

ENGINEERED BY SYNRAD

ti Series Lasers

Operator's Manual



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1 General Information

For your protection, carefully read these instructions before installing and operating the laser.

Retain these instructions for future reference.

Novanta reserves the right to update this user manual at any time without prior notification.

If product ownership changes, this manual should accompany the product.

1.1 Trademark & Copyright

Novanta and ti Series lasers are registered trademarks of Novanta.

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

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1.2 Warranty Information

This is to certify that ti Series lasers are guaranteed by Novanta to be free of all defects in materials and workmanship for the period defined in the Novanta Terms and Conditions, as defined on the Novanta website: <https://novanta.com/terms/novanta-sales-terms-and-conditions/>

This warranty does not apply to any defects 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 Novanta of any shortage or damage. If no discrepancies are reported, Novanta shall assume the shipment was delivered complete and free of defects.

If, within the warranty period, any part of the laser should fail to operate, contact the Novanta CO₂ Laser Customer Care department using the Service Request form on the website (<https://novantaphotonics.com/service-request-form-header/>) or by emailing co2lasercustomer@novanta.com. When requesting support, please 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 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 Novanta for evaluation unless otherwise instructed.

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

Novanta and Novanta Authorized Distributors have the sole authority to make warranty statements regarding Novanta products. Novanta 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. Novanta 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 Novanta harmless from 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 Novanta, or the use thereof, infringes upon any Patent, foreign or domestic.

1.3 Contact Information

The CO₂ laser business (SYNRAD) is headquartered north of Seattle in Mukilteo, Washington, USA. Our mailing address is:

Novanta
4600 Campus Place
Mukilteo, WA 98275
USA

The fastest way to contact us is using the online contact us form. You can also call one of our global offices. See the following sections for more information.

1.3.1 Online Contact Form

For the fastest response, please fill out a request form on our website:

<https://novantaphotonics.com/contact-us/>

1.3.2 Americas, Asia Pacific

Novanta Headquarters, Bedford, USA

Phone: +1-781-266-5700

co2lasercustomer@novanta.com

1.3.3 Europe, Middle East, Africa

Novanta Europe GmbH, Wackersdorf, Germany

Phone: +49 9431 7984-0

sales-europe@novanta.com

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1.3.4 China

Novanta Sales & Service Office, Shenzhen, China

Phone: +86-755-8280-5395

Novanta Sales & Service Office, Suzhou, China

Phone: +86-512-6283-7080

1.3.5 Japan

Novanta Service & Sales Office, Tokyo, Japan

Phone: +81-3-5753-2460

1.4 Application Testing

Novanta Regional Sales Managers work with customers to identify and develop the best CO₂ 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, utilize the contact information listed above.

You can also use the Application Test Request form on our website:

<https://novantaphotonics.com/application-test-request-form-header/>

1.5 General Inquiries

For assistance with order or delivery status or service status, please use the Information Request form on our website: <https://novantaphotonics.com/info-request-form-header/>

To obtain a Return Authorization (RA) number, please use the Service Request form on our website:

<https://novantaphotonics.com/service-request-form-header/>

For all other inquiries, please contact our Customer Care team by emailing

co2lasercustomer@novanta.com.

1.6 Technical Support

Novanta Regional Sales Managers can 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 submit questions using the Technical Support Request form on our website

(<https://novantaphotonics.com/technical-support-request-form-header/>) or by sending an email to co2lasercustomer@novanta.com.

1.7 Reference Materials

Your Regional Sales Manager can provide reference materials including Outline & Mounting drawings, Operator's Manuals, Technical Bulletins, and Application Newsletters.

Additional reference information can be found online in our resource hub:

<https://novantaphotonics.com/the-resource-hub/>




2 Laser Safety

2.1 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.

2.1.1 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, could 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 moderate or minor 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.

2.1.2 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 CO₂ wavelength band, depending on model.

Do not allow laser radiation to enter the eye by viewing direct or reflected laser energy. CO₂ 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 CO₂ 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 wherever possible. Exposure to direct or diffuse CO₂ laser radiation can seriously burn human or animal tissue, which may cause permanent damage.

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

**Danger: Serious Personal Injury**

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

**Warning: Serious Personal Injury**

For laser systems being used or sold within the USA, customers should refer to and follow the laser safety precautions described American National Standards Institute (ANSI) document Z136.1-2022, *Safe Use of Lasers*.

For laser systems being used or sold outside the USA, customers should refer to and follow the laser safety precautions described in European Normative and International Electrotechnical Commission documents IEC/ TR 60825-14:2022, *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 (SDS) 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 Z136.1-2022, *Safe Use of Lasers*, section 7.3.

U.S. Government's *Code of Federal Regulations*: 29 CFR §1910, §§ 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**

Using unspecified controls, adjustments, or procedures 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 affect mode quality and/or cause laser energy to extend beyond the confines of optical elements in the system, damaging acrylic safety shielding. Do not use air dusters containing difluoroethane in any area adjacent to CO₂ laser systems because difluoroethane persists for long time periods over wide areas.

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 Z136.1-2022, *Safe Use of Lasers* always 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 CO₂ laser is an intense energy 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.

Using unspecified controls, adjustments, or procedures may result in exposure to 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.

2.1.3 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.

2.1.4 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 Novanta who, for a fee, will ensure adequate disassembly, recycling and/or disposal of the product.

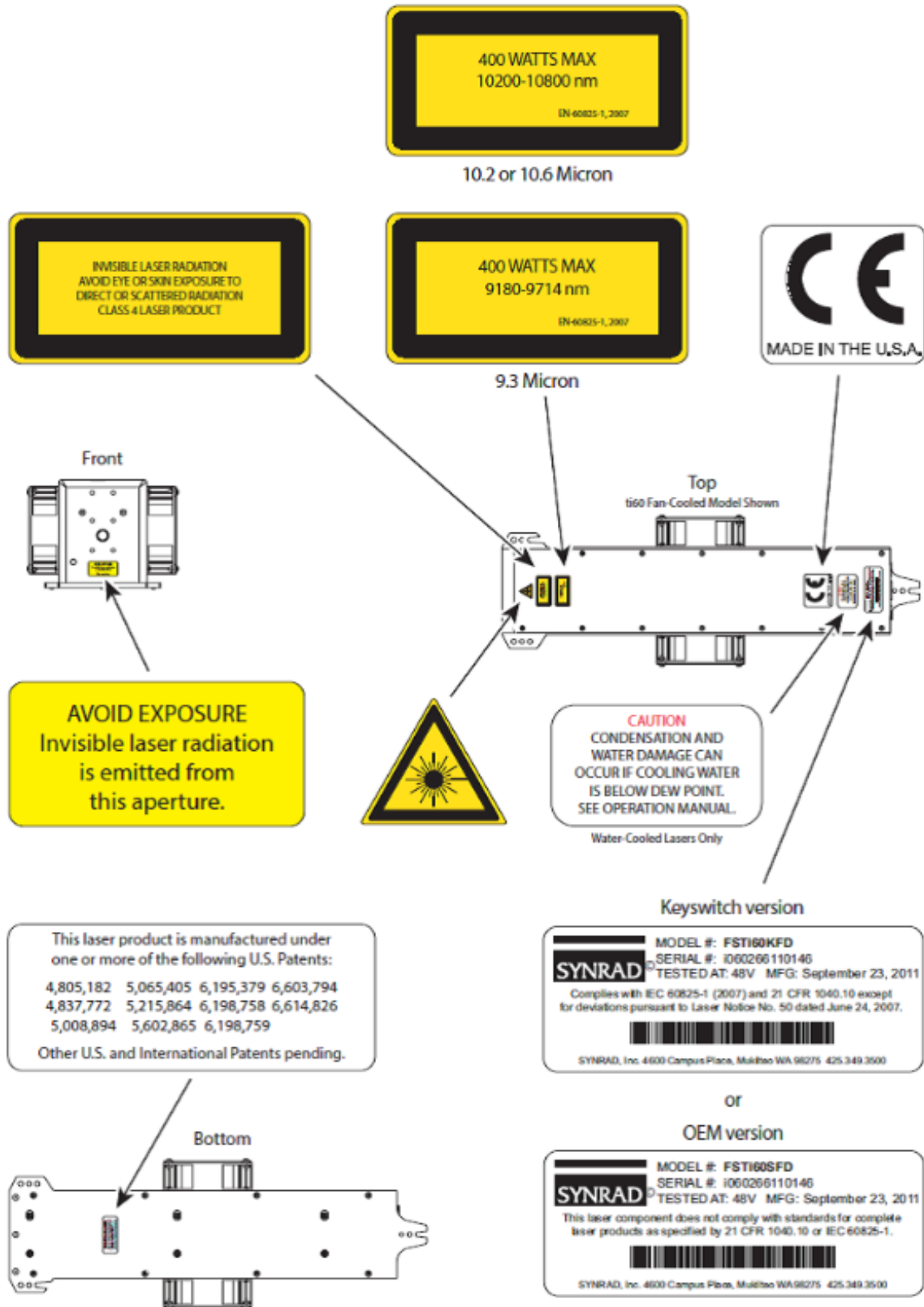
2.1.5 Additional Laser Safety Information

The Occupational Safety and Health Administration (OSHA) provides an online Technical Manual located at <https://www.osha.gov/otm> . Section III, Chapter 6 and Appendix III are useful resources for laser safety information.

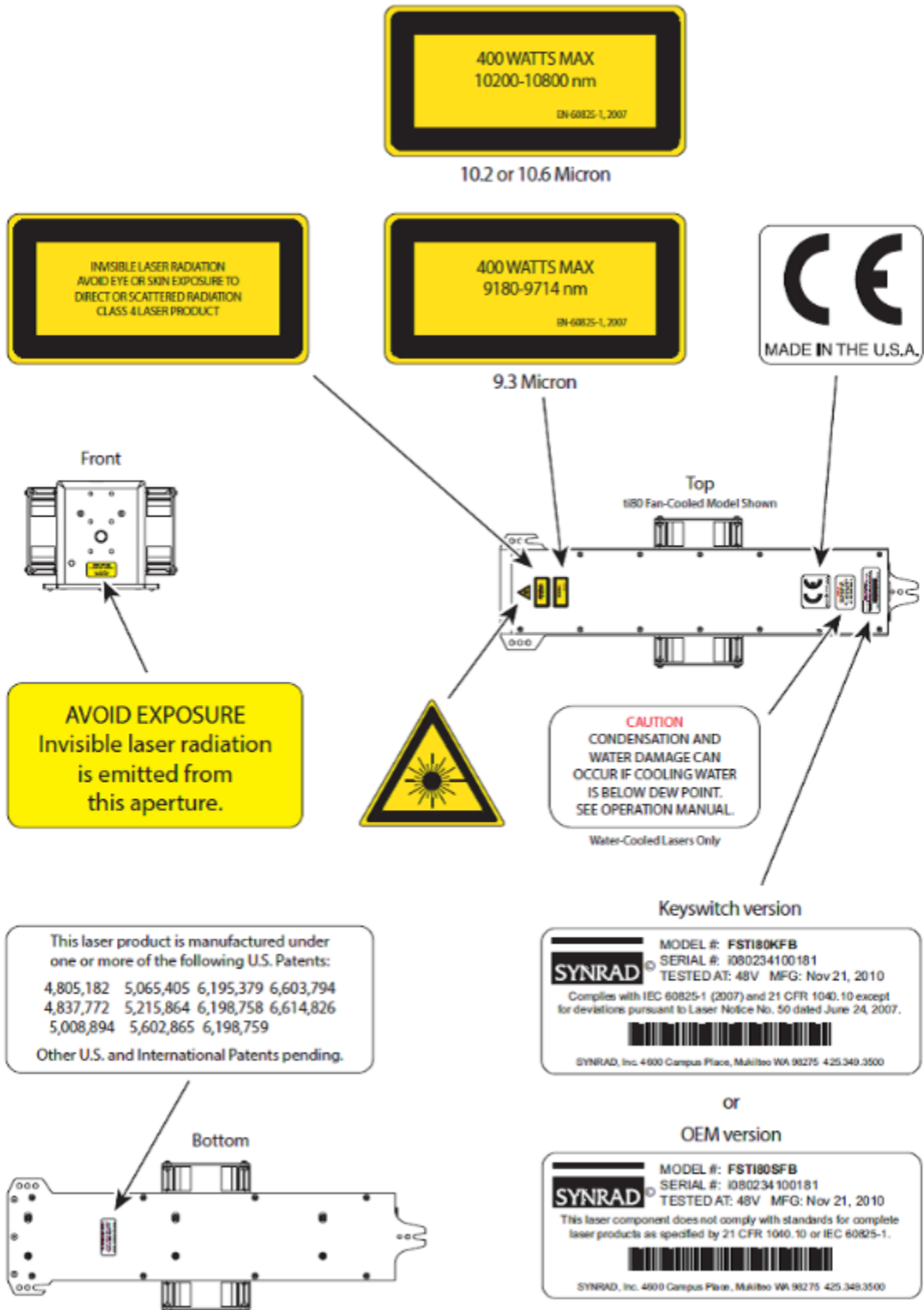
Another excellent laser safety resource is the Laser Institute of America (LIA). Their comprehensive web site is located at <http://www.lia.org>.

2.2 Label Locations

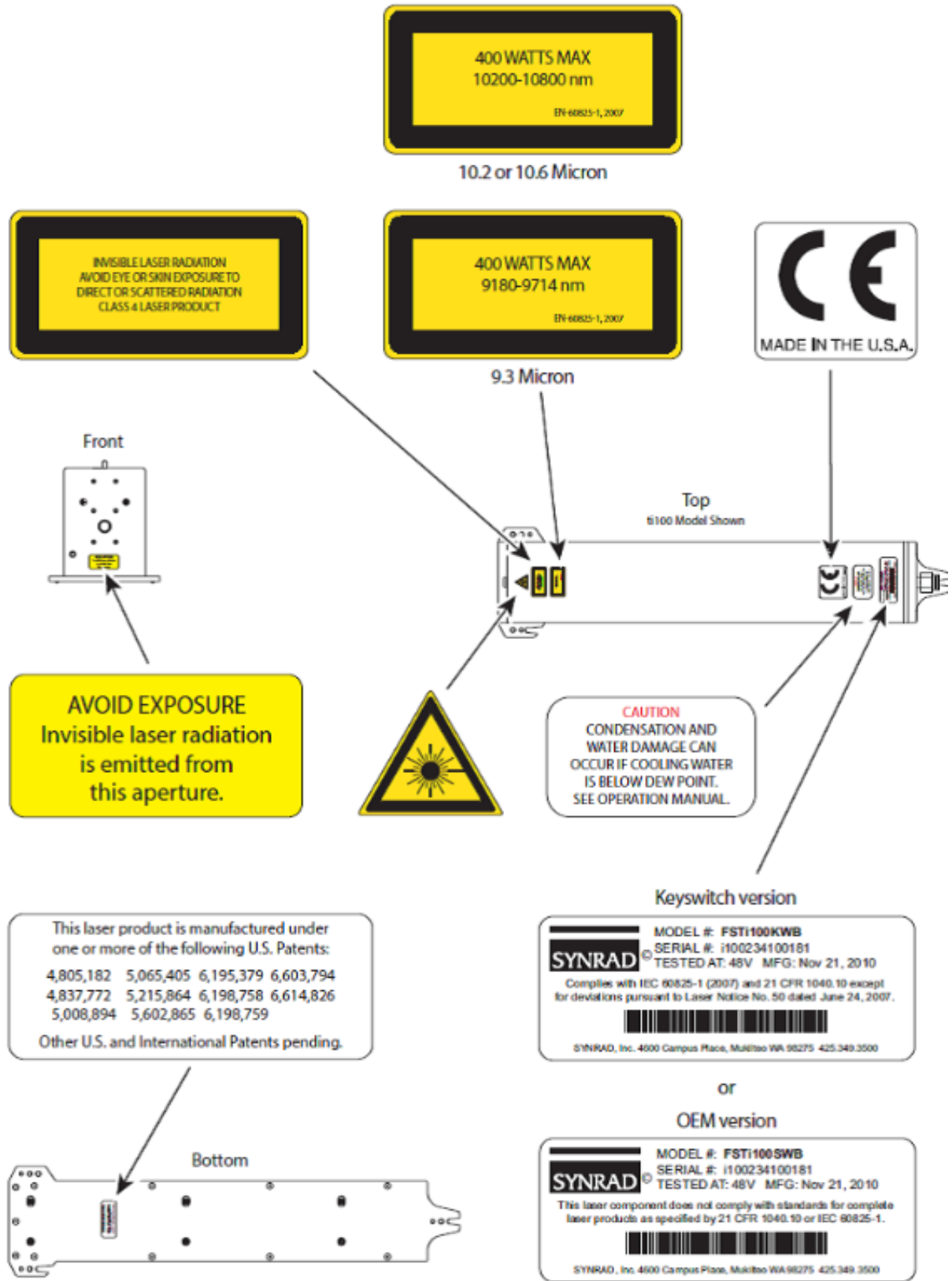
2.2.1 Figure: ti60 Laser Label Location



2.2.2 Figure: ti80 Laser Label Locations



2.2.3 Figure: ti100 Laser Label Locations



2.3 Agency Compliance

Novanta 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 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 authority 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, Novanta 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 the Standards for complete laser processing systems as specified by 21 CFR, Part 1040 or EN 60825-1. Novanta assumes no responsibility for the compliance of the system into which OEM laser products are integrated.

2.3.1 Center for Devices and Radiological Health (CDRH) Requirements

Note:

Ti Series lasers are available in either Keyswitch or OEM versions.

2.3.1.1 Keyswitch models

The 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 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 2.3.4 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.

2.3.1.2 OEM models

The ti Series lasers are OEM products intended for incorporation as components in laser processing systems. As supplied by Novanta, 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.

There are features incorporated into the design of ti Series lasers to comply with CDRH requirements. The features are integrated as panel controls or indicators, internal circuit elements, or input/output signal interfaces. Specifically, these features include lase and laser ready indicators, remote interlock for power on/off, a laser aperture shutter switch, and a five-second delay between power on and lasing.

Incorporation of certain features is dependent on the laser version (Keyswitch or OEM). See 2.3.4 *Table: Class 4 Safety Features Required by CDRH & EN60825* for the features available on ti Series lasers, the type and description of the feature, and if the feature is required by CDRH regulations.

2.3.2 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 is 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.

Novanta 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, Subpart C for Radiated and Conducted Emissions.

2.3.2.1 FCC Information

Note:

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

Interference Potential

In our testing, Novanta has not discovered any significant electrical interference traceable to ti Series lasers.

System Maintenance

Ensure that all exterior covers are properly fastened in position.

Measures to Correct Interference

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

FCC Caution to the User

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

2.3.3 European Union (EU) Requirements

Note:

Ti Series lasers are available in either Keyswitch or OEM versions.

2.3.3.1 RoHS Compliance

Novanta ti Series lasers meet the requirements of the European Parliament and Council Directive 2015/863/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.

2.3.3.2 Laser Safety Standards

Under the Low Voltage Directive, 2014/35/EU, the European Norm (EN) document EN 60825- 1:2014 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 60825-14:2022 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

The ti Series Keyswitch models are designed to comply with the requirements imposed by EN 60825-1 for Class 4 laser products. Table 2.3.4, 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

The ti Series OEM lasers are OEM products intended for incorporation as components in laser processing systems. As supplied by Novanta, 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 60825-1:2014, EN 60204-1:2016, Safety of Machinery; the Machinery Directive, 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. See table 2.3.4 *Class 4 Safety Features Required by CDRH & EN60825-1*, for a summary of product features, indicating the type and description of features and whether those features are required by European Union regulations.

2.3.4 Table: Class 4 Safety Features Required by CDRH & EN60825-1

Feature	Location	Description	Required by:		Available on ti Series
			CDRH	EN60825-1	
Keyswitch ¹	Rear Panel Control	On/Off/Reset Key switch controls power to laser electronics. Key cannot be removed from switch in the "On" position.	Yes	Yes	Yes ¹
Shutter Function ¹	Laser Control	Functions as a beam attenuator to disable RF driver/laser output when closed.	Yes	Yes	Yes ¹
Shutter indicator (SHT)	Rear Panel Indicator (Blue)	Illuminates blue to indicate shutter is open.	No	No	Yes
Ready Indicator (RDY)	Rear Panel Indicator (Yellow)	Indicates that laser has power applied and is capable of lasing.	Yes	Yes	Yes
Lase Indicator (LASE)	Rear panel indicator (Red)	Indicates that laser is actively lasing. Lase LED illuminates when the duty cycle of the command cycle is long enough to produce laser output.	No	No	Yes
Five second delay ²	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 ³
Power Fail Lockout ¹	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 ³
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 Indicator (INT)	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	Circuit Element	Temperature shutdown occurs if temperature of the laser tube rises above safe operating limits	No	No	Yes
Temperature indicator (TMP)	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	Laser exterior	Labels attached to various external housing locations to warn personnel of potential laser hazards.	Yes	Yes	Yes

¹Not available nor required on ti Series OEM lasers.

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

³ Keyswitch versions only

2.3.4.1 Electromagnetic Interference Standards

The European Union’s Electromagnetic Compatibility (EMC) Directive, 2014/30/EU, 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 ti Series lasers, EN 61000- 6-4:2018 defines radiated and conducted RF emission limits while EN 61000-6-2:2016 defines immunity standards for industrial environments.

The ti Series lasers have been tested and found to comply by demonstrating performance characteristics that have met or exceeded the requirements of EMC Directive 2014/30/EU.



When integrating 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, Novanta’s testing program has demonstrated that ti Series lasers comply with the relevant requirements of 2014/30/EU, the Electromagnetic Compatibility Directive, as summarized in Table 2.3.4.2 below.

2.3.4.2 Table: European Union Directives



Applicable Standards/ Norms	
2014/30/EU	Electromagnetic Compatibility Directive
2014/35/EU	Low Voltage Directive
2015/863/EU	RoHS Directive
EN 61010-1	Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use - Part 1: General Requirements
EN 61000-6-4	Radiated Emissions Group 1, Class A
EN 61000-6-4	Conducted Emissions Group 1, Class A
EN 61000-6-2	Electrostatic Discharge Immunity
EN 61000-6-2	RF Electromagnetic Field Immunity
EN 61000-6-2	Electrical Fast Transient/Burst Immunity
EN 61000-6-2	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 a Declaration of Conformity.



2.3.5 Ti60 Declaration of Conformity

Declaration of Conformity	
in accordance with ISO / IEC 17050-2:2004	
We,	
Manufacturer's Name:	SYNRAD® A Novanta® Company
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:	FSti60KxH, KxG (Keyswitch) FSti60SxH, SxG (*OEM)
Conforms to the following Directive(s) and Standard(s):	
Applicable Directive(s):	2014/30/EU Electromagnetic Compatibility Directive 2014/35/EU Low Voltage Directive (EU) 2015/863 RoHS Directive
Applicable Standard(s):	
EN 61010-1:2010	Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use - Part 1: General Requirements
EN 60825-1-4:2014	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 Electronic 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 60825-1:2014, <i>Safety of Laser Products</i> . Buyers of OEM laser products are solely responsible for meeting applicable Directives and Standards for CE compliance and marking.	
Corporate Officer:	European Contact:
 Justin Ryser, Quality Manager of SYNRAD	Novanta Distribution (USD) GmbH Werk 4 92442 Wackersdorf, Germany
Dated: 12/7/23	
	 MADE IN THE U.S.A. 900-20976-01 Rev E

2.3.6 Ti80 Declaration of Conformity

Declaration of Conformity	
in accordance with ISO / IEC 17050-2:2004	
We,	
Manufacturer's Name:	SYNRAD® A Novanta Company
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:	FSti80KxC, KxD (Keyswitch) FSti80SxC, SxD (*OEM)
Conforms to the following Directive(s) and Standard(s):	
Applicable Directive(s):	2014/30/EU Electromagnetic Compatibility Directive 2014/35/EU Low Voltage Directive (EU) 2015/863 RoHS Directive
Applicable Standard(s):	
EN 61010-1:2010	Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use - Part 1: General Requirements
EN 60825-1-4:2014	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 Electronic 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 60825-1:2014, <i>Safety of Laser Products</i> . Buyers of OEM laser products are solely responsible for meeting applicable Directives and Standards for CE compliance and marking.	
Corporate Officer:	European Contact:
	Novanta Distribution (USD) GmbH
Justin Ryser, Quality Manager of SYNRAD	Werk 4 92442 Wackersdorf, Germany
Date: 12/7/23	
	
	MADE IN THE U.S.A. 900-20976-15 Rev E

2.3.7 Ti100 Declaration of Conformity

Declaration of Conformity	
in accordance with ISO / IEC 17050-2:2004	
We,	
Manufacturer's Name:	SYNRAD® A Novanta Company
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:	FSti100KWC, KFB (Keypress) FSti100SxB, SxC (*OEM)
Conforms to the following Directive(s) and Standard(s):	
Applicable Directive(s):	2014/30/EU Electromagnetic Compatibility Directive 2014/35/EU Low Voltage Directive (EU) 2015/863 RoHS Directive
Applicable Standard(s):	
EN 61010-1:2010	Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use - Part 1: General Requirements
EN 60825-1-4:2014	Safety of Laser Products (Keypress 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 Electronic 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 60825-1:2014, <i>Safety of Laser Products</i> . Buyers of OEM laser products are solely responsible for meeting applicable Directives and Standards for CE compliance and marking.	
Corporate Officer:	European Contact:
	Novanta Distribution (USD) GmbH
Justin Ryser, Quality Manager of SYNRAD	Werk 4 92442 Wackersdorf, Germany
Date: 12/7/23	
	 MADE IN THE U.S.A. 900-20976-11 Rev D

3 Getting Started

Use information in this chapter to prepare your OEM ti series laser for operations. 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*.

3.1 Introduction

The ti Series lasers are a series of small-footprint lasers 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, our compact ti Series lasers mount easily to flatbed cutters, robotic arms, or gantry systems making integration into your production line simple and fast. The high-performance RF circuitry designed specifically to match its compact resonator delivers fast rise times with outstanding performance. High power, fast pulsing capabilities, and exceptional optical quality are ideally suited for applications where rapid scanning or pulsing of the laser beam is required.

The ti series lasers are available in an air-cooled, fan-cooled, and water-cooled configuration. Air-cooled configurations require that the OEM or end user supply the appropriate means of cooling the laser.

The ti Series lasers are OEM products intended for incorporation as a component in a laser processing system, and as such do not comply with 21 CFR, Subchapter J, or EN60825-1, without additional safeguards.

3.1.1 Nomenclature

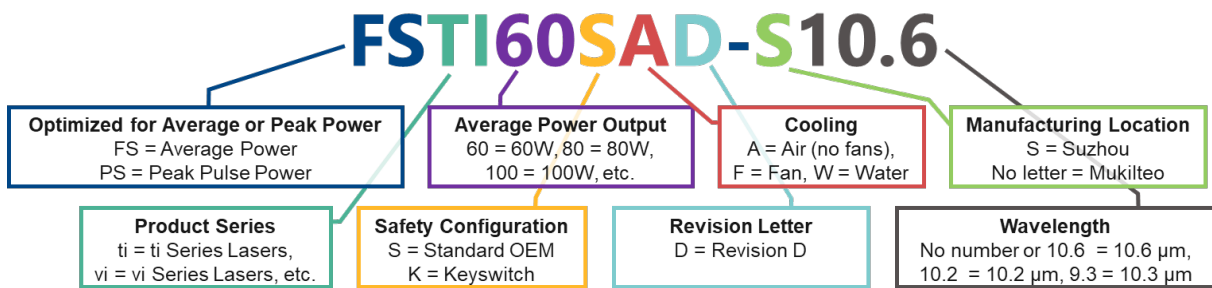
The ti Series lasers are divided into two distinct functional categories: Keyswitch and OEM models. In addition to a manual Keyswitch, all Keyswitch-equipped lasers include a manual shutter switch that allows the laser output aperture to be blocked. OEM lasers do not incorporate either a manual keyswitch 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.

The laser part number structure is shown in 3.1.2 *Figure: Decoding Part Numbers*. The part number includes information specifying:

- Average power or peak power optimization: "FS" indicates the laser is optimized for average power and CW operation, "PS" indicates it is optimized for high peak power and pulsed operation.
- Product family: "ti" indicates it is part of the ti Series product family. Other options include "vi", "f", "i", and "p".
- Average power: "60" for 60W, "80" for 80W and "100" for 100W
- Safety configuration: "K" for Keyswitch or "S" Standard OEM models.
- Cooling option: "W" for water-cooled units, "F" for fan-cooled units, and "A" for air-cooled lasers (where the OEM or end user must provide cooling via fans or blowers)
- Revision letter: indicates the current model revision
- Manufacturing location: "S" for Suzhou, or no letter for Mukilteo
- Wavelength: No number or "10.6" for 10.6 μm wavelength, "10.2" for 10.2 μm , etc.

For example, the model number FSTI60SAD-10.6 designates a CW laser, part of the ti Series family, 60W average power, standard OEM, air-cooled, revision D, manufactured in Mukilteo and 10.6 μm wavelength.

3.1.2 Figure: Decoding Part Numbers



3.2 Unpacking

3.2.1 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 Novanta.

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

3.2.2 Packaging Guidelines

- To prevent equipment damage or loss of smaller components, use care when removing packaging materials
- After unpacking, review Inventory (Table 3.2.3) and verify that all components are on hand
- Save all shipping containers and packaging materials, including covers and plugs. Its unique design prevents damage to your laser during storage, relocation and/or shipping.

Caution: Possible Equipment Damage

Lift the laser only by the mounting feet or baseplate. Do not lift or support the laser by anything else, e.g. its cooling fittings.

3.2.2.1 Repackaging or Storing

When shipping Novanta lasers to another facility, we highly recommend that you ship the unit in its original Novanta shipping container. If you no longer have the original shipping box and inserts, contact Novanta Customer Service about purchasing replacement packaging.

When packing a laser for shipment, be sure to remove all accessory items not originally attached to the laser, including beam delivery components, connectors, etc.

Refer to the Packaging Instructions drawing (Figure 4.7.8) in the Technical Reference chapter for details on packaging the laser using Novanta-supplied shipping materials.

Caution: Possible Equipment Damage

When preparing the 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 less than 29 PSI (Use appropriate eyewear for protection) to remove any residual water. When finished, cap all connectors to prevent debris from entering the cooling system.

Important Note:

Failure to properly package the laser using Novanta-supplied shipping boxes and foam/cardboard inserts as shown in the Packaging instructions (Figure 4.7.8) may void the warranty. Customers may incur additional repair charges for shipping damage caused by improper packaging.

3.2.3 Table: ti Series Shipment Inventory

Contents	Qty	Additional Information
ti Series Laser	1	For cutting, welding, drilling, and marking a wide variety of products and materials
Customer Communication Flier	1	Follow the instructions on the flier to access the latest manual on the Novanta website
Cooling kit	1	Only with water-cooled models - Contains 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
Cooling Tubing	1	Only with water-cooled models - 1/2-inch Polyethylene tubing
Mounting Screws	3	Three each 1/4-20 x 5/8 UNC caps crews are provided for fastening the ti Series laser to your mounting surface.
Spare Fuse	2 / 4	Fast-acting mini ATO-type fuse protects ti Series internal circuitry. Two fuses are shipped with the ti60 and four 4 fuses with ti80 and ti100.
Quick Start Plug	1	Quick Start Plug, not included for SA models

3.3 Mounting

The ti Series baseplates are designed so the laser is easily mounted to either vertical or horizontal surfaces using only three fasteners. Three ball bearing “feet” pressed into the baseplate eliminate any possible distortion of the laser tube caused by variations in the flatness of the mounting surface. When mounting ti Series lasers, you can choose to fasten from above, into your mounting surface, or from below, into the laser’s base plate. Refer to the outline and mounting drawings in the Technical Reference chapter for mounting locations and dimensions.

Read through the mounting sections below to determine which set of mounting holes are required for your application. When mounting your ti Series lasers, you can choose to fasten from above, into your mounting surface, or from below, into the laser’s base plate.

Important Note

To prevent possible distortion of the tube, you must fasten the ti Series laser directly to your mounting surface using the base plate.

Caution: Possible Equipment Damage

Novanta does not recommend mounting lasers in a vertical “head-down” or equipment “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.

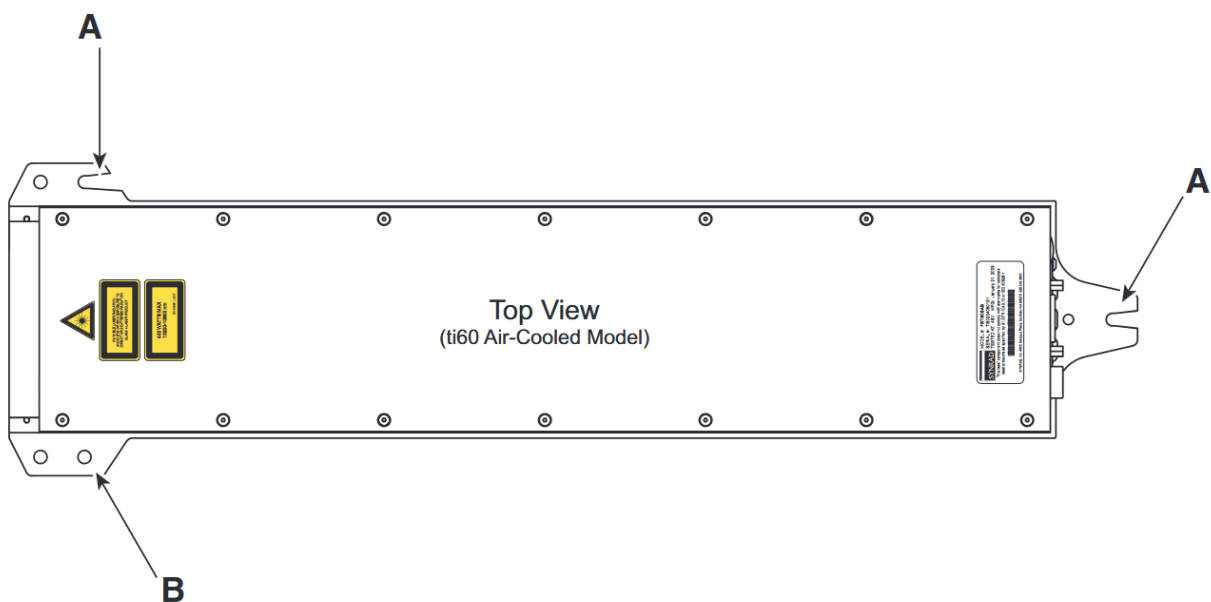
Failure to properly package the laser using Novanta shipping box and foam/cardboard inserts as shown in Packaging Instructions (Figure 4.7.8) may void the warranty. Customers may incur additional repair charges due to shipping damage caused by improper packaging.

3.3.1 Mounting the ti Series Laser from Above (ISO/UNC fasteners)

To fasten your 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 3.3.1.1.
2. Place the laser 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 cap screws through the ti Series' baseplate into the threaded holes of the mounting surface. Turn the screws by hand until the threads engage.
4. Evenly tighten all three cap screws to a maximum torque of 6.1 Nm (54 in-lb)

3.3.1.1 Figure: ti Mounting Locations for mounting from above

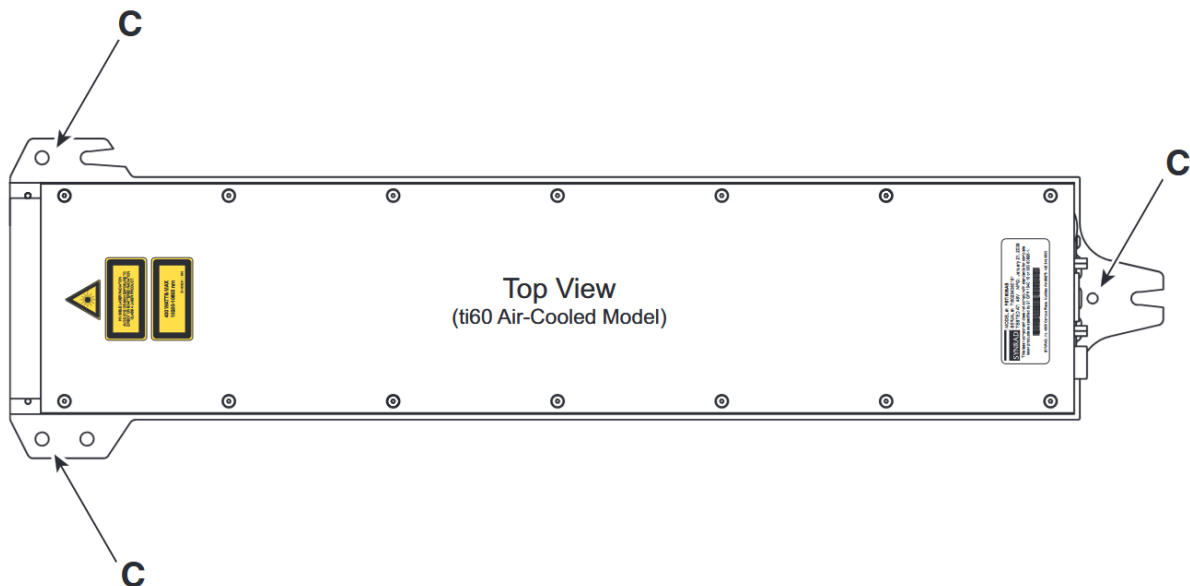


3.3.2 Mounting the ti Series Laser from Below (UNC fasteners only)

To fasten the ti Series laser to your mounting surface using a base or 'mounting plate', 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 3.3.2.1.
2. Place the laser on the mounting surface so the threaded holes in the baseplate line up with the 0.261" holes drilled through the mounting surface.
3. Insert 1/4–20 × 5/8" UNC cap screws through the mounting surface into the corresponding threaded holes in the baseplate. Turn the screws by hand until the threads engage.
4. Evenly tighten all three fasteners to a maximum torque of 6.1 Nm (54 in-lb).

3.3.2.1 Figure: ti Mounting Locations for mounting from below



3.4 Cooling

There are three cooling configurations available:

1. **Air:** Also referred to as the OEM cooling configuration. Customers must provide forced air cooling to prevent the laser from overheating.
2. **Fan:** Includes a fan shroud that fits over the laser. Shroud includes fans that are positioned on both sides of the laser.
If your laser is fan-cooled (i.e. FSiti60SFD...) you may skip ahead to section 3.5 Electrical Connections.
3. **Water:** Chassis design includes tubing for water circulation. Customers must provide a chiller to cool and circulate the water.
If your laser is water-cooled (i.e. FSti60SWD...) you may skip ahead to section **3.4.2 Water Cooling**.

3.4.1 Air Cooling

The air-cooled versions of the ti Series lasers do not include cooling fans. Customers must provide some type of air cooling to prevent the laser from overheating.

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.

3.4.1.1 Side Cooling

Novanta recommends using two cooling fans rated at least 4.0 m³/min (140 CFM) for the ti60, and 5.4m³/min (190 CFM) for the ti80. This assumes a static air pressure of 9.1 mm H₂O (0.36" H₂O) and 17.8 mm H₂O (0.70" H₂O). The cooling fans should measure 120 × 120 mm (4.7" × 4.7") and have at least 57.2 mm (2.25") of unobstructed clearance between the rear face of the fan housing and any mounting surface or enclosure.

For free-space mounting (no fan shroud), position the fans symmetrically, as shown in 3.4.1.2 *Figure: Cooling Fan Locations*, where they are centered horizontally with the laser chassis and vertically with the heat-sink fins. Position both fans so the front face is no more than 76mm (3.0") from the ti Series' heat-sink fins.

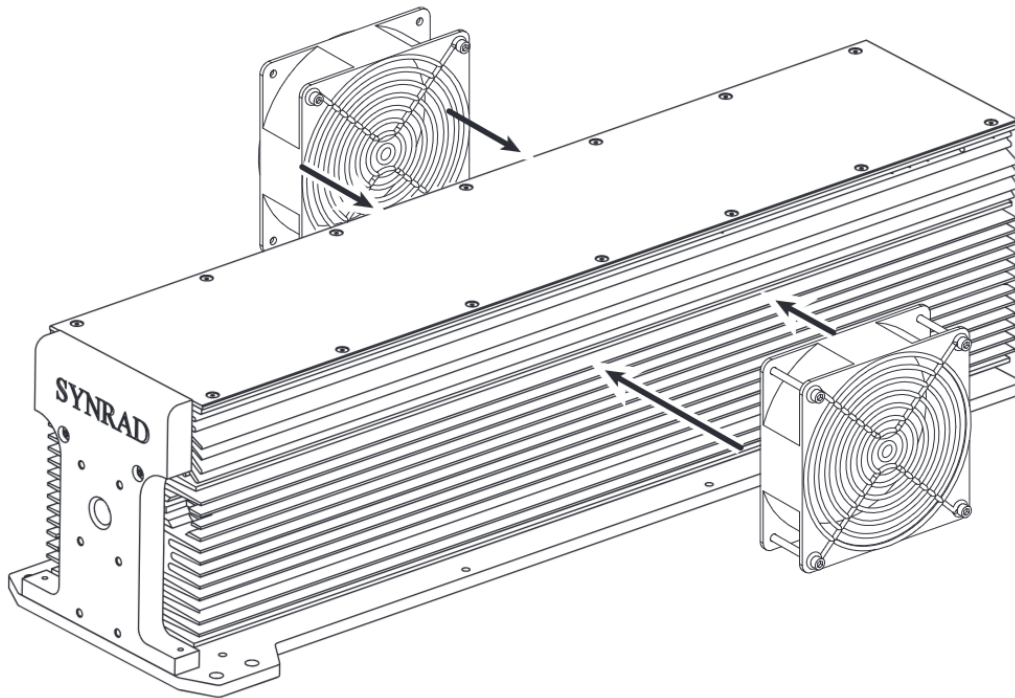
When using a tight-fitting fan shroud designed for side cooling, the cooling fans can be positioned within 5–25 mm (0.20–1.0") of the heat-sink fins, as long as the same gap is maintained on either side.

Important Note:

Fans should be centered both horizontally and vertically on each side of the laser.

Gap between fan and laser must be less than 3.0" (76 mm) for sufficient air flow through the cooling fins.

Gap between fan and wall (or other housing structure) must be at least 2.25" (57 mm).

3.4.1.2 Figure: Recommended ti60/ti80 Cooling Fan Locations**3.4.2 Water Cooling**

For the water-cooled version, customers are required to provide a chiller to cool and circulate the water. This section explains how to connect the laser and chiller and includes guidelines for operating.

3.4.2.1 Cooling Fitting Adaptors

If your integrated laser application uses metric cooling tubing, you should install tubing adaptors to convert the lasers WATER IN and WATER OUT fittings from 1/2-inch tubing to 12mm 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.**

3.4.2.2 Cutting and Installing Tubing

- Cut tubing lengths generously to allow for trimming
- Cut tubing squarely; diagonal cuts may not seal properly. Carefully trim any burrs if the cut is ragged
- Avoid excessive stress of 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 release collet evenly towards the fitting, and then pull the tubing free.
- After disconnecting the tubing from a fitting, trim about 12.7 mm (0.5") from its end before reconnecting. Trimming the end of the tubing before reconnecting the fitting provides an undisturbed sealing surface.

3.4.2.3 Chiller Preparation

- 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 the ti Series 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.

3.4.2.4 Coolants

Novanta recommends that the laser's cooling fluid contains at least 90% distilled or tap 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. If you must use glycol, do not add more than 10% by volume. 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). Install a filter on the chiller's return line and inspect frequently. The following wetted materials are in the cooling path in the laser: nickel-plated brass, copper, acetal, PBT, polyethylene, stainless steel, and Viton.

Ensure that coolant flow is 1.0 GPM (3.8 LPM), and the pressure does not exceed 60 PSI (4.1 bar, 414 kPa).

Caution: Possible Equipment Damage

Do **not** use de-ionized (DI) water as a coolant. DI water is unusually corrosive and is not recommended for mixed material cooling systems.

3.4.2.5 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 set-point 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 1.0 GPM (3.8 lpm). Do not exceed a coolant pressure of 60 PSI (414 kPa).

See 3.4.2.6 *Table: Dew Point Temperatures* for a range of air temperatures and relative humidity values. Remember that the laser's coolant temperature must be set above the dew point temperature shown in the table. For best results and performance, however, do not exceed a coolant temperature of 22 °C (72 °F).

Caution: Possible Equipment Damage

The laser's coolant temperature must be set above the dew point temperatures but should not exceed 22 °C (72 °F).

Note

The 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.

3.4.2.6 Table: Dew Point Temperatures

The laser's coolant temperature must be set above the dew point temperatures shown in the chart but should not exceed 22 °C (72 °F).

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

To use this table, look down the Air Temp column and locate an air temperature that corresponds to the air temperature in the area where your laser is operating. Follow this row across until you reach a column that matches the relative humidity in your location. The value at the intersection of the Air Temp and Relative Humidity columns is the Dew Point Temperature. The chiller's temperature setpoint must be **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.

3.4.2.7 Cooling Tubing Connections

The following procedure will guide you in configuring the most efficient cooling system. Please connect your system exactly as described below.

To connect cooling tubing to your laser, perform the following steps:

1. Locate the 1/2-inch O.D. polyethylene cooling tubing in the ship kit.
2. Cut and connect a length of 1/2-inch O.D. polyethylene cooling tubing to fit between the chiller's Outlet port and the upper WATER IN power on the rear of the 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.
4. Turn on the chiller and adjust the coolant temperature setpoint to be between 18 and 22°C. Regulate coolant flow to 1.0 GPM (3.8 lpm) and less than 60 PSI (414 kPa) of pressure.
5. Closely examine all cooling connections and verify that there are no leaks.

Caution: Possible Equipment Damage

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

Do not exceed coolant pressure of 60 PSI (414 kPa).

3.5 Electrical Connections

The following procedures describe how to complete electrical connections to the ti Series lasers. The ti series DC power cables are manufactured from #12 AWG wire and measure 1.7 meter (70 inches) in length.

3.5.1 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 may damage the ti Series laser's internal RF and control board circuitry. Carefully follow the directions to ensure that DC cable leads are properly connected to the correct DC output terminals.

The 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.

To connect your ti Series laser to a 48 VDC power supply, perform the following steps:

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 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

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.

3.5.2 Control Connections

Control connections to the ti Series lasers are made through the DB-15 I/O connector on the laser's rear panel. The DB-15 interface connector receives the PWM Command signals and serves as the connection point for auxiliary signal between the laser and any parts handling, automation, or monitoring equipment. See the DB-15 I/O connections section in the Technical Reference chapter for details.

**Warning: Serious Personal Injury**

Always use shielded cable when connecting your PWM Command signal source to PWM Positive/PWM Negative inputs.

In electrically noisy environments, long lengths of unshielded wire act like an antenna and may generate enough voltage to trigger uncommanded lasing.

3.5.2.1 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 troubleshooting by qualified personnel. In normal operation, the laser's Remote Interlock input should be connected to the machine's safety interlock circuitry.

3.5.2.2 UC-2000 Universal Laser Controller

For testing, troubleshooting, and basic operation, we recommend using a UC-2000 Controller to generate Pulse Width Modulation (PWM) command signals necessary to control laser output power. To connect a UC-2000 Controller, perform the following steps:

1. Remove DC power from the laser.
2. Locate the Quick Start Plug in the ship kit.
3. Connect the Quick Start Plug to the DB-15 I/O connector on the rear of the laser.
4. Connect the mini-DIN connector of the UC-2000's Power/Control cable to the Laser connector on the UC-2000's rear panel.
5. Attach the BNC connector from the Power/Control cable to the BNC connector on the Quick Start Plug attached to the User I/O port
6. Connect the miniature DC power plug on the UC-2000's Power/Control cable to the miniature connector on the wall plug transformer cable.
7. Plug the compact transformer into any 100–240 VAC, 50–60 Hz outlet.

Caution: Possible Equipment Damage

Turn off DC power before installing or removing any plug or cable from the DB-9 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.

Note:

The UC-2000 Universal Laser Controller, also available from Novanta, is sold separately.

Note:

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.

3.6 Controls and Indicators

Use information in this chapter to familiarize yourself with the ti Series controls and indicators on the front and rear panels of the laser.

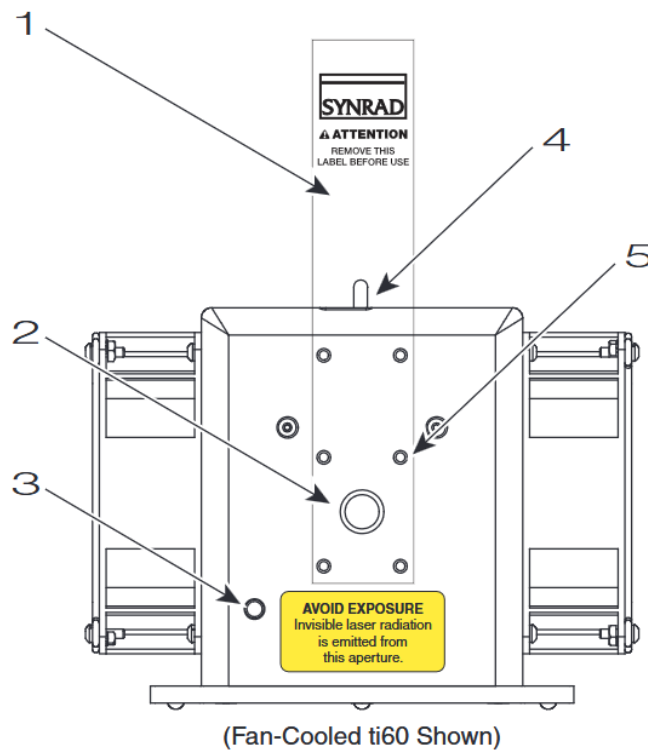
3.6.1 ti Series Front Panel

The front panel contains the following features, also shown in Figure 3.6.2.

1. Aperture Seal – prevents dust from damaging laser optics during shipping. Remove the self-adhesive label before applying power to the laser.
2. Laser Aperture – provides an opening in the ti Series' front panel 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 Novanta 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 Novanta before mounting components not specifically designed as options. Refer to the ti Series outline and mounting drawings in the Technical Reference section for mounting dimensions.

3.6.2 Figure: ti Series Front Panel



Important Note:

Remove the self-adhesive seal before applying power to the laser.

Important Note:

To prevent damage when mounting optical components to the ti Series lasers, the 8–32 UNC fasteners must extend no further than 4.8 mm (0.19") into the laser's faceplate.

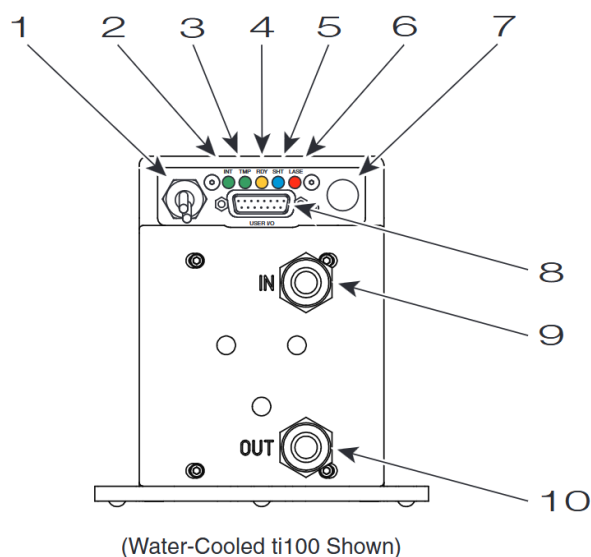
3.6.3 ti Series Rear Panel

The rear panel contains the following features, also shown in Figure 3.6.4:

1. DC Power Cables – receives +48 VDC from the DC power supply. The DC power cables are manufactured from #12 AWG wire and measure 1.7 meter (70 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.

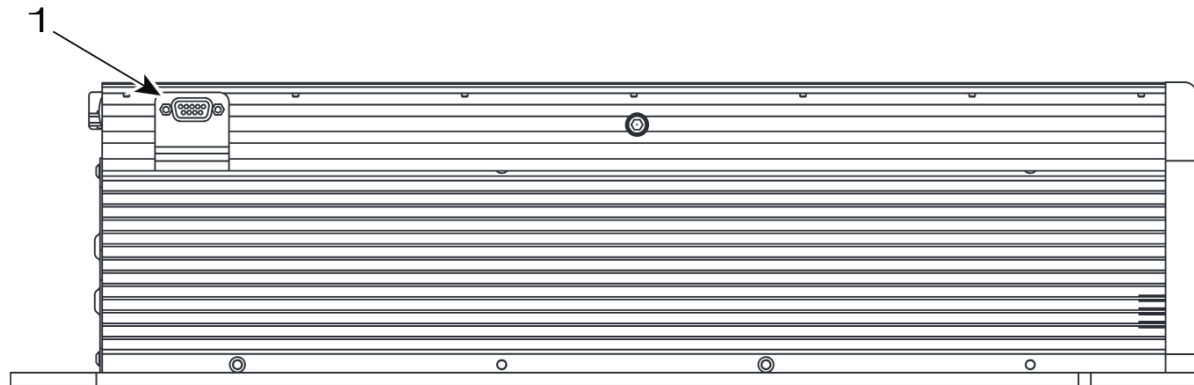
3. TMP (Temperature) Indicator – illuminates green to indicate that laser temperature is within limits and that lasing may be enabled. The TMP indicator is red, and lasing is disabled if the laser’s temperature rises above safe operating limits.
4. RDY (Ready) Indicator – illuminates yellow when the laser is enabled, indicating that, after an initial 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. The laser is enabled when the Keyswitch is turned to the ON position. Turn the Keyswitch OFF to disable lasing.
8. DB-15 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 ti Series’ water-cooling system.
10. WATER OUT Port (water-cooled models only) – labeled OUT, this connection provides the cooling water outlet from ti Series’ water-cooling system.

3.6.4 Figure: ti Series Rear Panel



3.6.5 Side Panel (SA models)

3.6.6 Figure: Side Panel (SA model)



(Air-Cooled ti60 OEM Shown)

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.

3.7 Initial Start-Up

This section explains the status indicators and how to start the laser with and without a UC-2000 controller.

3.7.1 Status Indicators

The ti Series LED indicators, also mirrored as output signals on the User I/O connector, provide status information to the user. Table 3.7.2 shows the ti Series 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.

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 the laser 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:

Note: The ti Series 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.

3.7.2 Table: Status Indicators Overview

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



Danger: Serious Personal Injury

Any Class 4 CO₂ laser product that emits invisible infrared laser radiation in the 9–11 μm wavelength band can seriously burn human tissue.

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 allow the laser beam to contact a person.

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 CO₂ 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 troubleshooting 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, ti Series lasers have significantly higher power densities than other Novanta 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.

3.7.3 With a UC-2000 Controller

Before your laser is used, 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.

Start Auxiliary Equipment

1. Ensure that all personnel in the area wear protective eyewear.
2. Remove the self-adhesive aperture seal from the laser faceplate.
3. Place a power meter, or appropriate beam block, about 2 feet (61 cm) from the laser aperture to prevent the beam from traveling beyond the work area.
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.

Start ti Series Laser

1. If the laser has a Diode Pointer installed, remove its aperture dust cover.
2. Turn on the +48 VDC 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:

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

3. Place the Shutter Switch (if equipped) in the Open position. The blue SHT (Shutter) indicator on the laser's rear panel will illuminate.
4. Rotate the keyswitch (if equipped) to the ON position. Verify that the RDY (Ready) indicator on the laser's rear panel is illuminated.

Note:

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

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.

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

If your laser fails to lase, refer to Troubleshooting in Maintenance and Troubleshooting chapter for troubleshooting information.

3.7.4 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 the ti Series 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.

Start Auxiliary Equipment

1. Ensure that all personnel in the area wear protective eyewear.
2. Remove the self-adhesive aperture seal from the laser faceplate.
3. Place a power meter, or appropriate beam block, about 2 feet (61 cm) from the laser aperture to prevent the beam from traveling beyond the work area.
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 (at a +5 volt level) and ensure that the controller's duty cycle is set to zero percent output (0.0%).

Start ti Series Laser

1. If the laser has a Diode Pointer installed, remove its aperture dust cover.
2. Turn on the +48 VDC 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.
3. Place the Shutter Switch (if equipped) in the Open position. The blue SHT (Shutter) indicator on the laser's rear panel will illuminate.
4. Rotate the keyswitch (if equipped) to the ON position. Verify that the RDY (Ready) indicator on the laser's rear panel is illuminated.

Note:

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

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.

5. 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. The spot where the beam hits the beam block should increase in brightness to indicate increased power output.
6. Remove the PWM Command signal from the laser and reapply tickle pulses every 200 μ s. The LASE indicator on 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.

If your laser fails to lase, refer to Troubleshooting in Maintenance and Troubleshooting chapter for troubleshooting information.

4 Technical References

Use Information in this chapter as a technical reference for your ti Series laser.

4.1 Technical Overview

4.1.1 ti Series Laser Design

4.1.1.1 Laser Tube

The ti Series lasers were developed using new technology patented by Novanta, Inc. This patented “t” technology, based on a combination of free-space and waveguide resonator designs, enables Novanta to economically produce a symmetrical laser beam from a small but powerful laser capable of operating for many years with virtually no maintenance. Its 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.

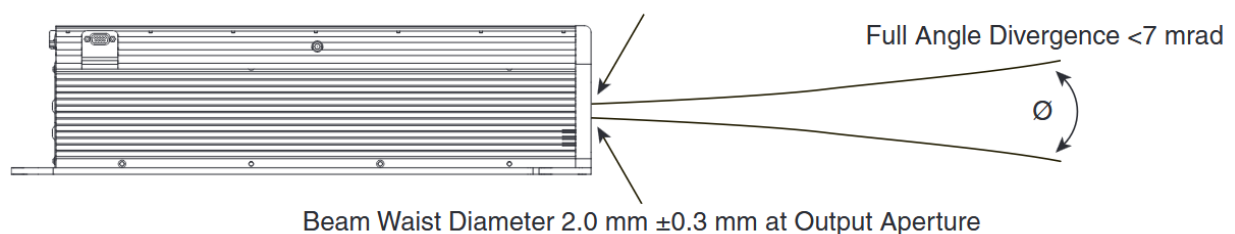
Caution: Possible Equipment Damage

Because of their smaller beam diameter, ti Series lasers have significantly higher power densities than previous Novanta lasers. This means that even a small amount of contamination on the laser’s output window (or on any optic in the beam path) can absorb enough energy to damage the optic. Inspect the output window and other beam delivery optics periodically for signs of contaminants and carefully clean as required. In dirty environments, purge laser optics using filtered air or nitrogen to prevent vapor and debris from accumulating on optical surfaces.

4.1.1.2 Optical resonator

The optical resonator, in conjunction with the electrodes and the gas mixture, generates the laser beam. The 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. 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 (M2 factor) of < 1.2. As shown in the following figure, beam waist diameter is 2.0 mm \pm 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).

4.1.1.3 Figure: ti series beam characteristics



4.1.1.4 Internal RF power supply

The 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 (CO₂) gas in the tube to produce lasing.

4.1.1.5 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.

4.1.2 Optical Setup

After selecting a laser for a CO₂ laser processing system, the two most crucial 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.

4.1.2.1 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 increase beam diameter by a selectable magnification factor while reducing beam divergence at the same time. Adding an expander/collimator 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.

Important 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.

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.

4.1.2.2 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 selecting 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.

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 principal issue affecting performance and becomes increasingly important as laser power increases. Dirty or scratched lenses will underperform, 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 specification as shown in the following table.

4.1.2.3 Table: 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 ; $\leq -40^\circ\text{F}$ 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

4.2 Controlling Laser Power

4.2.1 Control Signals

Much of the information provided in this section describes the use of a Novanta UC-2000 Universal Laser Controller to provide tickle and 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, *DB-15 I/O Connections*, for an understanding of the signal requirements necessary to control lasers. For more information about the UC-2000, please consult the UC-2000 Laser Controller Operator's Manual found on the Novanta website.

4.2.1.1 Tickle Pulses

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 are signals that 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 instantaneously to PWM Command signals, even when there are longer pauses (laser off time) between applied Command signals. All ti Series lasers incorporate a built-in tickle generator, freeing customers from the need to supply external tickle pulses between lasing commands.

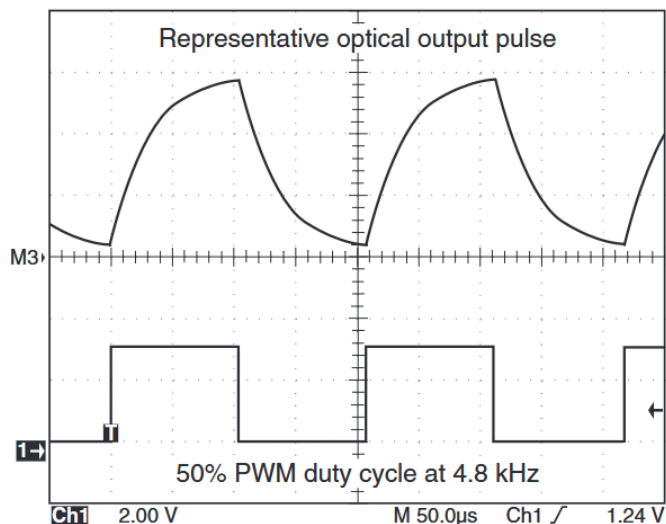
Internal circuitry monitors the incoming PWM signal and determines the amount of time the laser was on (lasing) during the last 200 microsecond (μs) interval. If the lasers on time was greater than the preset tickle value, then no tickle pulse is generated, because the PWM signal was sufficient to maintain 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.

4.2.1.2 Pulse Width Modulation (PWM)

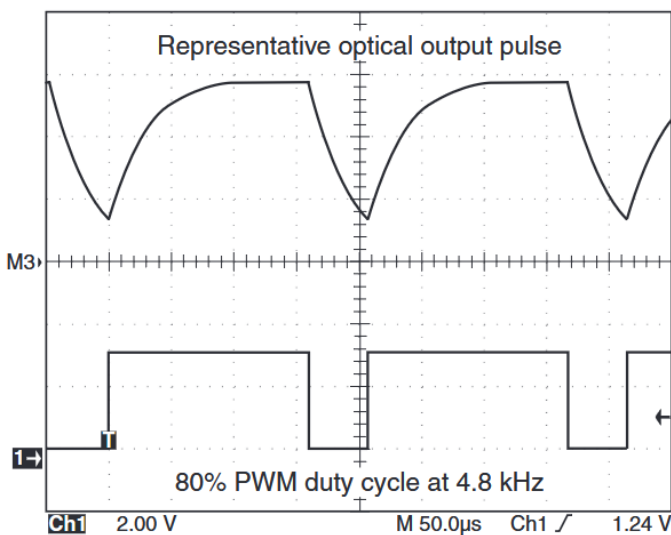
Pulse Width Modulation, or PWM, controls laser power by varying the duty cycle of the laser's RF amplifiers, which in turn control the time-averaged RF power applied to the laser. Typically, laser output follows the PWM input with a rise and fall time constant of $\sim 75 \mu\text{s}$; however, the laser 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). Figures 4.2.1.3 and 4.2.1.4 show representative ti Series optical output waveforms at two different duty cycles with the same PWM frequencies.

The 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 many 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.

4.2.1.3 Figure: Typical Optical Output Pulse (50%) Duty Cycle at 4.8 kHz



4.2.1.4 Figure: Typical Optical Output Pulse (50%) Duty Cycle at 4.8 kHz



4.2.1.5 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 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 a square wave that 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.

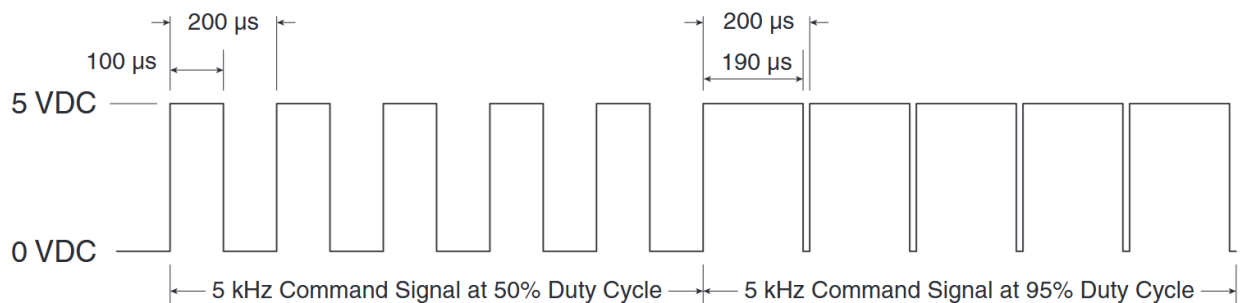
Base frequency, the second parameter, is the repetition rate of the PWM input signal. The standard base frequency is 5 kHz, which has a period of 200 μ s. Maximum PWM frequency is 160 kHz.

The third Command signal parameter, PWM duty cycle, is the percentage of the period that the Command signal is high. If the Command signal's amplitude (at 5 kHz) is high for 100 μ s and low for 100 μ s, it has a 50% duty cycle. If the amplitude is high for 190 μ s and low for 10 μ s, it has a 95% duty cycle. Figure 4.2.1.6 illustrates PWM Command signal parameters while Table 4.2.1.7 lists PWM signal specifications.

Important Note:

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

4.2.1.6 Figure: PWM Command Signal Waveform



The ti Series DB-15 I/O PWM input consists of a high-speed optoisolator LED with a forward voltage drop (V_f) of 1.5 VDC. The PWM input frequency can range from DC (0 Hz) to 100 kHz. Table 4.2.1.7, below, provides minimum, maximum, and nominal PWM signal specifications.

4.2.1.7 Table: 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 (5 mA)	+5.0 VDC (9 mA)	+6.7 VDC (10 mA), continuous
Frequency Range	0 Hz (DC)	5 kHz	100 kHz
Duty Cycle	0%		100% (95% recommended)

4.2.2 Operating Modes

This section discusses external control, analog voltage or current control, continuous wave operation, and gated operation.

4.2.2.1 External Control

In addition to controlling the ti Series lasers using a UC-2000 Universal Laser Controller, there are other methods of external control. 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 providing tickle pulses in addition to sending PWM signals at the proper time (gating) and with the proper duty cycle (power).

4.2.2.2 Analog Voltage or Current Control

Although the 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.

To generate the correct analog voltage for the UC-2000 Controller 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.

4.2.2.3 Continuous Wave (CW) Operation

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

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 DB-15 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 to the Pulse Width Modulation (PWM) section for information regarding high frequency operation.

4.2.2.4 Gated Operation



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 VDC 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.

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.

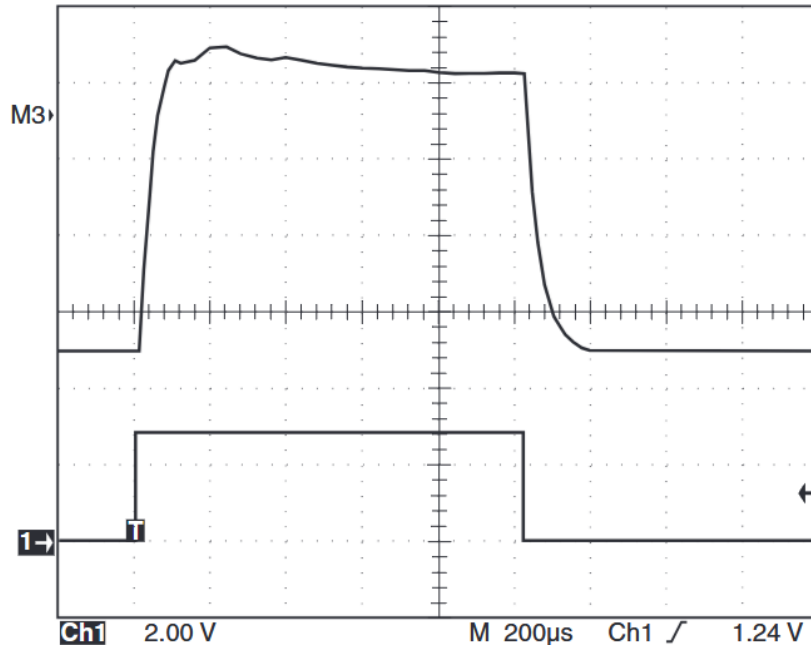
Users who intend to use a gating signal should set the UC-2000's gate input logic to internal Pull-Down (normally off) mode. This prevents the beam from being enabled unless a high level (+3.5 to +5.0 VDC) signal is applied to the Gate input connector. In the pull-down (normally off) mode, an asserted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

Many CO₂ 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 CO₂ 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.

The ti Series lasers produce an optical output pulse that is almost exactly square (see Figure below), 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.

4.2.2.5 Representative ti Series optical output pulse (10% duty cycle at 100 Hz)



4.2.2.6 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), the ti Series on-board tickle generator sends a tickle pulse to maintain plasma ionization in the tube. Because the on-board tickle generator cannot 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.

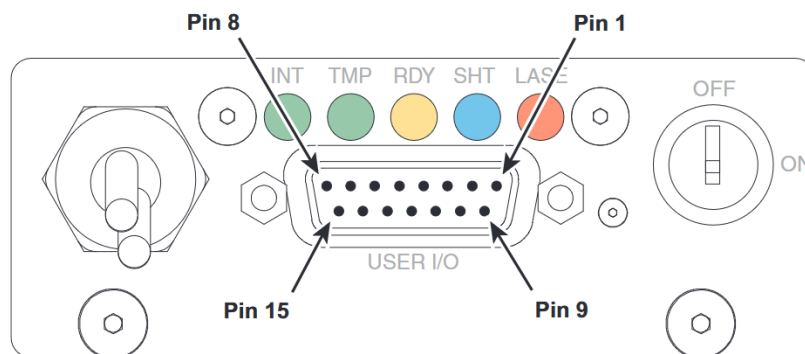
4.3 DB-15 I/O Connections

4.3.1 DB-15 I/O Connection Summary

The ti Series 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.

The ti Series laser PWM inputs are optoisolated; however, all other inputs and outputs operate using standard 5V logic levels (0V – logic low; 5V – logic high). Both inputs and outputs are ESD protected but are not optoisolated; all input signals sent to the laser must be clean or conditioned by the user. The figure below illustrates the pin arrangement of the DB-15 I/O (15-pin female D-type subminiature) connector on the ti Series' rear panel while the following table provides connection descriptions.

4.3.2 Figure: DB-15 I/O Connector Pinouts



4.3.3 Table: DB-15 I/O Pin Descriptions

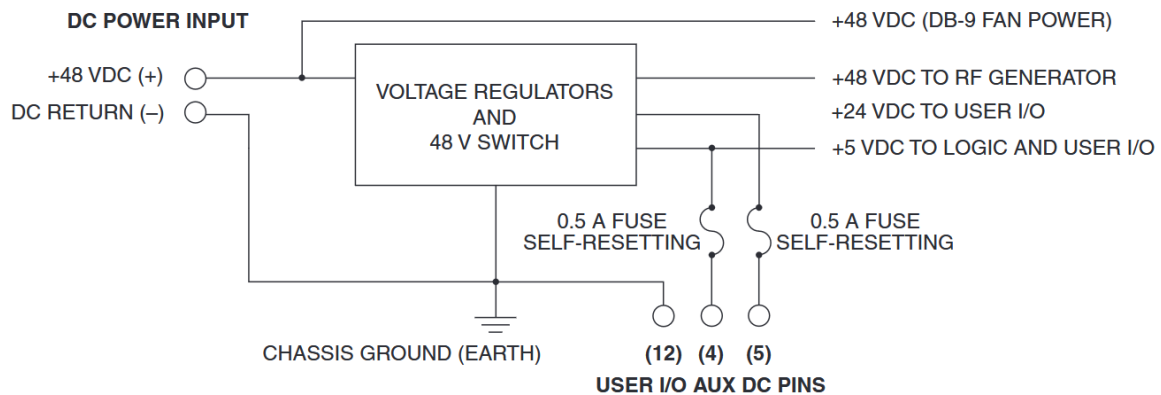
Pin	Description	Function
1	PWM Return	This input provides the negative, or return, side of the optoisolated PWM Command signal referenced to PWM Input (Pin 9).
2	Remote Reset/Start Request input	Apply a positive or negative voltage (± 5 –24 VDC) with respect to Pin 11, Input Common, to reset or remote 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.
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 4.3.3.6 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.

Pin	Description	Function
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).
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 4.3.3.6 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).

4.3.3.1 Auxiliary DC power

The ti Series 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. The Figure below illustrates the ti internal DC supply wiring.

4.3.3.2 Figure: Auxiliary DC power supply wiring



4.3.3.3 Table: Auxiliary Power Pin descriptions

Pin	Description	Function
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.
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.

4.3.3.4 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.

4.3.3.5 Table: Input Signal Pin description

Pin	Description	Function
1	PWM Return	Connect the return side of your PWM Command signal to this pin. Refer to Table for input circuit specifications.
2	Remote Reset/Start Request input	Apply a positive or negative voltage ($\pm 5\text{--}24$ 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. 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 4.3.3.8 for input circuit specifications. 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 $\pm 5\text{--}24$ VDC to Pin 2. This reset action initiates a five-second delay after which lasing is enabled.
3	Remote Interlock input	Apply a positive or negative voltage ($\pm 5\text{--}24$ VDC) with respect to Pin 11, Input Common, to enable lasing. If your system does not use an interlock, connect this pin to a $\pm 5\text{--}24$ VDC source. Refer to Figure 4.3.3.6 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 4.3.3.8 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).
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 4.3.3.8 for input circuit specifications

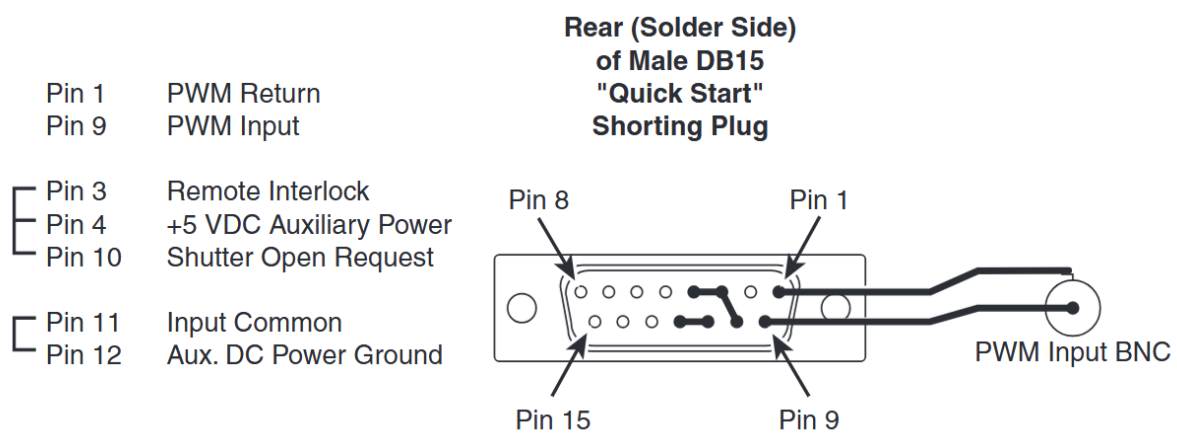
Pin	Description	Function
10	Shutter Open Request input	Apply a positive or negative voltage (± 5 –24 VDC) with respect to Pin 11, Input Common, to enable lasing. If your system does not supply a Shutter Open Request signal, this pin must be connected to a voltage source in the range of ± 5 –24 VDC. Refer to Figure 4.3.3.6 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 4.3.3.8 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
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 4.3.3.8 for input circuit specifications.

Note:

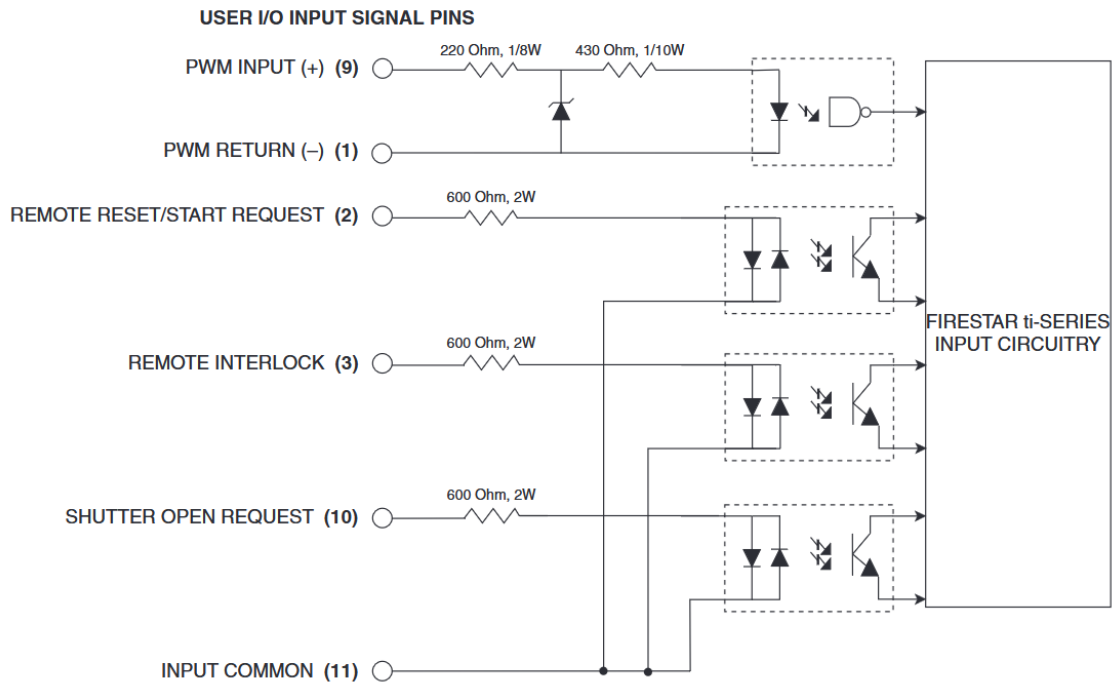
When connecting field wiring to the Remote Reset/Start Request input, use twisted pair and/or shielded cabling.

Figure 4.3.3.6 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.

Figure 4.3.3.7 illustrates the input circuit's equivalent internal schematic while Table 4.3.3.8 provides its Series input circuit specifications.

4.3.3.6 Figure: Quick Start Plug wiring diagram


4.3.3.7 Figure: Input equivalent schematic



4.3.3.8 Table: Input Circuit Specifications

Input Signals	Input device type and specifications
PWM Positive 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 Remote Interlock Shutter Open Request	Bidirectional optoisolator LED, forward voltage drop (Vf) .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

4.3.3.9 Output Signals

The ti Series' five user outputs correspond to the status functions described below. Outputs are optoisolated, bidirectional 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.

The ti Series' 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).

4.3.3.10 Table: Output Signal Pin description

Pin	Description	Function
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 4.3.3.11 for output circuit specifications.
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 4.3.3.11 for output circuit specifications.
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 4.3.3.11 for output circuit specifications.
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 0.3 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 (Keypress-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). Refer to Table 4.3.3.11 for output circuit specifications.
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). Refer to Table 4.3.3.11 for output circuit specifications.

4.3.3.11 Table: Output circuit specifications

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

4.3.4 Sample I/O Circuits

4.3.4.1 Sample Inputs

The following Figure illustrates one method of supplying a Remote Interlock signal using a customer-supplied limit switch. The ti Series +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.

4.3.4.2 Figure: Customer supplied interlock

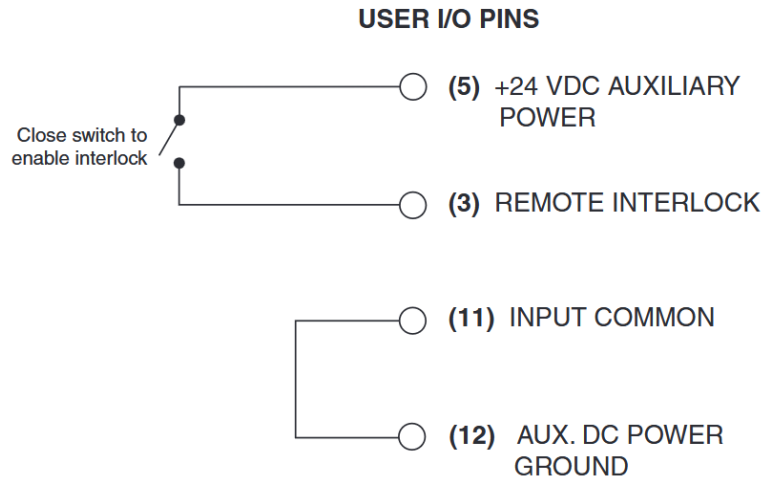
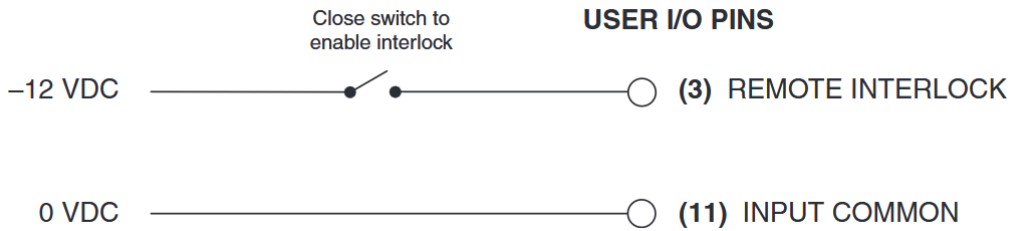


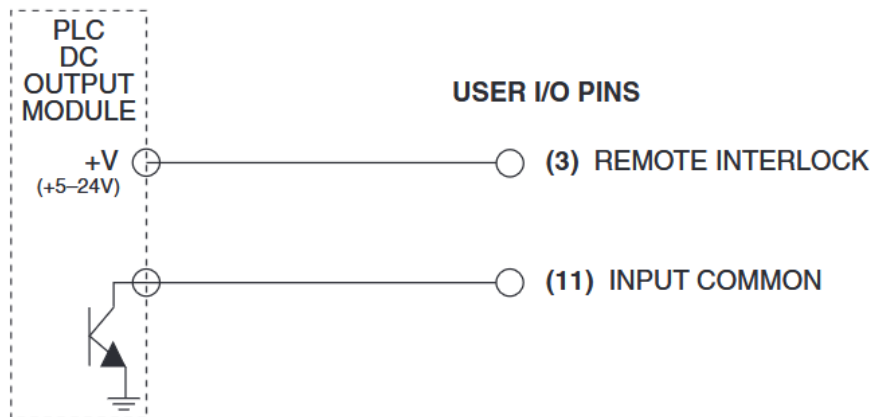
Figure 4.3.4.3 shows another variation for supplying a Remote Interlock signal to the laser. In this case, the customer is using a switch and supplying a negative voltage to drive the laser's input circuit.

4.3.4.3 Figure: Customer supplied interlock, negative voltage



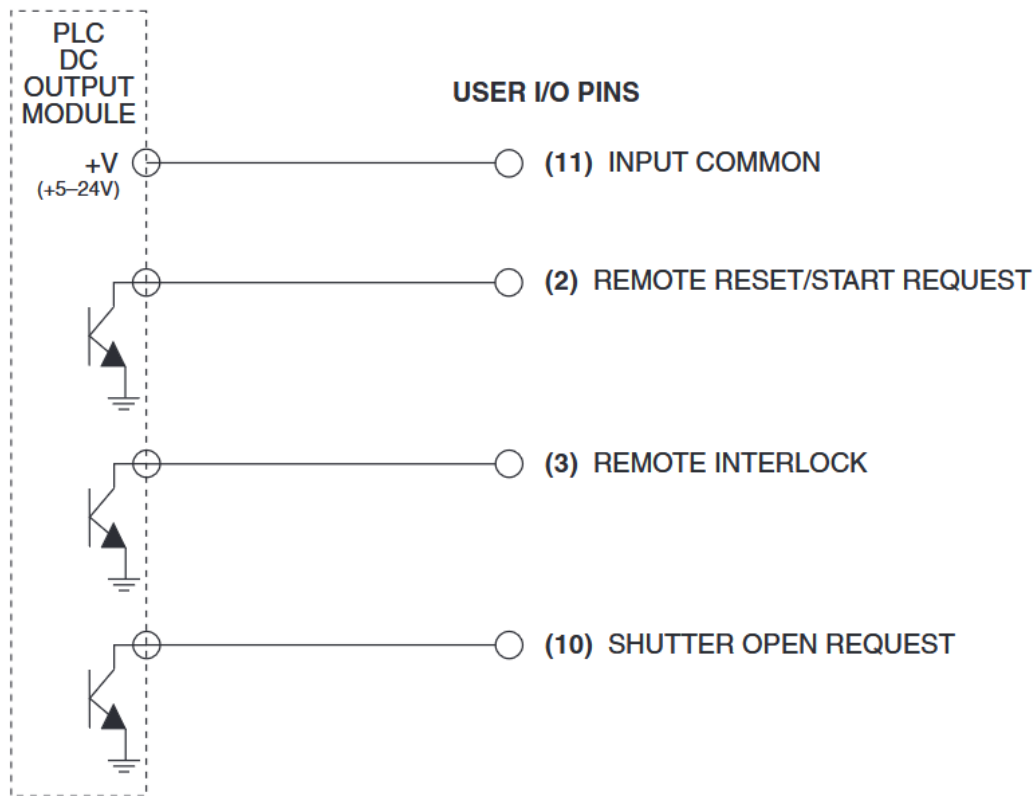
A Programmable Logic Controller (PLC) can also drive ti Series inputs. The Figure below shows a typical method for connecting to a PLC input module when only one laser input is used.

4.3.4.4 Figure: PLC driven interlock signal



When multiple PLC inputs are required, connect the ti Series inputs to the PLC as shown in Figure 4.3.4.5. 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.

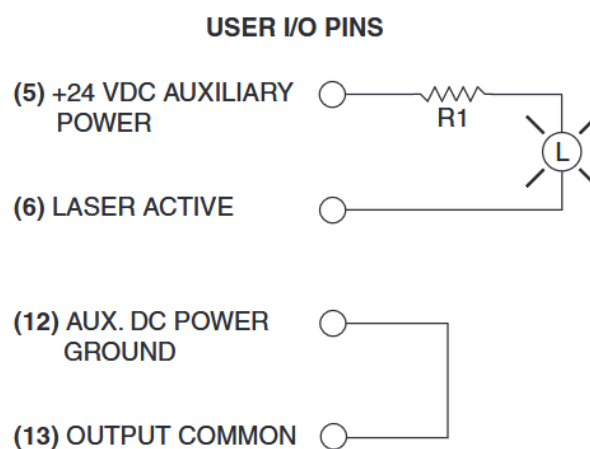
4.3.4.5 Figure: Multiple PLC driven inputs



4.3.4.6 Sample Outputs

The ti Series' optoisolated, bi-directional switched outputs can drive small loads (50 mA max), PLC inputs, or relays that can control higher current loads. Figure 4.3.4.7 illustrates one method of controlling a remote warning lamp using power supplied by the lasers +24 VDC Auxiliary Power output. Remember to size current-limiting resistor, R1, so that the current draw does not exceed 50 mA.

4.3.4.7 Figure: ti Series output driving a warning lamp



The figure below 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 the ti Series outputs.

4.3.4.8 Figure: ti Series output driving a relay

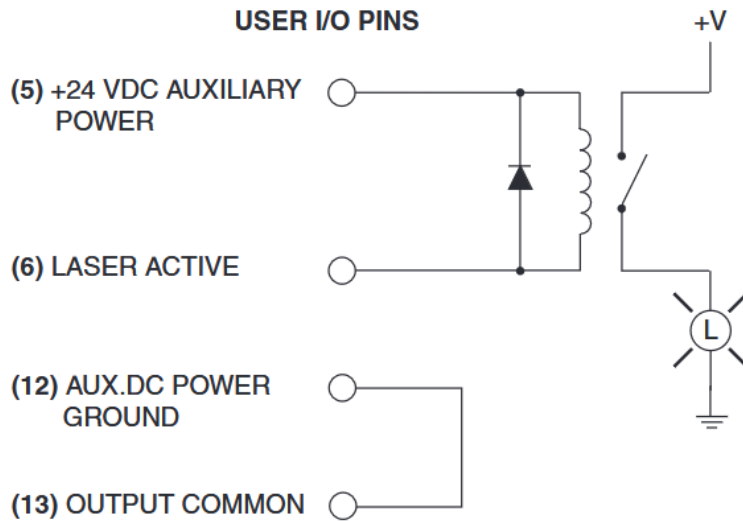
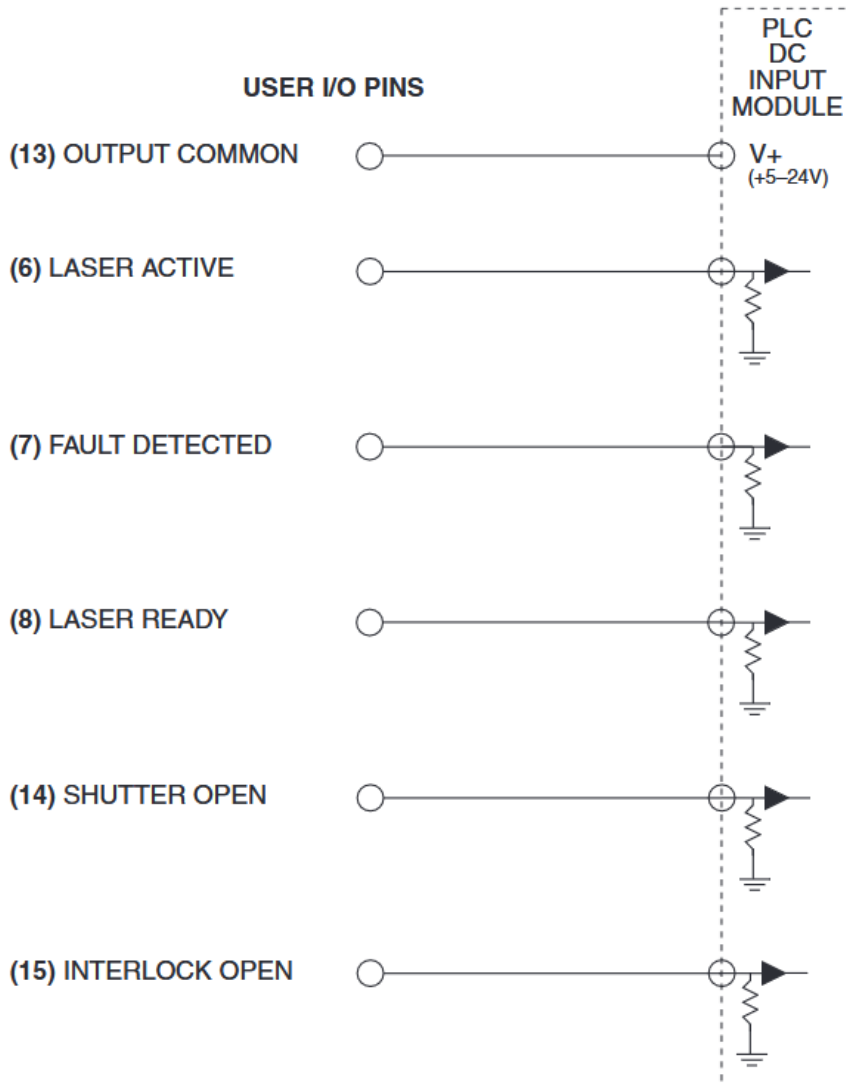


Figure 4.3.4.9 illustrates how ti Series' outputs can drive the DC Input Module of a Programmable Logic Controller (PLC). By supplying voltage (+VDC) to Pin 13, Output Common, each output is independently switched to activate individual PLC inputs.

4.3.4.9 Figure: ti Series outputs driving PLC input module



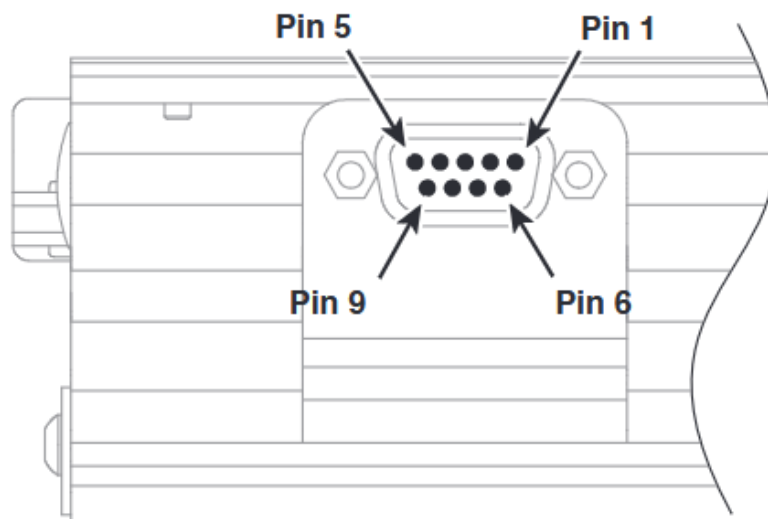
4.4 DB-9 I/O Connections

The Side-mounted DB-9 Pin connection is only available for SA models. It has a dedicated +48 VDC output for powering cooling fans.

4.4.1 DB-9 pin description

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 4.4.2 illustrates DB-9 pinouts and Table 4.4.3 describes the function of each pin on the DB-9 connector.

4.4.2 Figure: DB-9 connector pinouts



4.4.3 Table: Side-mounted DB-9 Pin Descriptions

Pin	Description	Function
1	PWM Control Output	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.
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 <u>combined</u> 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 <u>combined</u> 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.
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 <u>combined</u> 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.
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 <u>combined</u> 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.

4.4.4 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.

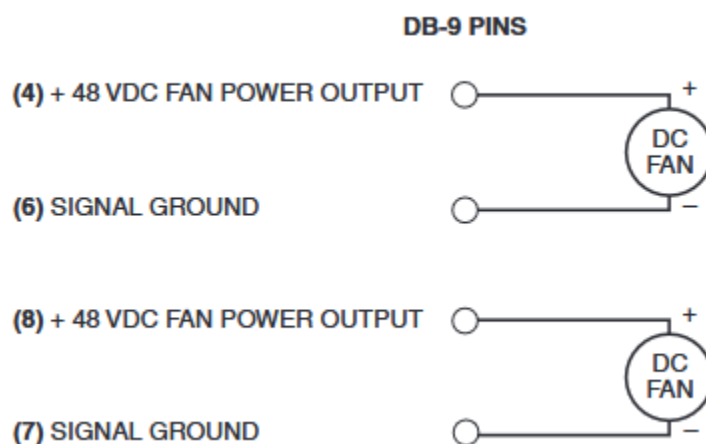
4.4.4.1 No fan speed control

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 4.4.4.2.

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.

4.4.4.2 Figure: 48 VDC fan connection – no speed control



4.4.4.3 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 4.4.4.4.

4.4.4.4 Figure: Internal fans speed control circuitry

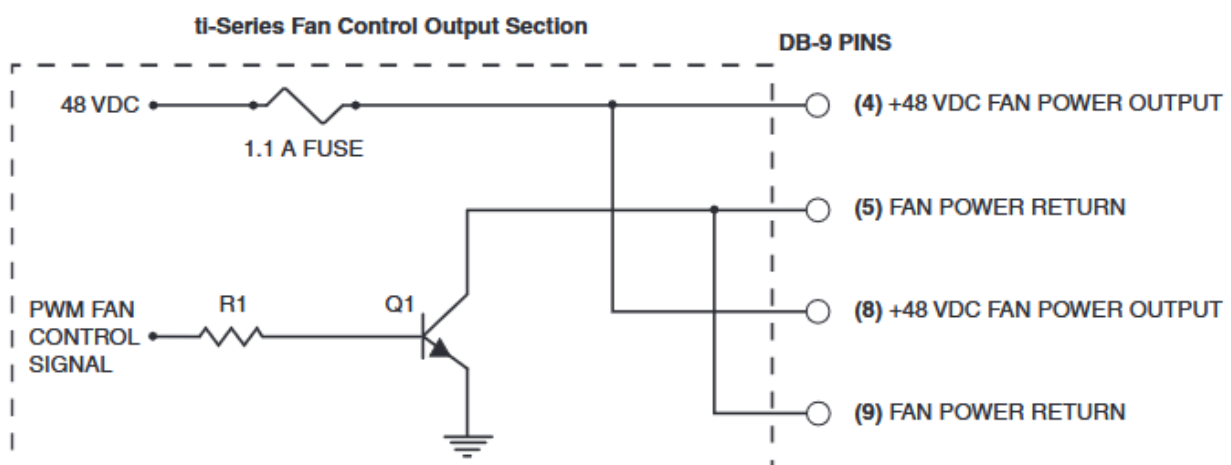
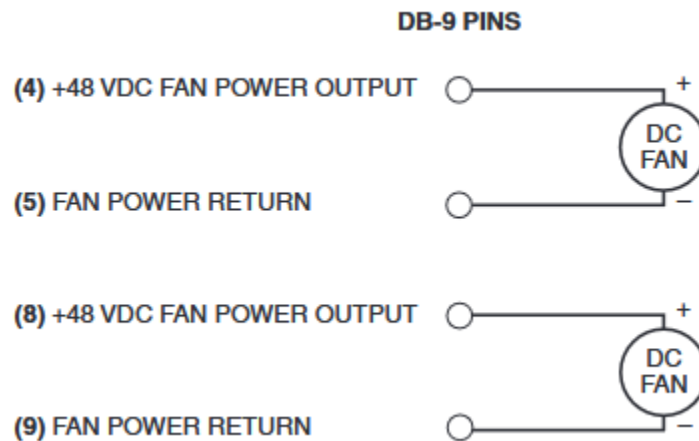


Figure 4.4.4.5 illustrates the connections for internal fan speed control when using customer-supplied 48 VDC cooling fans. Connect the positive (+) fan leads to Pin 4 and Pin 8, +48 VDC Fan Power Output, and connect the negative (-) fan leads to Pin 5 and Pin 9, Fan Power Return. Some types of cooling fans are not designed for PWM control and will stall at low speeds.

4.4.4.5 Figure: 48 VDC fan connection – internal speed control



4.4.4.6 External fan speed control (ti80 only)

On the 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 4.4.4.7. 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.

4.4.4.7 Figure: External fan speed control circuitry

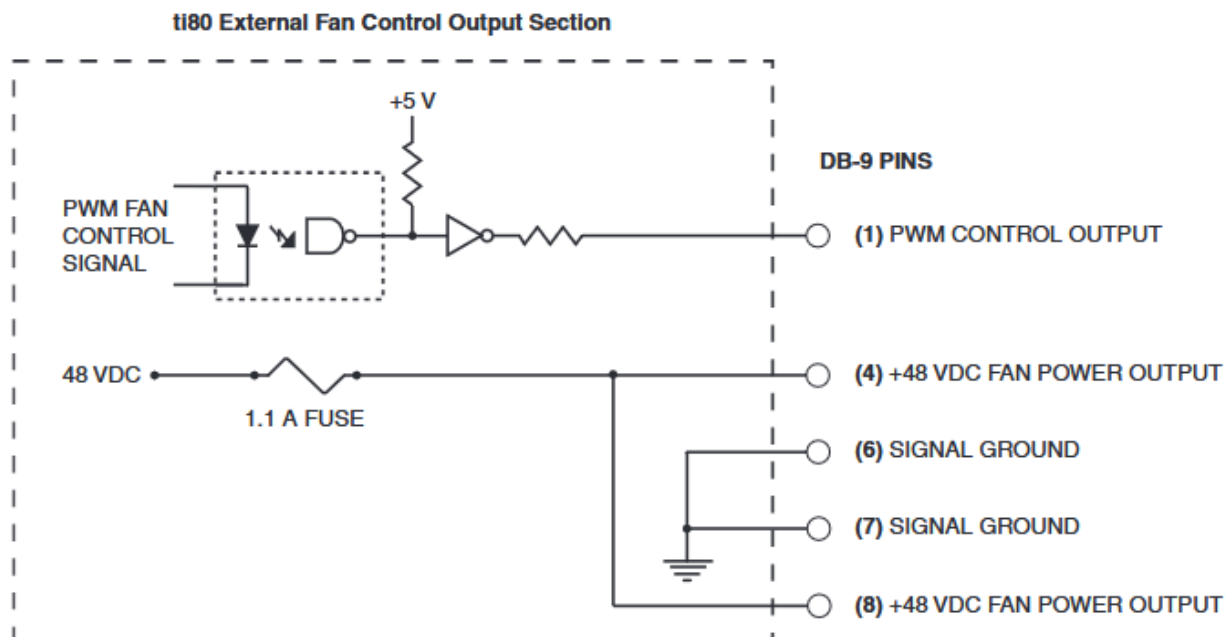
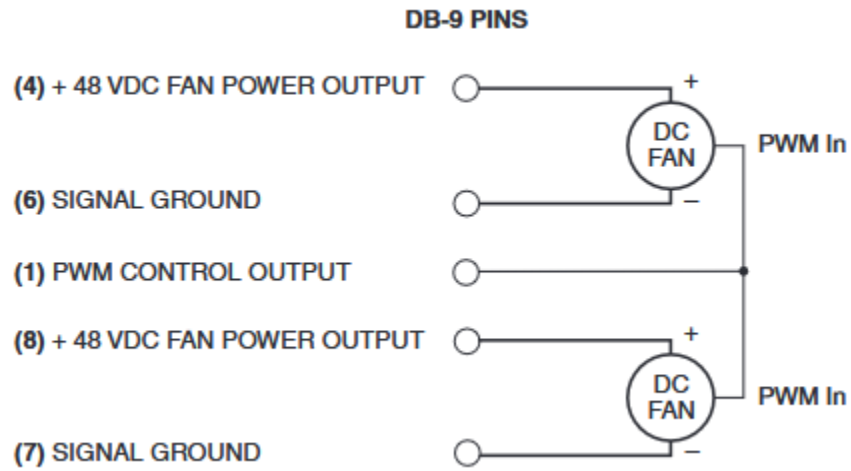


Figure 4.4.4.8 illustrates the connections for external fan speed control when using customer-supplied 48 VDC cooling fans with PWM control capability. Connect the positive (+) fan leads to Pin 4 and Pin 8, +48 VDC Fan Power Output, connect the negative (-) fan leads to Pin 6 and Pin 7, Signal Ground, and connect Pin 1, PWM Control Output, to the PWM input terminal of both fans.

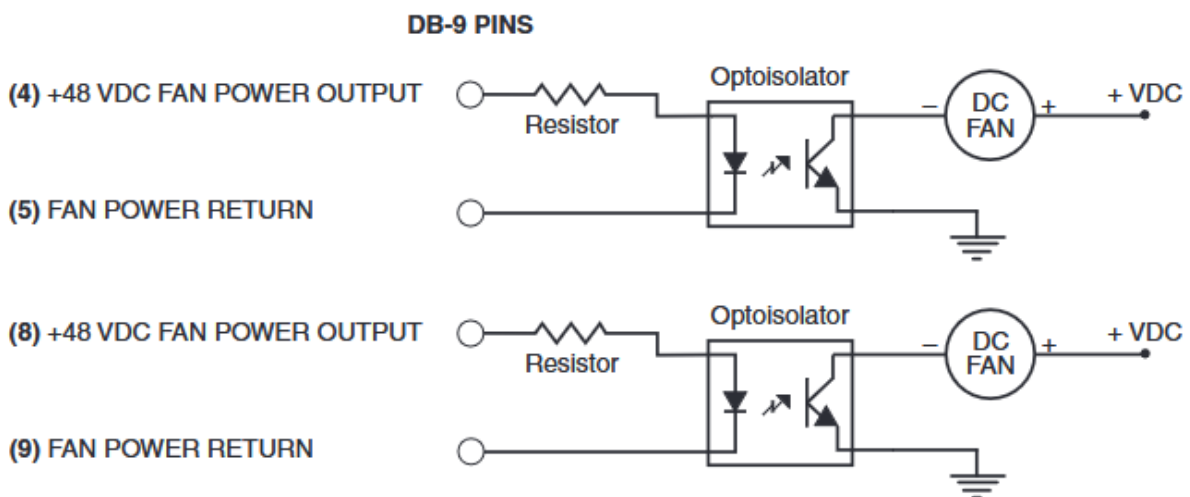
4.4.4.8 Figure: 48 VDC fan connection – external speed control



4.4.5 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 4.4.6 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.

4.4.6 Figure: 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.

4.5 Integrating ti Series safety features

The ti Series DB-15 User I/O connector allows system integrators or end-users to integrate safety features into their control system. The keyswitch, shutter, and remote interlock functions serve to enable or disable DC power to the lasers drive. Without DC power, the RF driver cannot supply RF energy to the resonator, causing the CO₂ gas to remain in a zero-energy state. The ti Series 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).

4.5.1 Keyswitch functions

4.5.1.1 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 4.3.4.9). 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.

4.5.1.2 OEM lasers

On OEM lasers, the RDY LED illuminates on DC power-up (if 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 4.3.4.9). 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.

4.5.2 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 Keypress-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 4.3.4.9). 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 (Keypress-equipped lasers only) before lasing is enabled.

4.5.3 Remote interlock functions

Interlock circuits are often used to disable machinery when a shield, panel or door is opened. The 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 the 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 Keypress-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 4.3.4.9). 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 (Keypress-equipped lasers only) before lasing is enabled.

4.6 General Specifications

4.6.1 ti Series General Specifications

Model	ti60	ti80	ti100	ti High Stability	ti100P
Wavelength	9.3 μm 10.2 μm 10.6 μm			10.6 μm	9.3 μm 10.2 μm 10.6 μm
Output Power ^{1,2}	> 60 W	> 80 W	> 100 W	> 60 W > 80 W > 100 W	> 100 W (avg.) ¹⁰ > 300 W (pulse) ¹¹
Power Stability ³ (cold start)	$\pm 7\%$			$\pm 4\%$ / $\pm 2\%$ (guaranteed after 3 mins)	$\pm 7\%$
Beam Quality (M^2) ⁴	< 1.2				
Beam Waist Diameter at $1/e^2$ ⁵	2.0 \pm 0.3 mm				6.5 \pm 2.0 mm ¹²
Beam Divergence, full angle	<7.0 mrad				
Ellipticity	< 1.2				
Polarization	Linear, vert				
Rise/ Fall time	<75 μs				<60 / <100 μs

Input specifications	ti60	ti80	ti100	ti High Stability	ti100P
Power Supply					
Voltage	48 V \pm 1.0 VDC				
Maximum Current ^{5,6}	18 A	22A	35A	18 / 22 / 35 A	35 A (50 A peak for < 500 μs)
Command Input Signal					
Voltage	+3.5 to +6.7 VDC				
Current	10 mA @ +6.7 VDC				
Frequency ⁷	0 – 160 kHz			0 – 100 kHz	
Duty Cycle	0 – 100%			0 – 50%	
Logic Low State	0.0 to +0.8 VDC				
Logic High State	+3.5 to +6.7 VDC				

Cooling specifications	ti60	ti80	ti100	ti High Stability	ti100P
Maximum Heat Load	900 W	1200 W	1700 W	See ti Series	1700W
Minimum Flow Rate, Air Static Air Pressure	140 CFM per fan (x2) 0.36" H ₂ O	190 CFM per fan (x2) 0.76" H ₂ O	n/a	See ti Series	n/a
Recommended Flow Rate Water	1-2 GPM				
Maximum Coolant Pressure	60 PSI				
Pressure Drop	11 PSI @ 1.5 GPM				
Coolant Temperature ⁸	18 – 22°C				

Environmental specifications	ti60	ti80	ti100	ti High Stability	ti100P
Operating ambient Temperature Range ⁹	15 – 40°C				
Humidity	0 – 95%, non-condensing				

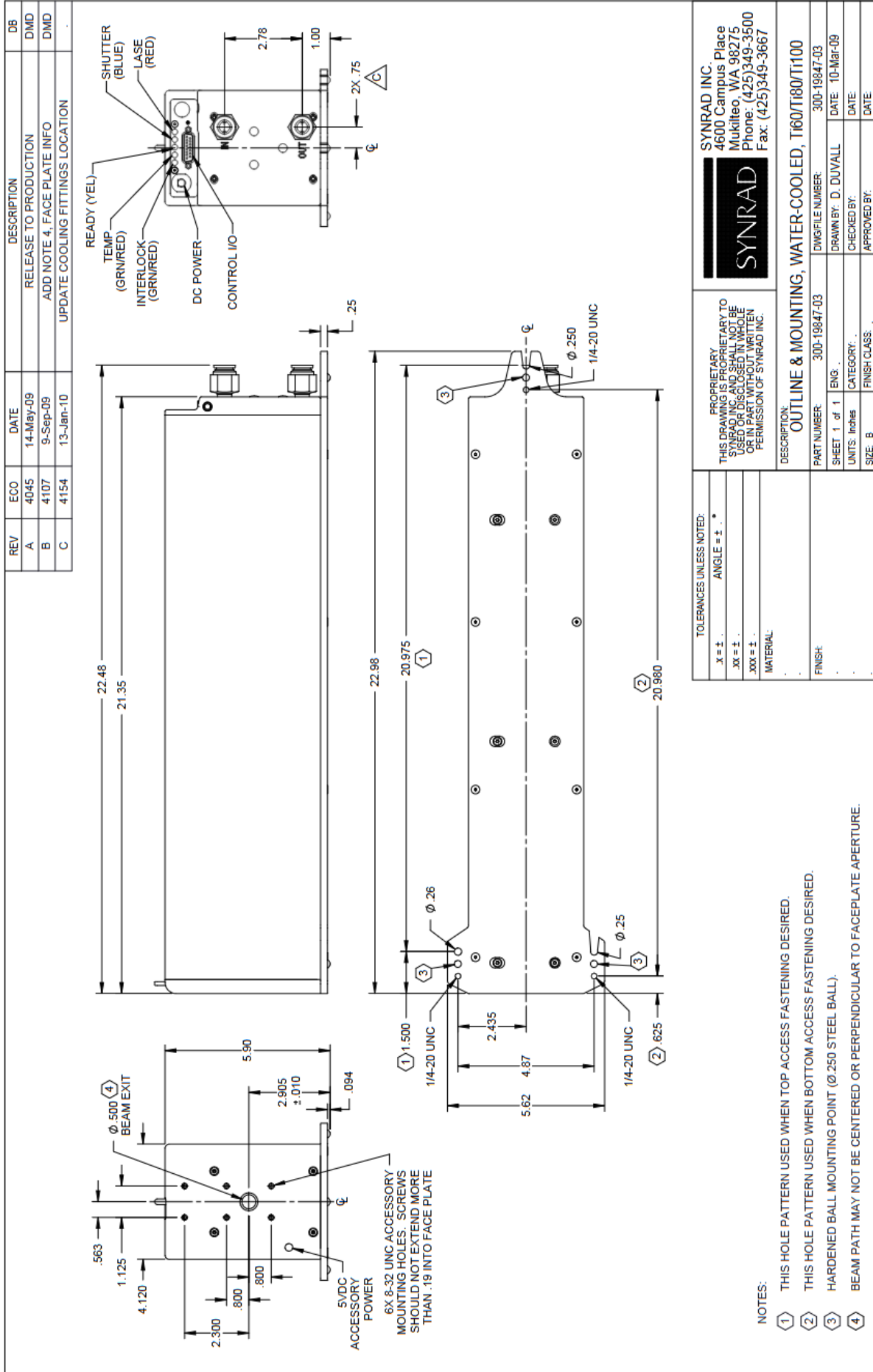
Physical specifications	ti60	ti80	ti100	ti High Stability	ti100P
Dimensions (air model) (LxWxH) mm (in.)	571 x 158 x 148 (22.5 x 6.2 x 5.8)		n/a	n/a	n/a
Dimensions (fan model) (LxWxH) mm (in.)	571 x 196 x 150 (22.5 x 7.7 x 5.9)			n/a	n/a
Dimensions (water model) (LxWxH) mm (in.)	584 x 143 x 150 (23 x 5.6 x 5.9)		544 x 104 x 150 (21.4 x 4.1 x 5.9)		633 x 142 x 150 (24.9 x 5.6 x 5.9)
Weight (air model) kg (lbs.)	11.6 kg (25.5 lbs.)		n/a	n/a	n/a
Weight (fan model) kg (lbs.)	13.1 kg (28.9 lbs.)		14.6 kg (32.1 lbs.)	n/a	n/a
Weight (water model) kg (lbs.)	11.9 kg (26.2 lbs.)			19 kg (42 lbs.)	12.1 kg (26.7 lbs.)

* Specifications subject to change without notice.

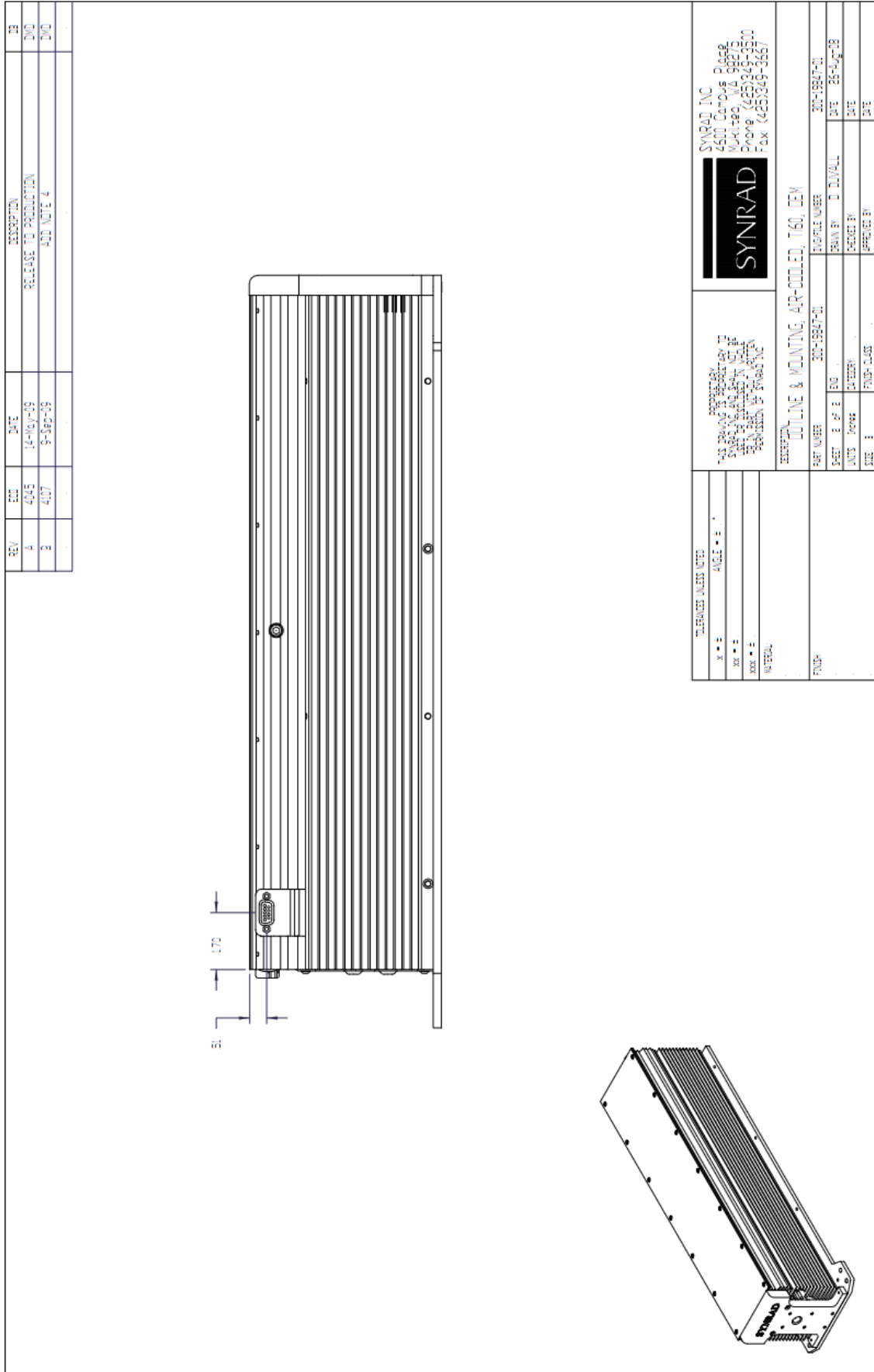
- 1 This power level is guaranteed for 12 months regardless of operating hours.
- 2 48 VDC input voltage to obtain guaranteed output power.
- 3 From cold start (guaranteed) at 95% duty cycle.
- 4 Measured at laser output.
- 5 User-supplied cooling fans on SA models may increase current load by an additional 1.0 A.
- 6 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
- 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
- 10 Measured at 50% DC, 5kHz
- 11 Measured at 10% DC, 1kHz
- 12 With 3x beam expander

4.7 Outline and Mounting Drawings

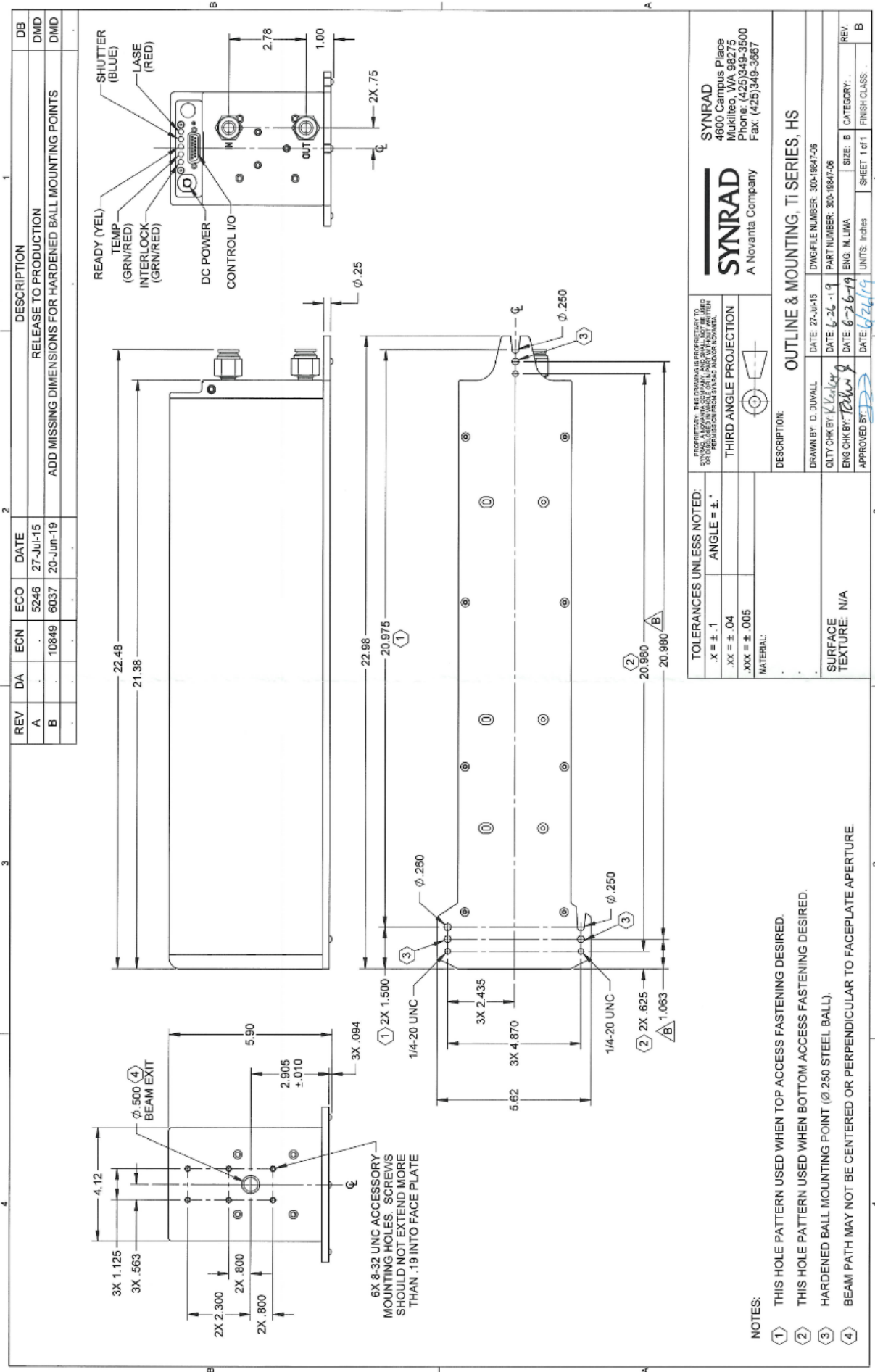
4.7.1 Figure: Water-cooled ti Series (ti60, ti80, ti100) package outline and mounting dimensions



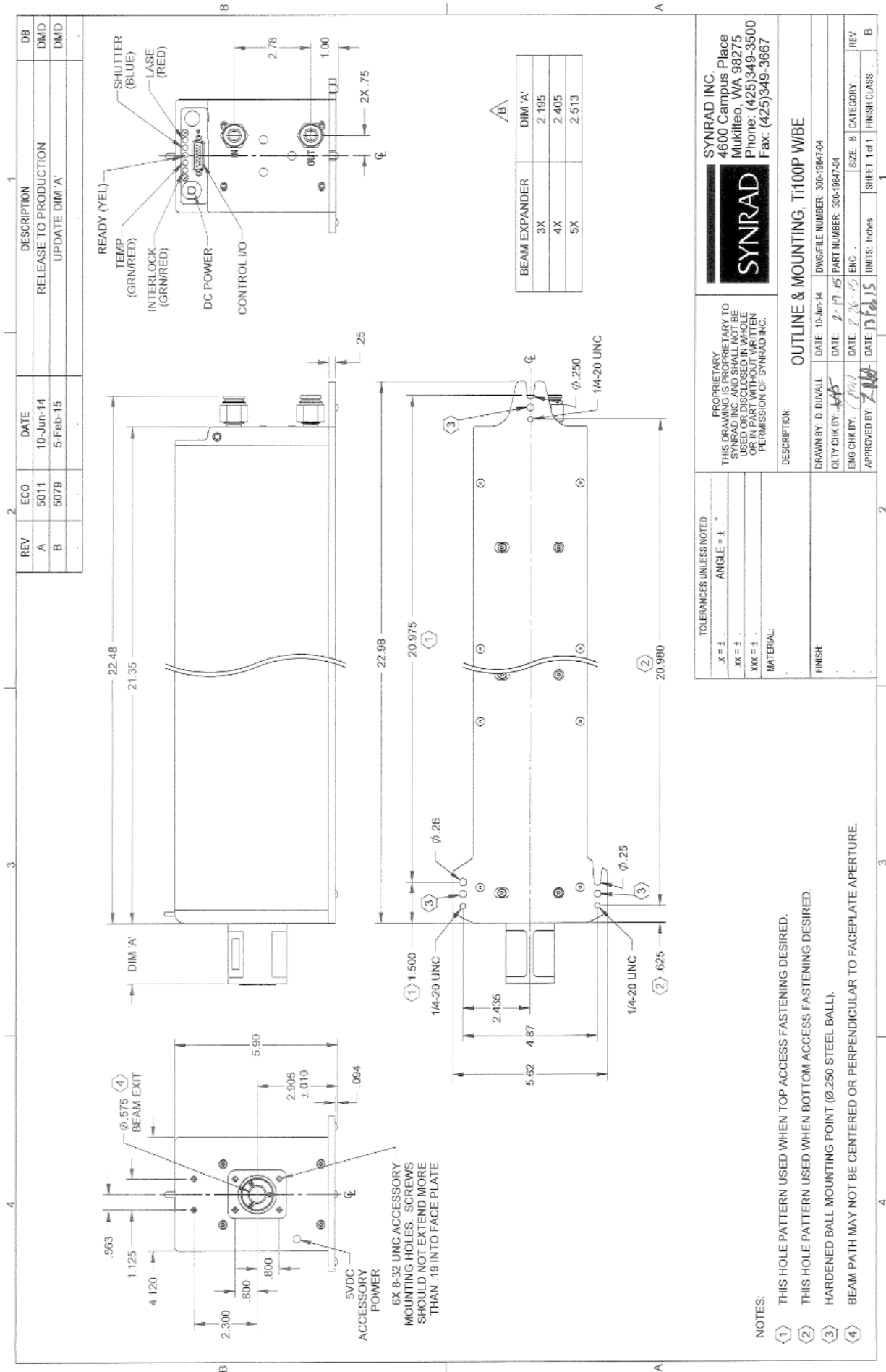
4.7.5 Figure: OEM air-cooled ti60 / ti80 (SA model) package outline and mounting dimensions, part 2



4.7.6 Figure: High Stability ti Series package outline and mounting dimensions



4.7.7 Figure: Pulsed ti100p package outline and mounting dimensions



5 Maintenance and Troubleshooting

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

5.1 Maintenance

5.1.1 Disabling the Laser

Before performing any maintenance on your ti Series laser, be sure to completely disable the laser by disconnecting the DC Power Cables from the DC power supply.

5.1.2 Daily Inspections

Perform the following steps daily to keep your 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 or beam delivery optics, contact our technical support team (see section 1.6 Technical Support) or the optics manufacturer for proper handling instructions.

Caution: Possible Equipment Damage

For optics in the beam path, even small amounts of contamination can absorb enough energy and damage the optic. Inspect 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.

If you plan to operate your laser in dirty or dusty environments, please contact our technical support team for more information about the associated risks, as well as precautions that you can take to increase the longevity of the laser and optical components.

1. Inspect all cooling tubing connections for signs of leakage. Check for signs of condensation that may indicate the cooling water temperature has been set below the dew point temperature. Condensation will damage electrical and optical components inside the laser. See the Setting Coolant Temperature section in the Getting Started chapter.
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 4.1.2.3 in the Technical Reference chapter.
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 the Laser Safety chapter for label types and locations.

5.1.3 Storage/Shipping

When preparing the 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 200 kPa (29 PSI) to remove any residual water. When finished, cap all connectors to prevent debris from entering the cooling system.

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

Important Note

Failure to properly package the laser using Novanta-supplied shipping boxes and foam/cardboard inserts as shown in the Packaging Instructions section may void the warranty. Customers may incur additional repair charges for shipping damage caused by improper packaging.

5.1.4 Cleaning Optical Components

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



Danger: Serious Personal Injury

Ensure that DC power to the laser is turned off and locked out before inspecting optical components in the beam path. Invisible CO₂ laser radiation is emitted through the aperture. Corneal damage or blindness may result from exposure to the laser radiation.

Caution: Possible Equipment Damage

Because of their smaller beam diameter, the ti Series lasers have significantly higher power densities than most of our other lasers. This means that any contamination of the laser's output window (or on any optic in the beam path) can absorb enough energy to damage the optic. Inspect the output window and other beam delivery optics periodically for signs of contaminants and carefully clean as required. In dirty environments, purge laser optics using filtered air or nitrogen to prevent vapor and debris from accumulating on optical surfaces.

Important Note

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

5.1.4.1 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 a tissue or suitable equivalent material for protection; never place optics on hard or rough surfaces.
- It may be necessary to use a cotton ball or fluffed cotton swab instead of a lens wipe to uniformly clean the entire surface of small-diameter mounted optics.
- Before using any cleaning agents, read Material Safety Data Sheets (SDS) and observe all necessary safety precautions.

5.1.4.2 Table: Required Cleaning Materials

The table below lists the type and grade of materials required to properly clean optical surfaces.

Cleaning Material	Requirement
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 bodies

5.1.4.3 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 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 vapors 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.

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

Note:

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

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 suitable lighting. 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.

5.2 Troubleshooting

5.2.1 Introduction

The Troubleshooting 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 Novanta or a Novanta Authorized Distributor for repair information.

To troubleshoot ti Series lasers, it is necessary to understand the sequence of events that must happen before the laser can operate. Before attempting any service, we advise you to read the entire troubleshooting guide and review both the operational flowchart in Figure 5.2.3 and the functional block diagram in Figure 5.2.2.

**Danger: Serious Personal Injury**

This Class 4 laser product emits **invisible** infrared laser radiation in the 9.3 – 10.6 μm CO₂ wavelength band, depending on model.

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 CO₂ 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.

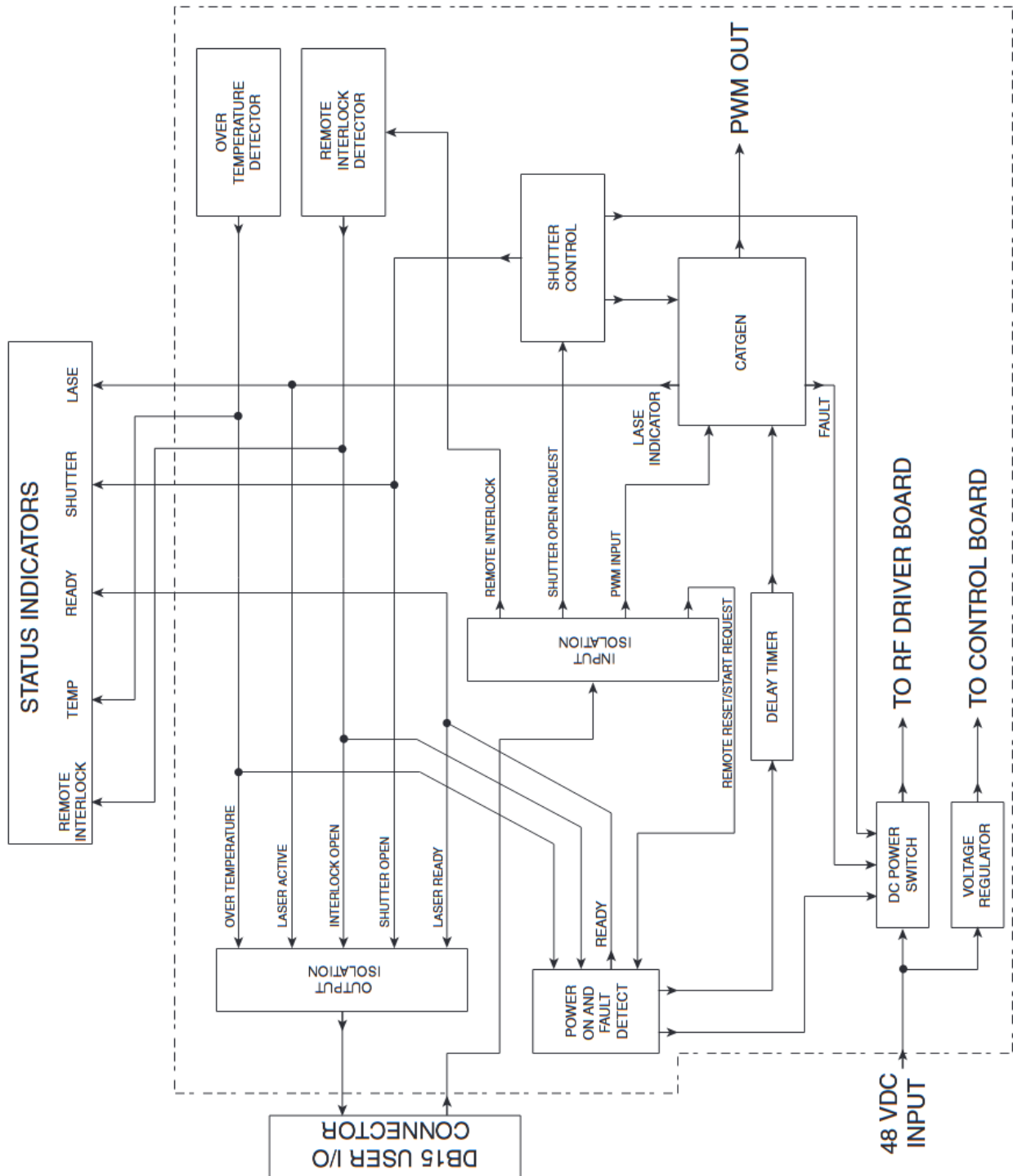
Do not contact the laser beam. This product emits an invisible laser beam that is capable of seriously burning human tissue. Always be aware of the beam's path and always use a beam block while testing.

Caution: Possible Equipment Damage

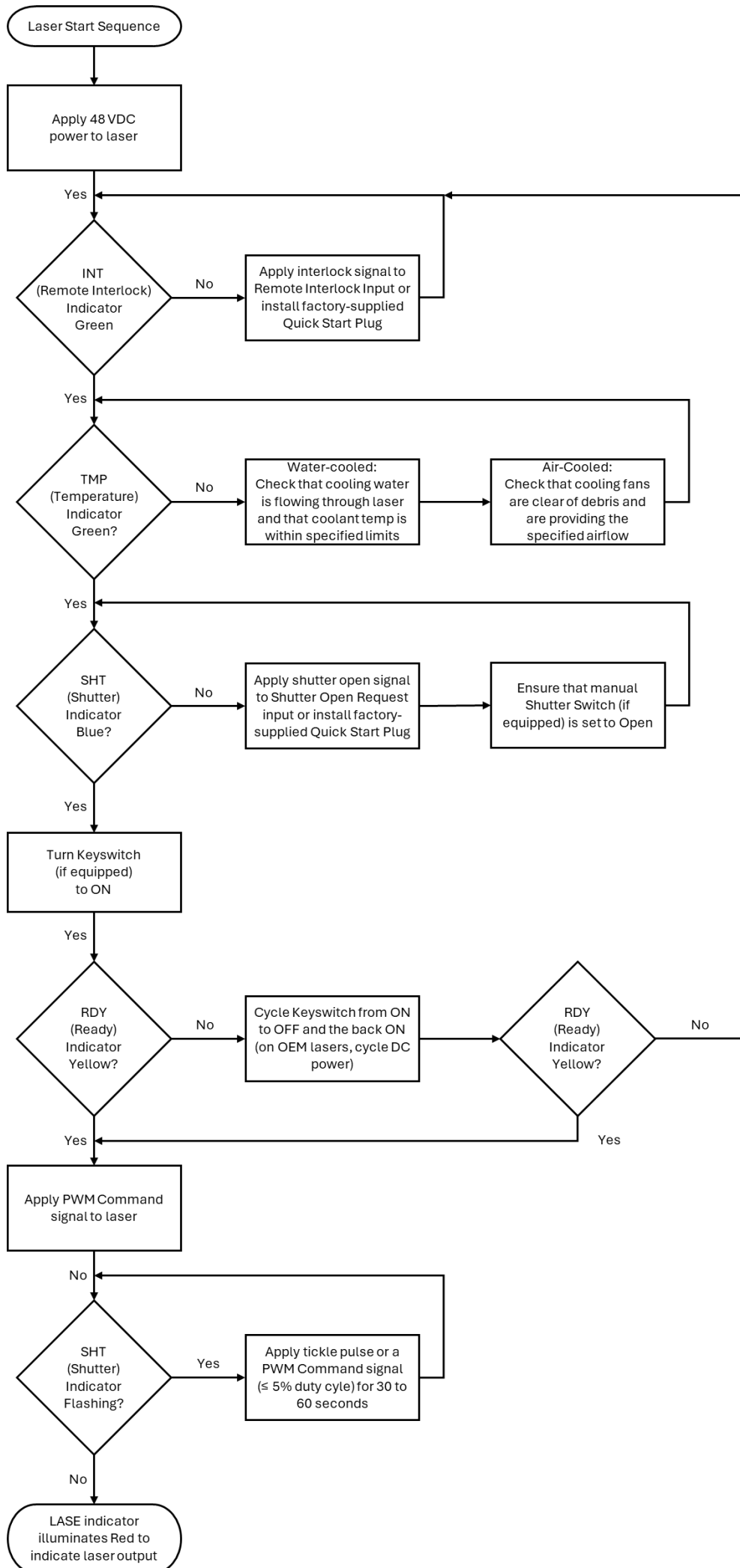
Attempting repair of a Novanta laser without the express authorization of Novanta will void the product warranty.

If troubleshooting or service assistance is required, please contact Technical Support (see section 1.6).

5.2.2 Figure: ti Series functional block diagram



5.2.3 Figure: Operational flowchart



5.2.4 Status LEDs

Three five status indicator LEDs on the rear of the ti Series laser provide a visual indication of operating status.

1. A green INT LED illuminates when a signal to the Remote Interlock input is applied or the factory supplied Quick Start Plug is used.
2. A green TMP LED indicates, that the laser operates below the thermal limit.
3. A blue SHT LED illuminates when a signal to the Shutter Open Request input is applied or the factory supplied Quick Start Plug is used.
4. The yellow RDY LED indicates that the laser is in operating conditions and ready to receive the PWM Command signal.
5. The LASE LED illuminates red to indicate that the PWM signal is sufficient to induce laser output.

In conjunction with the DB-15 I/O outputs, these status LEDs also provide information on fault conditions. See Table 3.7.2 and section 3.7.1 for more details.

5.2.5 Laser Fault Indicators

The 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.

See the following table for a summary of LED indicator and output signal states during normal and fault conditions.

5.2.6 Table: ti Series LED and I/O Status States

LASER CONDITION / FAULT	INPUT STATUS				LED STATUS							OUTPUT STATUS					COMMENTS
	Remote Interlock	Remote Reset / Start Request	Shutter Open Request	PWM	INT	TMP	RDY	SHT	LASE	Interlock Open	Fault Detected	Laser Ready	Shutter Open	Laser Active			
DC Power Off	X	X	X	X											No RF to tube		
DC Power Applied, Laser Disabled	0	X	X	X						C					No RF to tube		
	X	X	0	X								C			Tickle applied to tube for 5 seconds, then laser may fire		
DC Power Applied, Laser Enabled	1	0	1	0								C			Normal laser operation		
Laser Firing	1	0	1									C					
Interlock Open	0	0	1	X						C					No RF to tube		
Over Temperature	1	0	1	X							C				Cooling problem		
Mechanical Shutter Not Open	1	0	1	X								C			No RF to tube		
Under Voltage	1	X	1	X									C		Voltage below 46VDC		
Over Voltage	1	X	1	X									C		Voltage over 50VDC		
RF Drive Switch Fault	1	X	1	X									C		Laser service required		
PWM Drive Fault	1	X	1	X									C		Laser service required		
No Strike Fault	1	0	1	X									C		Output limited to 5%		

C : Closed

Blinking LED; number represents blink sequence
 Blinking LED; "C" represents continuous blinking sequence

0 = Input OFF
 1 = Input ON
 x = Does not matter

TABLE KEY:

5.2.7 Resetting Faults

5.2.7.1 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.

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 this fault occurs, the laser requires service - contact Novanta or a Novanta 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 this fault occurs, the laser requires service - contact Novanta or a Novanta 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 this fault occurs, the laser requires service - contact Novanta or a Novanta Authorized Distributor.

5.2.7.2 OEM Laser



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 CO₂ 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.

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 this fault occurs, the laser requires service - contact Novanta or a Novanta 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 this fault occurs, the laser requires service - contact Novanta or a Novanta 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 this fault occurs, the laser requires service - contact Novanta or a Novanta Authorized Distributor.

5.2.8 Other laser fault

When a laser fault occurs, the status LEDs and output signals will reflect a fault condition as indicated in the previous table. Each Symptom listed below described a particular fault. For each Symptom, specific causes and solutions are described under Possible Causes.



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 CO₂ 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

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.

Possible Causes: 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 m³/min (140 CFM) per fan at a maximum static pressure of 9.1 mm H₂O (0.36" H₂O) for ti60 lasers or at least 5.4 m³/min (190 CFM) per fan at a maximum static pressure of 17.8 mm H₂O (0.70" H₂O) 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 output = Open
- TMP LED = Green Fault Detected Output = **Closed**
- RDY LED = Yellow Laser Ready output = Closed
- SHT LED = **Blue (Flashing)** Shutter Open output = Closed
- LASE LED = Off/ Red Laser Active output = 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.

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

- 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/ Red Laser Active output = Open or Closed

Possible Causes: The Shutter Switch (if equipped) is Closed.

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

Possible Causes: 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 was 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.

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.

5.2.9 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 affect mode quality and/or cause laser energy to extend beyond the confines of optical elements in the system, damaging acrylic safety shielding. Do not use air dusters containing difluoroethane in any area adjacent to CO₂ laser systems because difluoroethane persists for long time periods over wide areas.

Caution: Possible Equipment Damage

If you plan to operate your laser in dirty or dusty environments, please contact our technical support team for more information about the associated risks, as well as precautions that you can take to increase the longevity of the laser and optical components.

Symptom:

- The laser loses power over time.
- Laser output power must be increased to maintain previous performance.

Possible Causes: Beam delivery optics are coated by vapor residue or debris.

**Danger: Serious Personal Injury**

Ensure that DC power is turned off and locked out before inspecting optical components in the beam path. **Invisible** CO₂ 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. If the optic requires cleaning, then refer back to the Maintenance section for cleaning instructions. Use only recommended cleaning materials (see 5.1.4.2 Required Cleaning Materials) to prevent scratching delicate optical surfaces.

**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 the laser, marking head, or beam delivery optics, contact Novanta or the optics manufacturer for handling instructions.

If the focusing optic is pitted, it must be replaced immediately. Because of the extremely high power density of the ti Series lasers, pits or debris on the lens may absorb enough energy from the focused beam to crack the lens. If this happens other optics in the beam path may become contaminated as well.

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 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 Assist Gas Purity Specifications (4.1.2.3) in the Technical Reference chapter for filtering and drying specifications.

6 Addendum

6.1 Stabilized ti Series Laser

Important Note:

This page contains important information about installation and operation of the High Stability ti Series laser (ti60HS, ti80HS, ti100HS) that differs from standard ti Series lasers. Except as noted here, refer to the ti Series Operator's Manual for mounting, connecting, and operating information.

The High Stability ti Series is available in 60W, 80W and 100W and in 10.6 μ m.

Front panel: The High Stability ti Series laser (HS) lasers do not provide DP power.

To achieve the high stability, the High Stability ti Series lasers are only available as water cooled version (SW models).

Output specifications	ti High Stability
Stabilized Laser Power (cold)	$\pm 4\%$
After 3 minutes (guaranteed)	$\pm 2\%$

6.2 Ti100p Pulsed Laser

Important Note:

This page contains important information about installation and operation of the Pulsed ti100 laser (ti100p) that differs from standard ti Series lasers. Except as noted here, refer to the ti Series Operator's Manual for mounting, connecting, and operating information.

The ti100p is available in 9.3 μ m, 10.2 μ m and 10.6 μ m wavelengths

The ti100p is a pulsed laser; therefore, the maximum PWM duty cycle is limited to 50%.

Maximum Pulse Repetition Frequency (PRF) is 100 kHz.

Pulse width is limited to 500 μ s maximum.

The ti100p is shipped with a beam expander mounted and aligned to the faceplate. Available expansion ratios are 3X, 4X, and 5X. Beam diameter ($1/e^2$) at the beam expander output is shown in the table below:

Expander Ratio	Beam Diameter	Beam Divergence
3X	6.6 mm	~2.3 mrad
4X	8.8 mm	~1.8 mrad
5X	11.0 mm	~1.4 mrad

Important Note:

Do not apply a tickle signal. Do not use a UC-2000 Controller or other PWM signal source that generates a tickle signal. Applying a tickle signal to the ti100p may interfere with its pulsing performance.

The minimum power supply requirement for the ti100p laser is:

Voltage: 48 V \pm 1.0 VDC

Current: 35 A (50 A peak for < 500 μ s)

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