At tickle, or very low PWM duty cycles, cooling fans run at reduced speed to minimize noise; at higher PWM duty cycles, fan speed increases to match the cooling rate to laser power output.

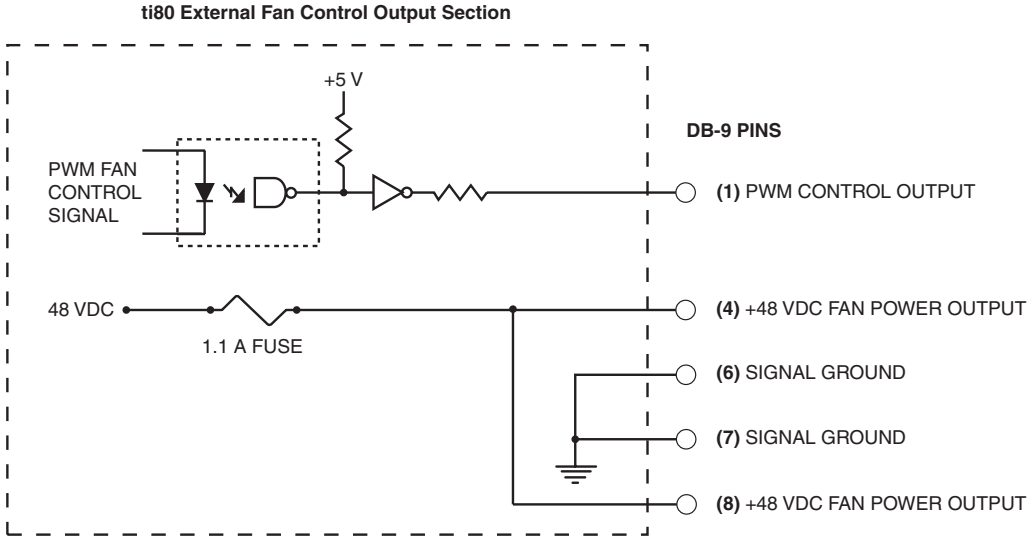


Figure 3-21 External fan speed control circuitry

DB-9 connections (SA models only)

Figure 3-22 illustrates the connections for external fan speed control when using customer-supplied 48 VDC cooling fans with PWM control capability. Connect the positive (+) fan leads to Pin 4 and Pin 8, +48 VDC Fan Power Output, connect the negative (–) fan leads to Pin 6 and Pin 7, Signal Ground, and connect Pin 1, PWM Control Output, to the PWM input terminal of both fans.

Important Note: The total current draw of ***both*** fans must not exceed 1.0 A to prevent tripping the internal 1.1 A self-resetting fuse.

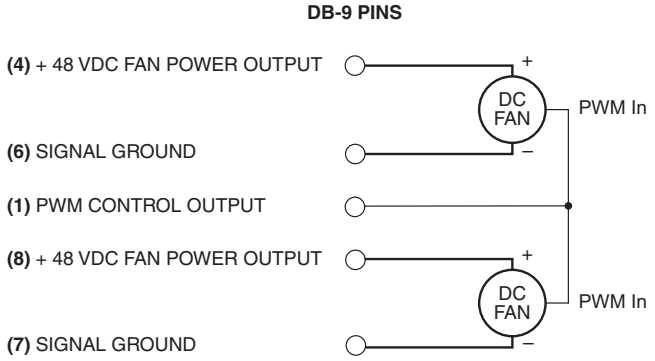


Figure 3-22 48 VDC fan connection – external speed control

Isolated cooling fan connections

To connect cooling fans operating at voltages other than 48 VDC or with currents greater than 1.0 A, a customer-designed isolation circuit like that shown in Figure 3-23 could power almost any type of DC cooling fan (with a suitably sized resistor and optoisolator device) while minimizing voltage or current spikes that might damage the laser's control board.

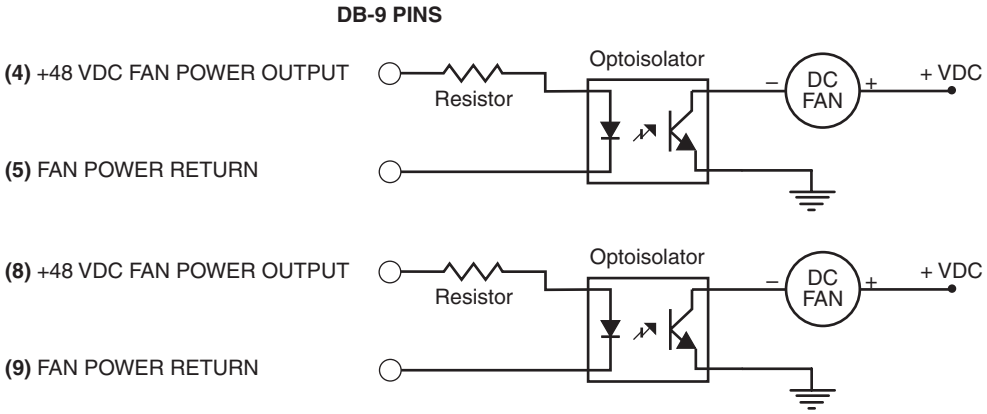


Figure 3-23 Alternate fan connections

For fans with PWM control capability, follow the circuit above except connect the optoisolator returns to Pin 6 and Pin 7, Signal Ground (instead of Pins 5 and 9), and connect Pin 1, PWM Control Output, to the PWM input terminal of both fans.

technical reference

Integrating Firestar safety features

The *Integrating Firestar safety features* section includes subsections:

- Keyswitch functions
- Shutter functions
- Remote interlock functions

Firestar's DB-15 *User I/O* connector allows system integrators or end-users to integrate Firestar safety features into their control system. Firestar's keyswitch, shutter, and remote interlock functions serve to enable or disable DC power to Firestar's RF drive. Without DC power, the RF driver cannot supply RF energy to the resonator, causing the CO_2 gas to remain in a zero-energy state. Firestar status indicators provide users with a quick visual indication of the laser's operational status. All power to the laser's RF driver is removed whenever *RDY* or *SHT* indicators are Off (Laser Ready or Shutter Open outputs open).

Keyswitch functions

Keyswitch lasers

After DC power-up or after a remote interlock fault, the *Keyswitch* must be toggled OFF/ON to reset the laser and enable the RDY LED, signaling 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*-equipped lasers in automated systems, this keyswitch/reset function is available via the Remote Reset/Start Request input on Pin 2 of the *User I/O* connector. To use this "remote keyswitch" functionality, first place the *Keyswitch* in the ON position. Then after each DC power-up cycle (or to reset a fault condition), apply a momentary voltage pulse in the range of ±5–24 VDC to Pin 2, the Remote Reset/Start Request input. Removing voltage allows DC power to reach the RF driver and begins a five-second delay after which lasing is enabled (*RDY* LED illuminates yellow). The RF driver is disabled as long as voltage is applied to Pin 2.

Your control system can monitor the laser's ready status on the *User I/O* connector by connecting your system's input between Pin 8, Laser Ready, and Pin 13, Output Common (see Figure 3-16). The Laser Ready output closes when the laser is enabled (*RDY* LED illuminated yellow), indicating that lasing is possible. The output is open (in a high-impedance state) and the *RDY* LED is off when lasing is disabled.

Note: After the Laser Ready output closes, a five-second delay occurs before lasing is enabled.

OEM lasers

On OEM lasers, the *RDY* LED illuminates on DC power-up (provided that Shutter Open Request and Remote Interlock inputs are enabled) and DC power is applied to the RF driver. Over temperature faults are reset by removing and then reapplying DC power after the laser has cooled. Remote interlock faults are not latched; the *RDY* LED illuminates yellow as soon as the interlock circuit is closed (when the *INT* LED turns from red to green) and lasing is enabled immediately.

Although a Remote Reset/Start Request input is not required to reset OEM faults, it can be used to inhibit (disable) lasing. Disable the laser by applying a voltage in the range of ±5–24 VDC to Pin 2, the Remote Reset/Start Request input. Removing voltage allows power to reach the RF driver and lasing is enabled (*RDY* LED illuminates yellow) immediately. The RF driver is disabled as long as voltage is applied to Pin 2.

Your control system can monitor the laser's ready status on the *User I/O* connector by connecting your system's input between Pin 8, Laser Ready, and Pin 13, Output Common (see Figure 3-16).

Integrating Firestar safety features

The Laser Ready output closes when the laser is enabled (*RDY* LED illuminated yellow), indicating that lasing is possible. The output is open (in a high-impedance state) and the *RDY* LED is off when lasing is disabled.

Shutter functions

A mechanical *Shutter Switch* is installed on all *Keyswitch*-equipped lasers. Lasing is enabled when the shutter is Open (*SHT* LED illuminated blue) and disabled when the shutter is Closed (*SHT* LED off). The *SHT* LED illuminates blue to indicate that DC power is applied to the RF driver.

For ti-Series OEM and *Keyswitch*-equipped lasers in automated systems, the shutter function is provided by the Shutter Open Request signal via Pin 10 on the *User I/O* connector. To use this "remote shutter", first place the *Shutter Switch* (if equipped) in the Open position and then apply a voltage in the range of ±5–24 VDC to Pin 10, Shutter Open Request. This input signal causes the *SHT* LED to illuminate and sends DC power to the RF driver, enabling lasing. On *Keyswitch*-equipped lasers, a five-second delay occurs after the input is enabled. Lasing is disabled until the manual *Shutter Switch* is placed in the Open position and a Shutter Open Request signal is applied to Pin 10.

Your control system can monitor the laser's shutter status on the *User I/O* connector by connecting your system's input between Pin 14, Shutter Open, and Pin 13, Output Common (see Figure 3-16). The Shutter Open output closes when the *Shutter Switch* is Open and a Shutter Open Request signal is present (*SHT* LED illuminated blue). The output is open (in a high-impedance state) and the *SHT* LED is off when the manual *Shutter Switch* is Closed or the Shutter Open Request signal is removed.

Note: After the Shutter Open output closes, a five-second delay occurs (*Keyswitch*-equipped lasers only) before lasing is enabled.

Remote interlock functions

Interlock circuits are often used to disable machinery when a shield, panel, or door is opened. Firestar's remote interlock function allows you to connect into an external remote interlock circuit and prevent lasing by removing DC power from the laser's RF driver when the circuit is electrically "open".

Lasing is enabled when a Remote Interlock signal is present (*INT* LED illuminated green), if *RDY* and *SHT* LEDs are illuminated, and disabled when the Remote Interlock signal is removed (*INT* LED red, *RDY* LED off). DC power is applied to the RF driver only when the *INT* LED is green and the *RDY* LED is yellow (and the *SHT* LED is illuminated blue). Remote interlock functionality is provided by the Remote Interlock input signal via Pin 3 on the *User I/O* connector.

To use Firestar's remote interlock feature, apply a voltage in the range of ±5–24 VDC to Pin 3, Remote Interlock. Applying an interlock signal causes the *INT* LED to illuminate green and sends DC power to the RF driver, which enables lasing (provided that the *RDY* LED is yellow and the *SHT* LED is blue). On *Keyswitch*-equipped lasers, a five-second delay occurs after the input is enabled. Removing the interlock signal removes DC power from the RF driver, causing the *INT* LED to turn red and the *RDY* LED to turn off. Lasing remains disabled until a Remote Interlock signal is reapplied to Pin 3.

Your control system can monitor the laser's remote interlock status on the *User I/O* connector by connecting your system's input between Pin 15, Interlock Open, and Pin 13, Output Common (see Figure 3-16). This output is closed when remote interlock circuitry is open (*INT* indicator illuminated red). The output is open (in a high-impedance state) and the *INT* LED is green when interlock circuitry is closed.

Note: After the Interlock Open output opens, a five-second delay occurs (*Keyswitch*-equipped lasers only) before lasing is enabled.

technical reference

Firestar ti60 general specifications

Table 3-7 Firestar ti60 general specifications

Parameter			
Output Specifications	**10.6 µm**	**10.2 µm**	**9.3 µm**
Wavelength, µm	10.55–10.68†	10.20–10.30	9.23–9.31
Power Output(1, 2)	60 W	60 W	60 W
Power Stability(3)	± 7%	± 7%	± 7%
Mode Quality, M^2	≤ 1.2	< 1.3	< 1.3
Beam Waist Diameter, at $1/e^2$, mm(4)	2.0 ±0.3	2.0 ±0.3	2.0 ±0.3
Beam Divergence, full angle, mrad	< 7.0	< 7.0	< 7.0
Ellipticity	< 1.2	< 1.2	< 1.2
Polarization	Linear, vert	Linear, vert	Linear, vert
Extinction Ratio	> 100:1	> 100:1	> 100:1
Rise Time	< 75 µs	< 75 µs	< 75 µs
Input Specifications			
Power Supply			
Voltage	48 V ±1.0 VDC		
Maximum Current(5, 6)	18 A		
Command Input Signal			
Voltage	+3.5 to +6.7 VDC		
Current	10 mA @ +6.7 VDC		
Frequency(7)	DC–160 kHz		
Duty Cycle	0%–100%		
Logic Low State (Vmin–Vmax)	0.0 to +0.8 VDC		
Logic High State (Vmin–Vmax)	+3.5 to +6.7 VDC		
Cooling Specifications	**(Air-cooled)**		**(Water-cooled)**
Maximum Heat Load	900 Watts		900 Watts
Minimum Flow Rate, Air	140 CFM per fan (×2)		N/A
Static Air Pressure	0.36 in H_2O		N/A
Recommended Flow Rate, Water	N/A		1.0–2.0 GPM
Maximum Coolant Pressure	N/A		60 PSI
Pressure Drop	N/A		11 PSI @ 1.5 GPM
Coolant Temperature(8)	≤ 40 °C, ambient		18–22 °C
Coolant Temperature Stability			± 1.0 °C

* Specifications subject to change without notice.

† Typical. Actual wavelength range may vary from 10.2–10.8 µm.

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

2 48 VDC input voltage to obtain guaranteed output power.

3 From cold start (guaranteed) at 95% duty cycle.

4 Measured at laser output.

5 User-supplied cooling fans on SA models may increase current load by an additional 1.0 A.

6 Firestar ti-Series lasers have no appreciable in-rush current.

7 Tested at 5 kHz.

8 Water-cooled lasers can be operated at coolant temperatures up to 30 °C (86 °F) in order to reduce problems associated with condensation; however, this may result in decreased laser performance and/or reduced laser lifetime.

Firestar ti60 general specifications

Parameter

Environmental Specifications

Operating Ambient Temperature Range[9] ...15 °C–40 °C

Humidity .....0–95%, non-condensing

Physical Specifications

ti60, water-cooled (KW, SW models)

Length .....22.98 in (58.4 cm)

Width ..... 5.62 in (14.3 cm)

Height ..... 5.90 in (15.0 cm)

Weight .....26.2 lbs (11.9 kg)

ti60, fan-cooled (KF, SF models)

Length .....22.46 in (57.1 cm)

Width ..... 7.72 in (19.6 cm)

Height ..... 5.90 in (15.0 cm)

Weight .....28.9 lbs (13.1 kg)

ti60, air-cooled (SA models)

Length .....22.46 in (57.1 cm)

Width ..... 6.22 in (15.8 cm)

Height ..... 5.83 in (14.8 cm)

Weight .....25.5 lbs (11.6 kg)

* Specifications subject to change without notice.

9 Published specifications guaranteed at a cooling temperature of 22 °C. For ti-Series lasers, some performance degradation may occur when operated in ambient air or cooling water temperatures above 22 °C. With air-cooled lasers, output laser power typically decreases 0.5–1% per degree Celsius increase in ambient temperature.

technical reference

Firestar ti80 general specifications

Table 3-8 Firestar ti80 general specifications

Parameter			
Output Specifications	**10.6 µm**	**10.2 µm**	**9.3 µm**
Wavelength, µm	10.55–10.68†	10.20–10.30	9.23–9.31
Power Output(1, 2)	80 W	80 W	80 W
Power Stability(3)	± 7%	± 7%	± 7%
Mode Quality, M^2	≤ 1.2	< 1.3	< 1.3
Beam Waist Diameter, at $1/e^2$, mm(4)	2.0 ±0.3	2.0 ±0.3	2.0 ±0.3
Beam Divergence, full angle, mrad	< 7.0	< 7.0	< 7.0
Ellipticity	< 1.2	< 1.2	< 1.2
Polarization	Linear, vert	Linear, vert	Linear, vert
Extinction Ratio	> 100:1	> 100:1	> 100:1
Rise Time	< 75 µs	< 75 µs	< 75 µs
Input Specifications			
Power Supply			
Voltage	48 V ±1.0 VDC		
Maximum Current(5, 6)	22 A		
Command Input Signal			
Voltage	+3.5 to +6.7 VDC		
Current	10 mA @ +6.7 VDC		
Frequency(7)	DC–160 kHz		
Duty Cycle	0%–100%		
Logic Low State (Vmin–Vmax)	0.0 to +0.8 VDC		
Logic High State (Vmin–Vmax)	+3.5 to +6.7 VDC		
Cooling Specifications	**(Air-cooled)**		**(Water-cooled)**
Maximum Heat Load	1200 Watts		1200 Watts
Minimum Flow Rate, Air	190 CFM per fan (×2)		N/A
Static Air Pressure	0.70 in H_2O		N/A
Recommended Flow Rate, Water	N/A		1.0–2.0 GPM
Maximum Coolant Pressure	N/A		60 PSI
Pressure Drop	N/A		11 PSI @ 1.5 GPM
Coolant Temperature(8)	≤ 40 °C, ambient		18–22 °C
Coolant Temperature Stability			± 1.0 °C

* Specifications subject to change without notice.

† Typical. Actual wavelength range may vary from 10.2–10.8 µm.

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

2 48 VDC input voltage to obtain guaranteed output power.

3 From cold start (guaranteed) at 95% duty cycle.

4 Measured at laser output.

5 User-supplied cooling fans on SA models may increase current load by an additional 1.0 A.

6 Firestar ti-Series lasers have no appreciable in-rush current.

7 Tested at 5 kHz.

8 Water-cooled lasers can be operated at coolant temperatures up to 30 °C (86 °F) in order to reduce problems associated with condensation; however, this may result in decreased laser performance and/or reduced laser lifetime.

Firestar ti80 general specifications

Parameter

Environmental Specifications

Operating Ambient Temperature Range[9] ...15 °C–40 °C

Humidity .....0–95%, non-condensing

Physical Specifications

ti80, water-cooled (KW, SW models)

Length .....22.98 in (58.4 cm)

Width ..... 5.62 in (14.3 cm)

Height ..... 5.90 in (15.0 cm)

Weight .....26.2 lbs (11.9 kg)

ti80, fan-cooled (KF, SF models)

Length .....22.46 in (57.1 cm)

Width ..... 7.72 in (19.6 cm)

Height ..... 5.90 in (15.0 cm)

Weight .....28.9 lbs (13.1 kg)

ti80, air-cooled (SA models)

Length .....22.46 in (57.1 cm)

Width ..... 6.22 in (15.8 cm)

Height ..... 5.83 in (14.8 cm)

Weight .....25.5 lbs (11.6 kg)

* Specifications subject to change without notice.

9 Published specifications guaranteed at a cooling temperature of 22 °C. For ti-Series lasers, some performance degradation may occur when operated in ambient air or cooling water temperatures above 22 °C. With air-cooled lasers, output laser power typically decreases 0.5–1% per degree Celsius increase in ambient temperature.

technical reference

Firestar ti100 general specifications

Table 3-9 Firestar ti100 general specifications

Parameter			
Output Specifications	**10.6 µm**	**10.2 µm**	**9.3 µm**
Wavelength, µm	10.55–10.68†	10.20–10.30	9.23–9.31
Power Output(1, 2)	100 W	100 W	100 W
Power Stability(3)	± 7%	± 7%	± 7%
Mode Quality, M^2	≤ 1.2	< 1.3	< 1.3
Beam Waist Diameter, at $1/e^2$, mm(4)	2.0 ±0.3	2.0 ±0.3	2.0 ±0.3
Beam Divergence, full angle, mrad	< 7.0	< 7.0	< 7.0
Ellipticity	< 1.2	< 1.2	< 1.2
Polarization	Linear, vert	Linear, vert	Linear, vert
Extinction Ratio	> 100:1	> 100:1	> 100:1
Rise Time	< 75 µs	< 75 µs	< 75 µs
Input Specifications			
Power Supply			
Voltage	48 V ±1.0 VDC		
Maximum Current(5)	35 A		
Command Input Signal			
Voltage	+3.5 to +6.7 VDC		
Current	10 mA @ +6.7 VDC		
Frequency(6)	DC–160 kHz		
Duty Cycle	0%–100%		
Logic Low State (Vmin–Vmax)	0.0 to +0.8 VDC		
Logic High State (Vmin–Vmax)	+3.5 to +6.7 VDC		
Cooling Specifications	**(Water-cooled)**		
Maximum Heat Load	1700 Watts		
Recommended Flow Rate, Water	1.0–2.0 GPM		
Maximum Coolant Pressure	60 PSI		
Pressure Drop	11 PSI @ 1.5 GPM		
Coolant Temperature(7)	18–22 °C		
Coolant Temperature Stability	± 1.0 °C		

* Specifications subject to change without notice.

† Typical. Actual wavelength range may vary from 10.2–10.8 µm.

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

2 48 VDC input voltage to obtain guaranteed output power.

3 From cold start (guaranteed) at 95% duty cycle.

4 Measured at laser output.

5 Firestar ti-Series lasers have no appreciable in-rush current.

6 Tested at 5 kHz.

7 Water-cooled lasers can be operated at coolant temperatures up to 30 °C (86 °F) in order to reduce problems associated with condensation; however, this may result in decreased laser performance and/or reduced laser lifetime.

Firestar ti100 general specifications

Parameter

Environmental Specifications

Operating Ambient Temperature Range[8] ...15 °C–40 °C

Humidity .....0–95%, non-condensing

Physical Specifications

ti100, water-cooled (KW, SW models)

Length .....22.98 in (58.4 cm)

Width ..... 5.62 in (14.3 cm)

Height ..... 5.90 in (15.0 cm)

Weight .....26.2 lbs (11.9 kg)

* Specifications subject to change without notice.

8 Published specifications guaranteed at a cooling temperature of 22 °C. For ti-Series lasers, some performance degradation may occur when operated in ambient air or cooling water temperatures above 22 °C.

Firestar ti-Series package outline drawings

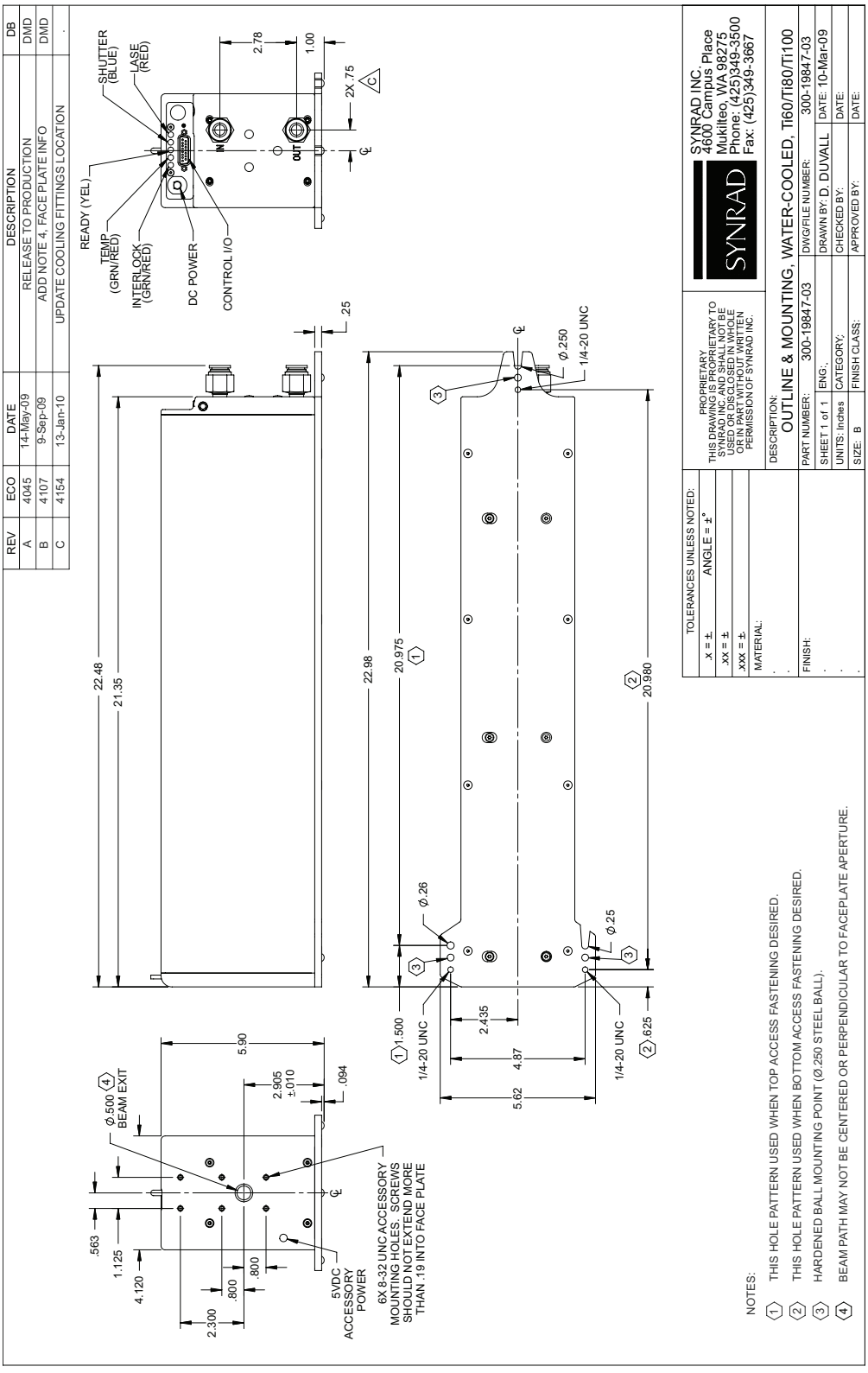


Figure 3-24 Water-cooled Firestar ti60/ti80/ti100 package outline and mounting dimensions

Firestar ti-Series package outline drawings

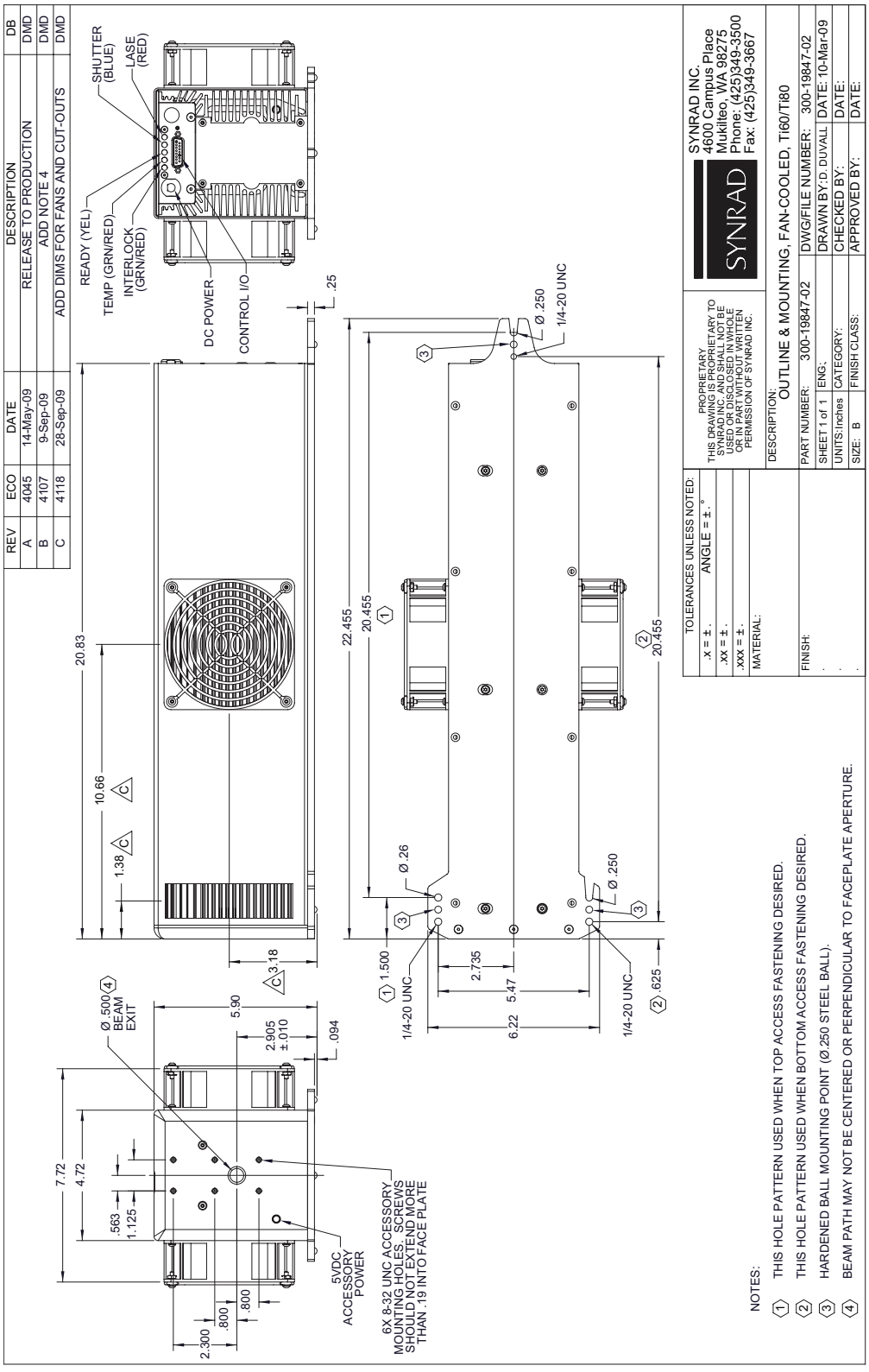


Figure 3-25 Fan-cooled Firestar ti60/ti80 package outline and mounting dimensions

Firestar ti-Series package outline drawings

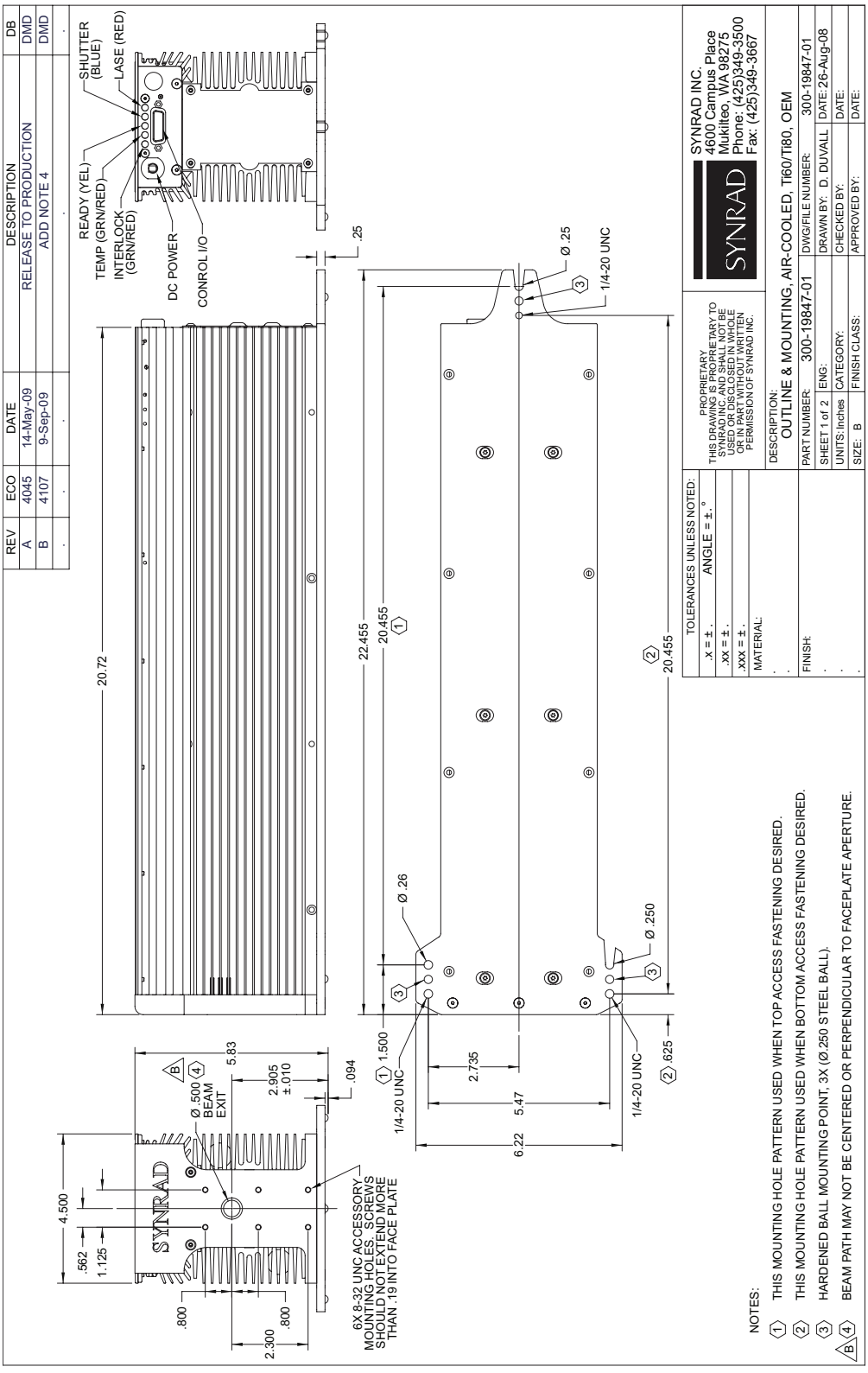


Figure 3-26 OEM air-cooled Firestar ti60/ti80 (SA model) package outline and mounting dimensions, sheet 1 of 2

Firestar ti-Series package outline drawings

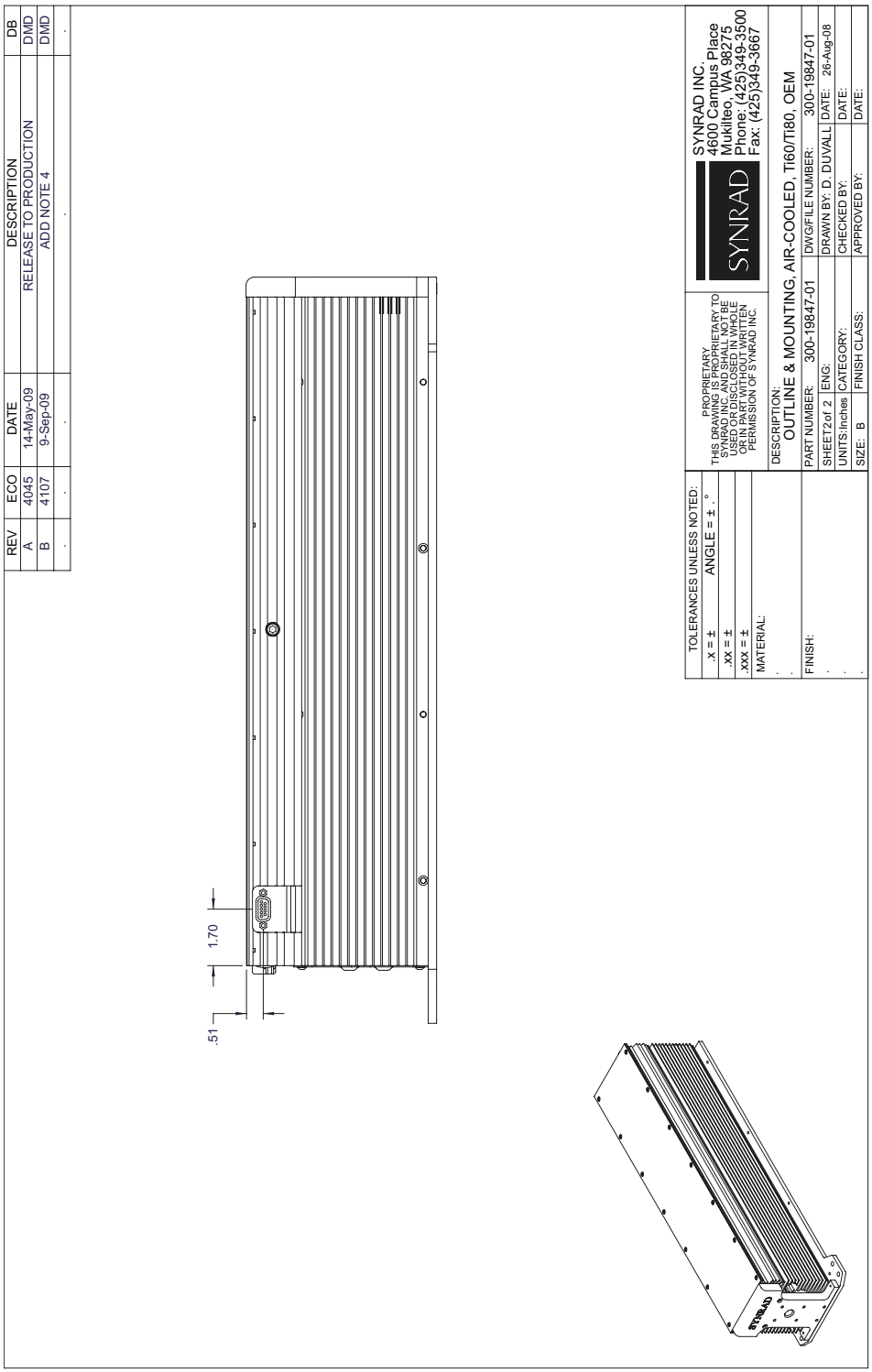


Figure 3-27 OEM air-cooled Firestar ti60/ti80 (SA model) package outline and mounting dimensions, sheet 2 of 2

Firestar ti-Series packaging instructions

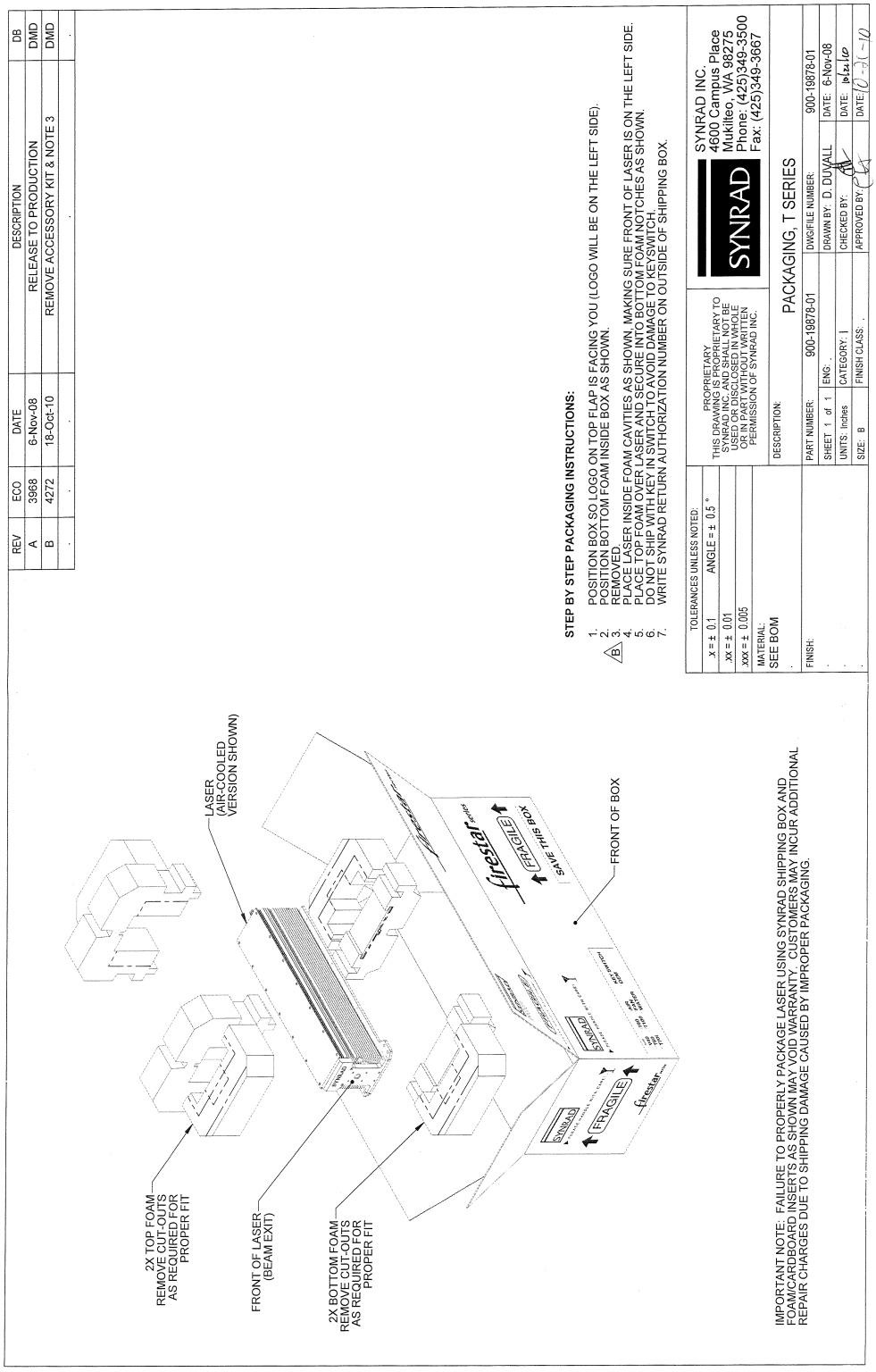


Figure 3-28 Firestar ti-Series packaging instructions

4 maintenance/ troubleshooting

Use information in this chapter to perform maintenance or troubleshoot your Firestar ti-Series laser.

This chapter contains the following information:

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

maintenance/ troubleshooting

Maintenance

The *Maintenance* section includes subsections:

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

Disabling the ti-Series laser

Before performing any maintenance on your Firestar® ti-Series laser, be sure to completely disable the laser by disconnecting DC power from the laser.

Daily inspections

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

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

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 precautions you can take to increase the longevity of your laser, marking head, and associated optical components.

1. For water-cooled lasers, inspect cooling tubing connections for signs of leakage. Check for signs of condensation that may indicate the cooling water temperature is set below the dew point temperature. Condensation will damage electrical and optical components inside the laser. See *Setting coolant temperature* in the Getting Started chapter for details on preventing condensation.
2. When using compressed air as a purge/assist gas for your beam delivery system, empty water traps and oil separators on each filter and/or dryer between the laser and your compressed air source. Compressed air purity must meet the gas purity specifications shown in Table 3-1 in the Technical Reference chapter.

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3 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.

4 Visually inspect the exterior housing of the laser to ensure that all warning labels are present. Refer to *Firestar ti-Series label locations* in the Laser Safety chapter for label types and locations.

Storage/shipping

When preparing a water-cooled 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.

When shipping SYNRAD lasers to another facility, we highly recommend that you ship the unit in its original SYNRAD shipping container. If you no longer have the original shipping box and inserts, contact SYNRAD Customer Service about purchasing replacement packaging. Refer to *Firestar ti-Series packaging instructions* in the Technical Reference chapter for detailed instructions on packaging the laser for shipment.

Important Note: Failure to properly package the laser using a SYNRAD-supplied shipping box and foam/cardboard inserts as shown in the *Firestar ti-Series packaging instructions* drawing may void the warranty. Customers may incur additional repair charges due to shipping damage caused by improper packaging.

Cleaning optical components

⚠ 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 aperture. Corneal damage or blindness may result from exposure to laser radiation.

Caution
possible equipment damage

Because of their smaller beam diameter, Firestar lasers have significantly higher power densities than previous SYNRAD lasers. This means that any 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.

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Maintenance

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.

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.

Cleaning guidelines

- Wear latex gloves or finger cots (powder-free) to prevent contamination of optical surfaces by dirt and skin oils.
- Never handle optics with tools; always use gloved hands or fingers.
- Hold optics by the outer edge; never touch the coated surface.
- Always place optics on lens tissue for protection; never place optics on hard or rough surfaces.
- It may be necessary to use a fluffed cotton swab or cotton ball instead of a lens wipe to uniformly clean the entire surface of small-diameter mounted optics.
- Before using cleaning agents, read 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
Latex gloves or finger cots	Powder free
Air bulb	Clean air bulb
Ethyl or isopropyl alcohol	Spectroscopic or reagent grade
Acetone	Spectroscopic or reagent grade
Lens wipe (preferred)	Optical (cleanroom) quality
Cotton balls or cotton swabs	High-quality surgical cotton/high-quality paper-bodied

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Maintenance

Cleaning optics

1 Shut off and lock out all power to the laser. You must verify that the laser is OFF (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.

Caution possible lens damage	Do not allow the nozzle of the air bulb to touch the optical surface. Any contact may damage the optic by scratching coatings on the optical surface. Do not use compressed shop air to blow contamination from the optic. Compressed air contains significant amounts of water and oil that form adsorbing films on the optical surface. Do not exert pressure on the surface of the optic during cleaning. Optical surfaces and coatings are easily scratched by dislodged contaminants. Use a new lens wipe on each pass as contaminants picked up by the wipe may scratch the optical surface.

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 lens wipe with the selected cleaning agent. Alcohol (least aggressive) is best for initial surface cleaning. Acetone (moderately aggressive) is best for oily residue or minor baked-on vapor and debris.

Important Note: If acetone is used as a cleaning solvent, a second follow-up cleaning of the optical surface using alcohol is required to remove any acetone residue.

5 Gently, and without applying pressure, drag the damp lens wipe across the optical surface in a single pass. **Do not rub or apply any pressure**, especially when using a cotton swab. Drag the wipe without applying any downward pressure.

Note: Use a clean lens wipe on each pass. The wipe will pick up and carry surface contaminants that may scratch optical surfaces or coatings.

To prevent streaking during the final alcohol cleaning, drag the lens wipe slowly across the surface so that the cleaning liquid evaporates right behind the wipe.

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
- Operational flowchart
- Functional block diagram
- Status LEDs
- Laser fault indications
- Resetting faults
- Other 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 outside 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/replacement information. To troubleshoot the Firestar ti-Series 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 both the operational flowchart and the functional block diagram. 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 paragraphs following each heading.

⚠ Danger
serious personal injury

This Class 4 laser product emits ***invisible*** infrared laser radiation in the 9.3–10.6 µm CO_2 wavelength band depending on model. Because 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 contact the laser beam. 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.

Caution
possible equipment damage

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

Troubleshooting

Operational flowchart

The flowchart in Figure 4-1 illustrates Firestar's start-up sequence.

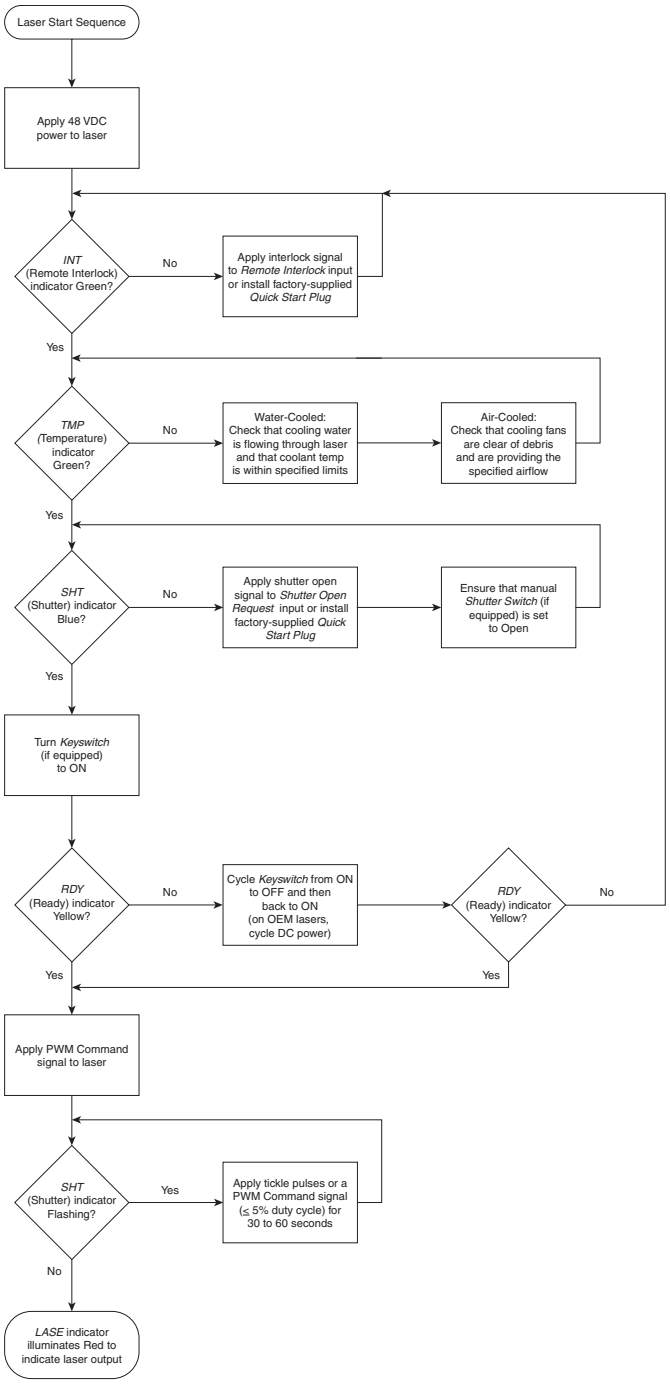

Figure 4-1 Operational flowchart

maintenance/ troubleshooting

Troubleshooting

Functional block diagram

Figure 4-2 is a functional block diagram illustrating ti-Series control architecture.

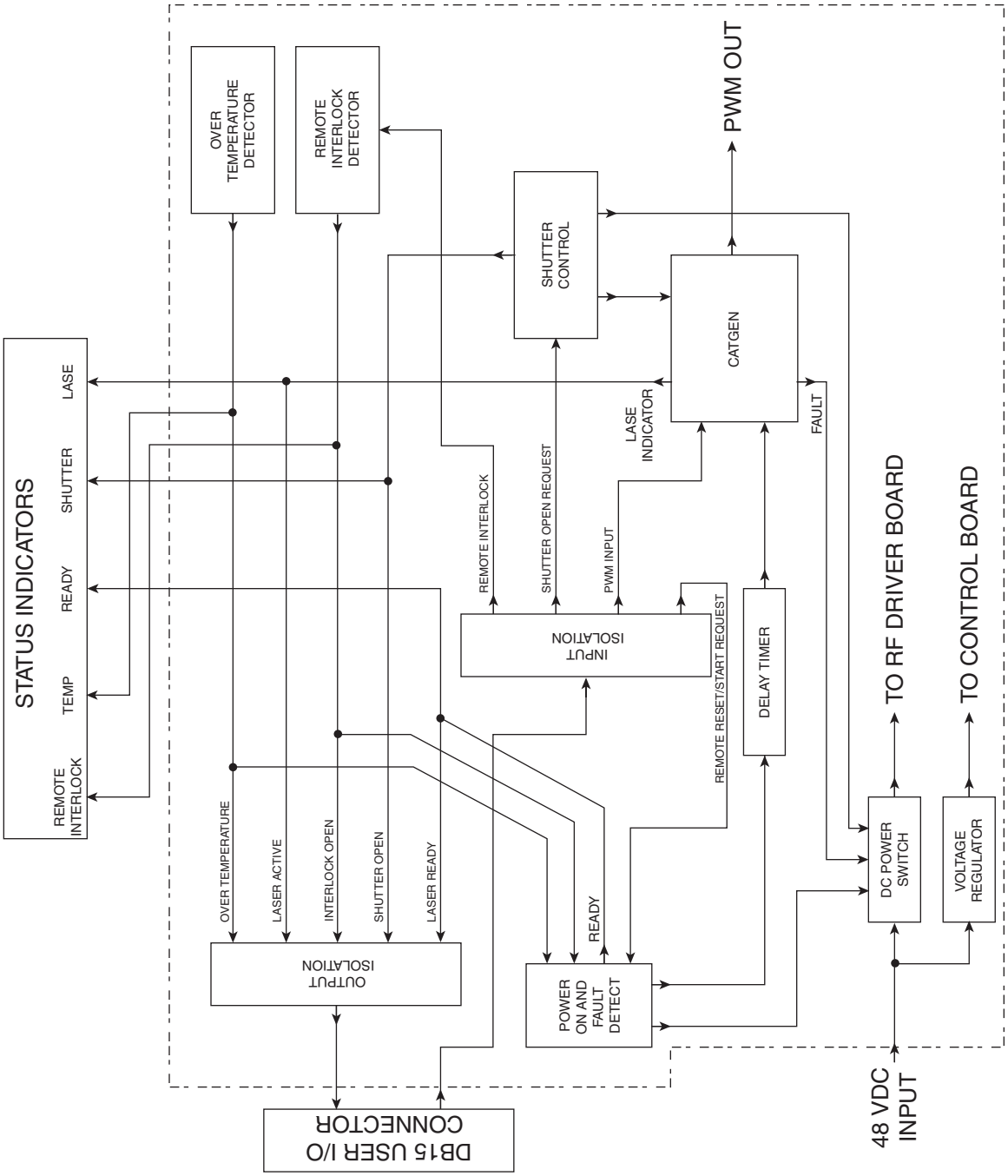

Figure 4-2 Firestar ti-Series functional block diagram

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Status LEDs

Firestar ti-Series LED indicators, also mirrored as output signals on the *User I/O* connector, provide status information to the user. Table 4-2 shows Firestar output signal and LED indicator states during normal and fault conditions. *User I/O* outputs are Closed when the state indicated by the signal name is True.

Table 4-2 Status signals

LED	LED Status		Output Signal Name	User I/O Output Status	
	Normal	Fault		Normal	Fault
INT	Green	– –	Interlock Open	Open	– –
	– –	Red	Interlock Open	– –	Closed
TMP	Green	– –	Fault Detected	Open	– –
	– –	Red	Fault Detected	– –	Closed
RDY	Yellow	– –	Laser Ready	Closed	– –
	– –	Off/Flashing	Laser Ready	– –	Open
SHT	Blue	– –	Shutter Open	Closed	– –
	– –	Off	Shutter Open	– –	Open
	– –	Flashing	Fault Detected	– –	Closed
LASE	Red	– –	Laser Active	Closed	– –
	– –	Off	Laser Active	– –	Open

On ti-Series keyswitch lasers, the *RDY* indicator illuminates yellow only when *INT* and *TMP* indicators are green and the *Keyswitch* is cycled from OFF to the ON position. After the *RDY* indicator illuminates, a five-second delay occurs before Firestar is permitted to lase. The *SHT* LED illuminates blue when a Shutter Open Request signal is applied and the manual *Shutter Switch* is set to Open. If the *RDY* indicator is lit and the shutter is switched from Closed to Open, there is a five-second delay until PWM inputs are recognized. When PWM Command pulses are applied (and are long enough to produce laser output) the *LASE* LED illuminates red.

On OEM lasers, the *RDY* lamp illuminates on DC power-up after *INT* and *TMP* indicators illuminate green. The *SHT* LED illuminates blue when a Shutter Open Request signal is applied. When both *RDY* and *SHT* indicators are lit, the laser is permitted to lase immediately. When PWM Command pulses are applied (and are long enough to produce laser output) the *LASE* LED illuminates red.

Note: Firestar *RDY* and *SHT* indicators (as well as Laser Ready and Shutter Open outputs) denote separate control functions. Although the *RDY* lamp may light while the *SHT* LED is Off (*Shutter Switch* Closed or Shutter Open Request signal missing), no power is applied to the RF driver until both *RDY* and *SHT* indicators are illuminated.

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Troubleshooting

Tables 4-3 through 4-8 show how Firestar's LED and output signal status changes as various operating and fault conditions occur. Table 4-9 lists specific laser faults that cause *RDY* and *SHT* indicators to flash.

Table 4-3 Normal operating condition

LED Indicator	LED Status	Output Signal	Output Status
INT	Green	Interlock Open	Open
TMP	Green	Fault Detected	Open
RDY	Yellow	Laser Ready	Closed
SHT	Blue	Shutter Open	Closed
LASE (tickle active)	Off	Laser Active	Open
LASE (if PWM applied)	Red	Laser Active	Closed

Table 4-4 Quick Start Plug or interlock/shutter inputs not connected

LED Indicator	LED Status	Output Signal	Output Status
INT	**Red**	Interlock Open	**Closed**
TMP	Green	Fault Detected	Open
RDY	**Off**	Laser Ready	**Open**
SHT	**Off**	Shutter Open	**Open**
LASE (tickle inactive)	Off	Laser Active	Open
LASE (if PWM applied)	Off	Laser Active	Open

Table 4-5 Interlock Open condition

LED Indicator	LED Status	Output Signal	Output Status
INT	**Red**	Interlock Open	**Closed**
TMP	Green	Fault Detected	Open
RDY	**Off**	Laser Ready	**Open**
SHT	Blue	Shutter Open	Closed
LASE (tickle inactive)	Off	Laser Active	Open
LASE (if PWM applied)	Off	Laser Active	Open

Troubleshooting

Table 4-6 Over Temperature fault

LED Indicator	LED Status	Output Signal	Output Status
INT	Green	Interlock Open	Open
TMP	**Red**	Fault Detected	**Closed**
RDY	**Off**	Laser Ready	**Open**
SHT	Blue	Shutter Open	Closed
LASE (tickle inactive)	Off	Laser Active	Open
LASE (if PWM applied)	Off	Laser Active	Open

Table 4-7 Shutter closed condition

LED Indicator	LED Status	Output Signal	Output Status
INT	Green	Interlock Open	Open
TMP	Green	Fault Detected	Open
RDY	Yellow	Laser Ready	Closed
SHT	**Off**	Shutter Open	**Open**
LASE (tickle inactive)	Off	Laser Active	Open
LASE (if PWM applied)	Off	Laser Active	Open

Table 4-8 No-Strike condition

LED Indicator	LED Status	Output Signal	Output Status
INT	Green	Interlock Open	Open
TMP	Green	Fault Detected	**Closed**
RDY	Yellow	Laser Ready	Closed
SHT	**Blue (Flashing)**	Shutter Open	Closed
LASE (tickle active)	Off	Laser Active	Open
LASE (if PWM applied*)	On	Laser Active	Closed

* A continuously flashing *SHT* LED indicates a No-Strike condition and the laser is limited to a 5% duty cycle (at 5 kHz) until the fault clears.

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Troubleshooting

Laser fault indications

Firestar ti-Series lasers have the ability to indicate five specific fault conditions. In the event of certain faults, the *RDY* LED will blink an error code, pause four seconds, and then repeat the error code. This sequence continues until the fault is corrected and the laser is reset by cycling DC power to the laser. If a No-Strike condition occurs, the *SHT* LED flashes continuously until the gas breaks down into a plasma state.

Table 4-9 lists error codes, the corresponding fault condition, and describes possible corrective actions.

Table 4-9 Laser error codes

LED	# of Blinks	Fault Condition	Corrective Action in Field
RDY	1 blink	Under-Voltage fault[1]	Verify 48 VDC (measured at laser under load).
RDY	2 blinks	Over-Voltage fault[1]	Verify 48 VDC (measured at laser under load).
RDY	3 blinks	RF Drive Switch fault[1]	Remove DC power to laser, wait 30 seconds, and then reapply DC power.
RDY	4 blinks	PWM Drive fault[1]	Remove DC power to laser, wait 30 seconds, and then reapply DC power.
SHT	Continuous	No-Strike fault[2]	Apply tickle or PWM signal (≤5% duty cycle) for 30 to 60 seconds.

1 The Laser Ready output opens (switches to a high impedance state) when a fault occurs.

2 A continuously flashing *SHT* LED indicates a No-Strike fault and the laser is limited to a 5% duty cycle (at 5 kHz). If the No-Strike fault clears, the laser will recover without cycling power. Common causes of No-Strike fault (gas breakdown) issues are environmental conditions—like cold overnight temperatures when the laser is off. In situations like this, it may take 30 to 60 seconds for gas breakdown to occur and begin normal daily operation. The Fault Detected output closes for a minimum of 50 ms or until the No-Strike fault clears.

Resetting faults

Keyswitch lasers

Remote interlock condition

A remote interlock condition occurs when the Remote Interlock input opens (*INT* LED changes from green to red). To reset a remote interlock fault, re-establish the Remote Interlock signal input (*INT* LED changes from red to green) and cycle the *Keyswitch* from OFF to ON (or apply a Remote Reset/Start Request pulse with the *Keyswitch* set to ON). When the *RDY* LED illuminates, lasing is enabled after a five-second delay.

Over temperature fault

Over temperature faults occur when thermal limits in the laser are exceeded (*TMP* LED changes from green to red). To reset an over temperature fault, lower coolant temperature below 30 °C (water-cooled) or 40 °C (air-cooled), cycle DC power to the laser, and then cycle the Keyswitch from OFF to ON (or apply a Remote Reset/Start Request pulse with the *Keyswitch* set to ON). When the *RDY* LED illuminates, lasing is enabled after five-seconds.

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Troubleshooting

Under/over voltage fault

An under-voltage or over-voltage fault occurs when the DC input voltage is below or above preset limits. This fault is indicated by the *RDY* LED flashing 1 blink (under-voltage) or 2 blinks (over-voltage). To reset an under-voltage or over-voltage fault, ensure that 48 VDC is applied to the laser under full-load conditions, cycle DC power, and then toggle the *Keyswitch* from OFF to ON (or apply a Remote Reset/Start Request pulse with the *Keyswitch* set to ON). When the *RDY* LED illuminates, lasing is enabled after a five-second delay.

Under- or over-voltage faults are typically caused by the DC power supply being unable to properly regulate output voltage under full-load or high inrush current conditions. Improper regulation may be caused by an undersized DC supply or insufficient AC line voltage.

RF Drive Switch fault

An RF Drive Switch fault is indicated by the *RDY* LED flashing 3 blinks. Reset the laser by removing DC power from the laser, wait 30 seconds, reapply DC power, and then toggle the *Keyswitch* from OFF to ON (or apply a Remote Reset/Start Request pulse with the *Keyswitch* set to ON). If the RF Drive DC fault reappears, contact SYNRAD or a SYNRAD Authorized Distributor.

PWM Drive fault

A PWM Drive fault is indicated by the *RDY* LED flashing 4 blinks. Reset the laser by removing DC power from the laser, wait 30 seconds, reapply DC power, and then toggle the *Keyswitch* from OFF to ON (or apply a Remote Reset/Start Request pulse with the *Keyswitch* set to ON). If the PWM Drive fault reappears, contact SYNRAD or a SYNRAD Authorized Distributor.

No-Strike condition

A continuously flashing *SHT* LED indicates a No-Strike condition and lasing is limited to a maximum 5% duty cycle (at a PWM Command signal frequency of 5 kHz). Apply tickle pulses or a PWM Command signal (≤ 5% duty cycle) for 30 to 60 seconds. When the gas breaks down into a plasma state, the laser will recover without cycling DC power. If the No-Strike fault persists, contact SYNRAD or a SYNRAD Authorized Distributor.

OEM lasers

⚠ Warning
serious personal injury

On Firestar ti-Series OEM lasers, remote interlock (*INT*) faults are not latched. Clearing the fault condition enables the *RDY* indicator and the laser will fire immediately provided the *SHT* indicator is lit and a PWM Command signal is applied. Because exposure to 9.3–10.6 µm CO_2 laser radiation can inflict severe corneal injuries and seriously burn human tissue, the OEM or System Integrator must ensure that appropriate safeguards are in place to prevent unintended lasing.

maintenance/ troubleshooting

Troubleshooting

Remote interlock condition

A remote interlock condition occurs when the Remote Interlock input opens (the *INT* indicator changes from green to red). On OEM lasers, remote interlock (*INT*) faults are not latched. Re-establish the Remote Interlock signal input (*INT* indicator changes from red to green) to enable the *RDY* indicator and begin lasing immediately.

Over temperature fault

Over temperature faults occur when thermal limits in the laser are exceeded (the *TMP* indicator changes from green to red). To reset an over temperature fault, lower coolant temperature below 30 °C (water-cooled) or below 40 °C (air-cooled) and then cycle DC power to the laser. When the *RDY* lamp is illuminated, lasing is enabled immediately.

Under/over voltage fault

An under-voltage or over-voltage fault occurs when the DC input voltage is below or above preset limits. This fault is indicated by the *RDY* indicator flashing 1 blink (under-voltage) or 2 blinks (over-voltage). To reset an under-voltage or over-voltage fault, ensure that 48 VDC is applied to the laser under full-load conditions and then cycle DC power. When the *RDY* indicator illuminates, lasing is enabled immediately.

Under- or over-voltage faults are typically caused by the DC power supply being unable to properly regulate output voltage under full-load or high inrush current conditions. Improper regulation may be caused by an undersized DC supply or insufficient AC line voltage.

RF Drive Switch fault

An RF Drive Switch fault is indicated by the *RDY* indicator flashing 3 blinks. Reset the laser by removing DC power to the laser, wait 30 seconds, and then reapply DC power. If the RF Drive Switch fault reappears, contact SYNRAD or a SYNRAD Authorized Distributor.

PWM Drive fault

A PWM Drive fault is indicated by the *RDY* indicator flashing 4 blinks. Reset the laser by removing DC power to the laser, wait 30 seconds, and then reapply DC power. If the PWM Drive fault reappears, contact SYNRAD or a SYNRAD Authorized Distributor.

No-Strike condition

A continuously flashing *SHT* LED indicates a No-Strike condition and lasing is limited to a maximum 5% duty cycle (at a PWM Command signal frequency of 5 kHz). Apply tickle pulses or a PWM Command signal (≤ 5% duty cycle) for 30 to 60 seconds. When the gas breaks down into a plasma state, the laser will recover without cycling DC power. If the No-Strike fault persists, contact SYNRAD or a SYNRAD Authorized Distributor.

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Other laser faults

When a laser fault occurs, Firestar's status LEDs and output signals will reflect a fault condition as indicated in Tables 4-3–4-8 or Table 4-9. Each Symptom listed below describes a particular fault. For each Symptom, specific causes and solutions are described under Possible Causes.

⚠ Warning
serious personal injury

On Firestar ti-Series OEM lasers, remote interlock (*INT*) faults are not latched. Clearing the fault condition enables the *RDY* indicator and the laser will fire immediately provided the *SHT* indicator is lit and a PWM Command signal is applied. Because exposure to 9.3–10.6 µm CO_2 laser radiation can inflict severe corneal injuries and seriously burn human tissue, the OEM or System Integrator must ensure that appropriate safeguards are in place to prevent unintended lasing.

Symptom:

- A remote interlock condition is indicated by the following status LED and I/O states:

INT LED	– **Red**	Interlock Open output	– **Closed**
TMP LED	– Green	Fault Detected output	– Open
RDY LED	– **Off**	Laser Ready output	– **Open**
SHT LED	– Blue	Shutter Open output	– Closed
LASE LED	– Off	Laser Active output	– Open

Possible Causes:

- No voltage applied to Pin 3 (Remote Interlock) of the *User I/O* connector.

On systems using remote interlocks, check to see that a positive or negative voltage (±5–24 VDC) is applied to Pin 3, Remote Interlock, with respect to Pin 11, Input Common, on the *User I/O* connector (refer to *User I/O connections* in the Technical Reference chapter for details). For systems not using interlocks, connect the factory-supplied *Quick Start Plug* to the *User I/O* connector on the laser's rear panel or wire your male DB-15 connector so that Pin 11 (Input Common) is jumpered to Pin 12 (Auxiliary DC Power Ground) and Pin 3 (Remote Interlock) is jumpered to Pin 4 (+5 VDC Auxiliary Power).

Symptom:

- An over temperature fault is indicated by the following status LED and I/O states:

INT LED	– Green	Interlock Open output	– Open
TMP LED	– **Red**	Fault Detected output	– **Closed**
RDY LED	– **Off**	Laser Ready output	– **Open**
SHT LED	– Blue	Shutter Open output	– Closed
LASE LED	– Off	Laser Active output	– Open

maintenance/ troubleshooting

Troubleshooting

Possible Causes:

- Water-cooled lasers – Cooling water temperature is above 30 °C (86 °F) or there is inadequate water flow through the laser.

Check that the chiller is maintaining a coolant temperature between 18 °C–30 °C (64 °F–86 °F) at a flow rate of 3.8–7.6 lpm (1.0–2.0 GPM). If coolant temperature is OK, check the flow rate. If a flow meter is not available, disconnect the cooling tubing from the chiller inlet (or the drain) and run the coolant for one minute into a five-gallon bucket; you should have close to 1.0–2.0 gallons. If there is much less than one gallon in the bucket, check the cooling path for kinked or pinched cooling tubes and check the chiller for a clogged or dirty filter.

Note: Water-cooled ti-Series lasers can be operated at coolant temperatures up to 30 °C to reduce problems associated with condensation; however, this may result in decreased laser performance and/or reduced laser lifetime.

- Fan-cooled lasers – Cooling fans are not providing adequate airflow to the laser.

Check that all cooling fans are clear of debris and are providing an airflow rate of at least 4.0 m^3/min (140 CFM) per fan at a maximum static pressure of 9.1 mm H_2O (0.36 in H_2O) for ti60 lasers or at least 5.4 m^3/min (190 CFM) per fan at a maximum static pressure of 17.8 mm H_2O (0.70 in H_2O) for ti80 lasers. To allow for proper airflow, cooling fans must have at least 57.2 mm (2.25 inches) of unobstructed clearance between the outside edge of the cooling fan housing and any mounting surface or enclosure.

Symptom:

- The *SHT* LED is flashing continuously because of a No-Strike condition as indicated by the following status LED and I/O states:

INT LED	– Green	Interlock Open	– Open
TMP LED	– Green	Fault Detected	**– Closed**
RDY LED	– Yellow	Laser Ready	– Closed
SHT LED	**– Blue (Flashing)**	Shutter Open	– Closed
LASE LED	– Off or Red	Laser Active	– Open or Closed

Possible Causes:

- A No-Strike condition has occurred, possibly due to cold environmental conditions that may prevent the gas from breaking down into a plasma state. If this occurs while a PWM signal is applied, laser output is limited to a PWM duty cycle of approximately 5% (at 5 kHz).

Apply tickle pulses or a PWM Command signal (≤ 5% duty cycle) for 30 to 60 seconds. When the gas breaks down into a plasma state, the laser will recover and begin lasing ***immediately*** at the commanded power level without cycling DC power.

maintenance/ troubleshooting

Troubleshooting

Symptom:

- A shutter closed condition is indicated by the following status LED and I/O states:

INT LED	– Green	Interlock Open output	– Open
TMP LED	– Green	Fault Detected output	– Open
RDY LED	– Yellow	Laser Ready output	– Closed
SHT LED	– **Off**	Shutter Open output	– **Open**
LASE LED	– Off	Laser Active output	– Open

Possible Causes:

- The *Shutter Switch* (if equipped) is Closed.

If your Firestar laser is equipped with a *Shutter Switch*, slide the switch to the Open position. The *SHT* indicator will illuminate blue.

- No voltage applied to Pin 10 (Shutter Open Request) on the *User I/O* connector.

Check to see that a positive or negative voltage (±5–24 VDC) is applied to Pin 10, Shutter Open Request, with respect to Pin 11, Input Common, on the *User I/O* connector (refer to *User I/O connections* in the Technical Reference chapter for details). If your system does not provide a Shutter Open Request signal, connect the factory-supplied *Quick Start Plug* to the *User I/O* connector on the laser's rear panel or wire your male DB-15 connector so that Pin 11 (Input Common) is jumpered to Pin 12 (Auxiliary DC Power Ground) and Pin 10 (Shutter Open Request) is jumpered to Pin 4 (+5 VDC Auxiliary Power).

Symptom:

- Your OEM laser has quit lasing or lasing halted and then restarted. The *LASE* LED may be Off or On depending on whether PWM Command signals are being applied, but no fault is indicated.

INT LED	– Green	Interlock Open output	– Open
TMP LED	– Green	Fault Detected output	– Open
RDY LED	– Yellow	Laser Ready output	– Closed
SHT LED	– Blue	Shutter Open output	– Closed
LASE LED	– Off or On	Laser Active output	– Open or Closed

Possible Causes:

- The remote interlock circuit momentarily opened.

Remote interlock faults are not latched on OEM lasers. This means that if an interlock open fault occurs, the *INT* indicator will turn red, the Interlock Open output will Close, the *RDY* light goes out, and lasing is disabled. However, if the interlock circuit closes again, the *INT* indicator will change from red to green, the Interlock Open output will Open, the *RDY* light illuminates, and lasing is enabled immediately.

maintenance/ troubleshooting

Troubleshooting

Symptom:

- The following status indications and output states appear on power-up:

INT LED	– **Red**	Interlock Open output	– **Closed**
TMP LED	– Green	Fault Detected output	– Open
RDY LED	– **Off**	Laser Ready output	– **Open**
SHT LED	– **Off**	Shutter Open output	– **Open**
LASE LED	– Off	Laser Active output	– Open

Possible Causes:

- The *Quick Start Plug* or Remote Interlock/Shutter Open Request inputs are not connected.

Connect the *Quick Start Plug* or interlock/shutter input field wiring to the DB-15 *User I/O* connector. See *User I/O connections* in the Technical Reference chapter for wiring details.

Symptom:

- There is no output laser beam; all LED status indicators are Off.

Possible Causes:

- No DC voltage is applied.

Ensure that DC power cable connections are tight and verify that +48 VDC is available on the power supply terminals under full-load (100% duty cycle) conditions.

Beam delivery optics

⚠ Warning
serious personal injury

The use of aerosol dusters containing difluoroethane causes "blooming", a condition that ***significantly*** expands and scatters the laser beam. This beam expansion can effect mode quality and/or cause laser energy to extend beyond the confines of optical elements in the system, possibly damaging acrylic safety shielding. Do not use air dusters containing difluoroethane in any area adjacent to CO_2 laser systems because difluoroethane persists for long time periods over wide areas.

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 precautions you can take to increase the longevity of your laser, marking head, and associated optical components.

maintenance/ troubleshooting

Troubleshooting

Symptom:

- The laser loses power over time; laser output power must be increased to maintain 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 aperture. 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. Because of the extremely high power density of Firestar lasers, pits or debris on the lens surface may absorb enough energy from the focused beam to crack the lens. If this happens, other optics in the beam path may be contaminated or damaged as well.

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

When the application requires air (instead of nitrogen) as an assist gas, we recommend the use of breathing quality air available in cylinders from a gas or 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, *Assist gas purity specifications*, in the Technical Reference chapter for filtering and drying specifications.

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