Novanta

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ENGINEERED BY SYNRAD

i 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 i Series lasers are registered trademarks of Novanta.

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

1.2 Warranty Information

This is to certify that i 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. This includes, but is not limited to, damage due to corrosion, condensation, or failing to supply properly conditioned purge gas.

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 CO_2 Laser Customer Care department using the Service Request form on the website (https://novantaphotonics.com/service-request-form-header/) or by emailing co2lasercustomercare@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 i 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 i 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 CO_2 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

co2lasercustomercare@novanta.com

1.3.3 Europe, Middle East, Africa

Novanta Europe GmbH, Wackersdorf, Germany

Phone: +49 9431 7984-0

sales-europe@novanta.com

Milan, Italy

Phone: +39-039-793-710

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 CO_2 laser solution for a given application. Because they are familiar with you and your laser application, use them as a first point of contact when questions arise. Regional Sales Managers also serve as the liaison between you and our Applications Lab in processing material samples per your specifications.

To speak to the Regional Sales Manager in your area, 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 co2lasercustomercare@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 co2lasercustomercare@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 CO_2 wavelength band, depending on model.

Do not allow laser radiation to enter the eye by viewing direct or reflected laser energy. CO_2 laser radiation can be reflected from metallic objects even though the surface is darkened. Direct or diffuse laser radiation can inflict severe corneal injuries leading to permanent eye damage or blindness. All personnel must wear eye protection suitable for 9.3 – 10.6 µm CO_2 radiation when in the same area as an exposed laser beam. Eyewear protects against scattered energy but is not intended to protect against direct viewing of the beam – never look directly into the laser output aperture or view scattered laser reflections from metallic surfaces.

Enclose the beam path wherever possible. Exposure to direct or diffuse CO_2 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 CO_2 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 CO_2 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.

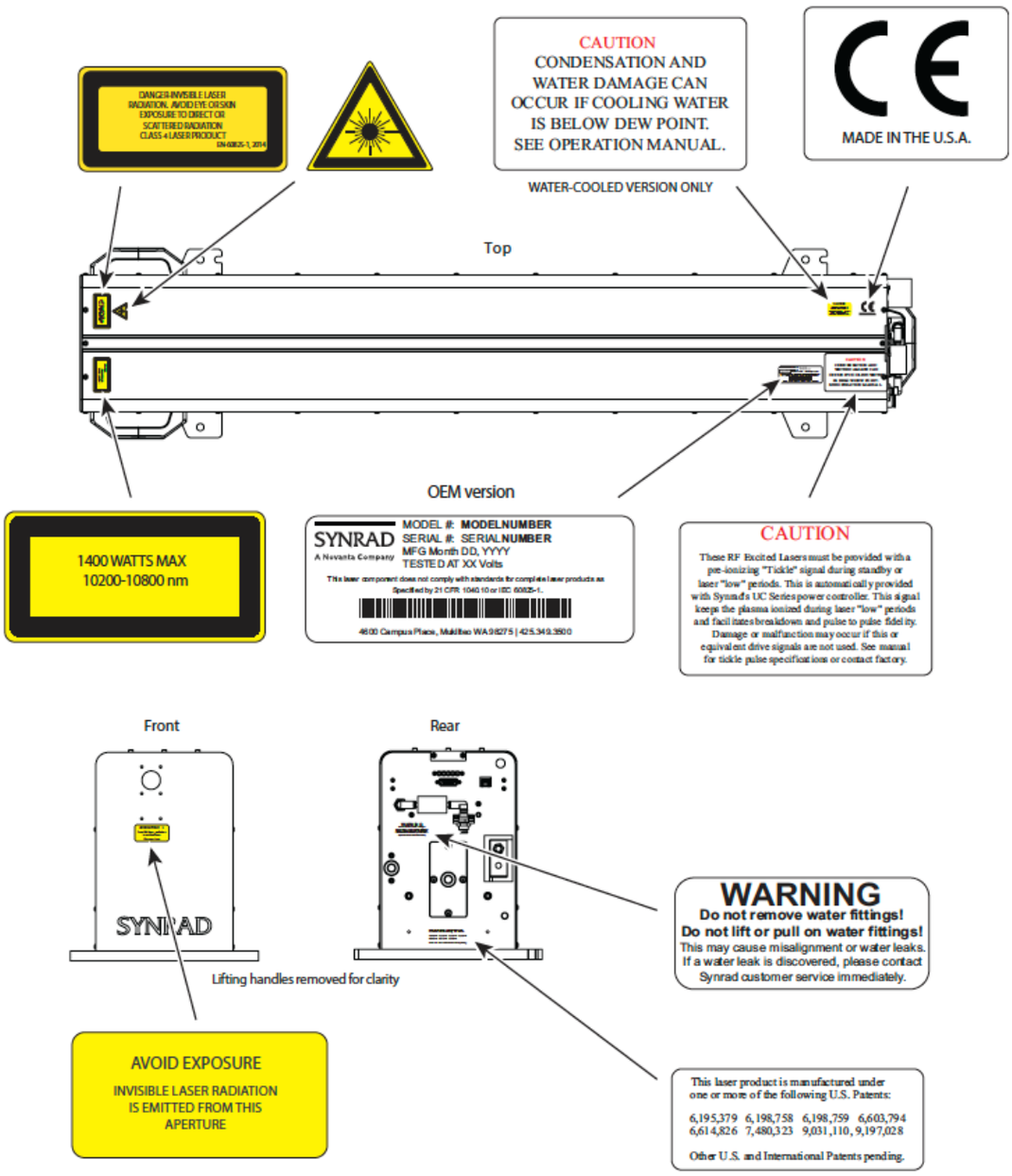
2.1.5 Additional Laser Safety Information

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: i Series Laser Label Location



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 i 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

Product features incorporated into the design of i 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 lase and laser ready indicators, remote interlock for power on/off, a laser aperture shutter switch, and a five-second delay between power on and lasing. Incorporation of certain features is dependent on the laser version (Keyswitch or OEM). *Table: Class 4 Safety Features Required by CDRH & EN60825*, indicate which features are available on i Series lasers, the type and description of the feature, and if the feature is required by CDRH regulations.

2.3.1.1 OEM models

The i 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.

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 i 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 to the user

> **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 i 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.

2.3.2.2 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

2.3.3.1 RoHS Compliance

Novanta i 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.

OEM models

The i 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 60204-1:2019, 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 for a summary of product features, indicating the type and description of features and whether those features are required by European Union regulations.

The Declaration of Incorporation is a document required by the Machinery Directive (2006/42/EC) for partly completed machinery. It serves as a statement from the manufacturer that the machinery component complies with certain essential safety and health requirements of the Directive, but it is not yet a complete machine. The manufacturer of the complete machine is responsible for ensuring the final product complies with the entire directive. The Declaration of Incorporation for the i Series laser is located in Chapter 6, Appendix.

2.3.3.3 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 i Series lasers, EN 61000- 6-4 defines radiated and conducted RF emission limits while EN 61000-6-2 defines immunity standards for industrial environments.

The i 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 i 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 i Series lasers comply with the relevant requirements of 2014/30/EU, the Electromagnetic Compatibility Directive, as summarized in Table 2.3.3.4 below.

2.3.3.4 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

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

Feature	Location	Description	Required by:		Available on i Series OEM
			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	No
Shutter Function	Laser Control	Functions as a beam attenuator to disable RF driver/laser output when closed.	Yes	Yes	Yes
Shutter indicator (SHT)	Rear Panel Indicator (Blue)	Illuminates blue to indicate the shutter is open.	No	No	Yes
Ready Indicator (RDY)	Rear Panel Indicator (Yellow)	Indicates that the 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	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
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	No
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 the Remote Interlock circuitry is closed. Illuminates red when the interlock circuitry is open.	No	No	Yes
Over Temperature Protection	Circuit Element	Temperature shutdown occurs if the 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

[1]Not available nor required on i Series OEM lasers.

2.3.5 i401 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™ OEM i401 Laser

Model Number: FSi401SB (*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 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, *Safety of Laser Products*. Buyers of OEM laser products are solely responsible for meeting applicable Directives and Standards for CE compliance and marking.

Corporate Officer:

Justin Ryser, Quality Manager of SYNRAD

Dated: 12/7/23

European Contact:

Novanta Distribution (USD) GmbH
Werk 4
92442 Wackersdorf, Germany

CE

MADE IN THE U.S.A.
900-20976-03 Rev F

3 Getting Started

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

3.1 Introduction

The i Series lasers are a new addition to Novanta's series of high-power lasers. This single tube laser features an integrated RF power supply with no external RF cables. The compact, single tube design mounts easily to flatbed cutters, robotic arms, or gantry systems making integration into your production line simple and fast.

The i Series lasers feature a built-in internal humidity sensor and a TCP/IP web-based Internet interface. Although i Series lasers are available only as OEM lasers, they do include a built-in electromechanical shutter assembly. The integrated RF modules are field replaceable to enable onsite support by our Novanta engineers. The built-in gas purge port allows for easy connection to nitrogen or CDA to protect the laser from two main sources of damage: condensation and particulate matter.

3.1.1 Nomenclature

OEM lasers, like the i Series laser, do not incorporate keyswitch or shutter functions required by CDRH and EN 60825-1 regulations because they are designed as components for integration into larger processing systems by the Original Equipment Manufacturer (OEM) or System Integrator who bears full responsibility for meeting the appropriate laser safety requirements for systems incorporating Class 4 lasers.

Although i Series lasers are available only as OEM lasers, they do include a built-in electromechanical shutter assembly.

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: "i" indicates it is part of the i Series product family. Other options include "vi", "f", "ti", and "p".

Average power: "401" for 400W and 501 for 500W

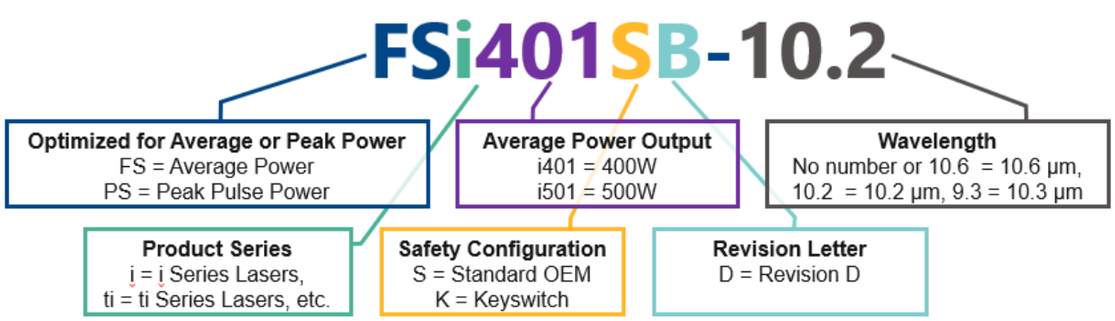
Safety configuration: "K" for Keyswitch or "S" Standard OEM models. Only available as OEM model.

Cooling option: "W" for water-cooled units, "F" for fan-cooled units, and "A" for air-cooled lasers. Only available as water cooled version, therefore this indicator is left out.

Revision letter: indicates the current model revision

Wavelength: No indicator for 10.6 µm wavelength, "10.2" for 10.2 µm, etc.

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

Warning: Possible Personal Injury

Lifting or moving the i Series laser poses a potential for injury. Use appropriate lifting techniques and/or equipment to prevent a risk of injury. In some cases, you may require assistance from additional personnel to safely unpack and move this equipment.

To prevent equipment damage or loss of smaller components, use care when removing packaging materials.

After unpacking, review Inventory (Table 3.2.8) 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.

i Series lasers are heavy and awkward to move. Use appropriate lifting techniques, additional personnel, and/or hoisting equipment to prevent a risk of injury when rigging this equipment.

3.2.3 Unpacking

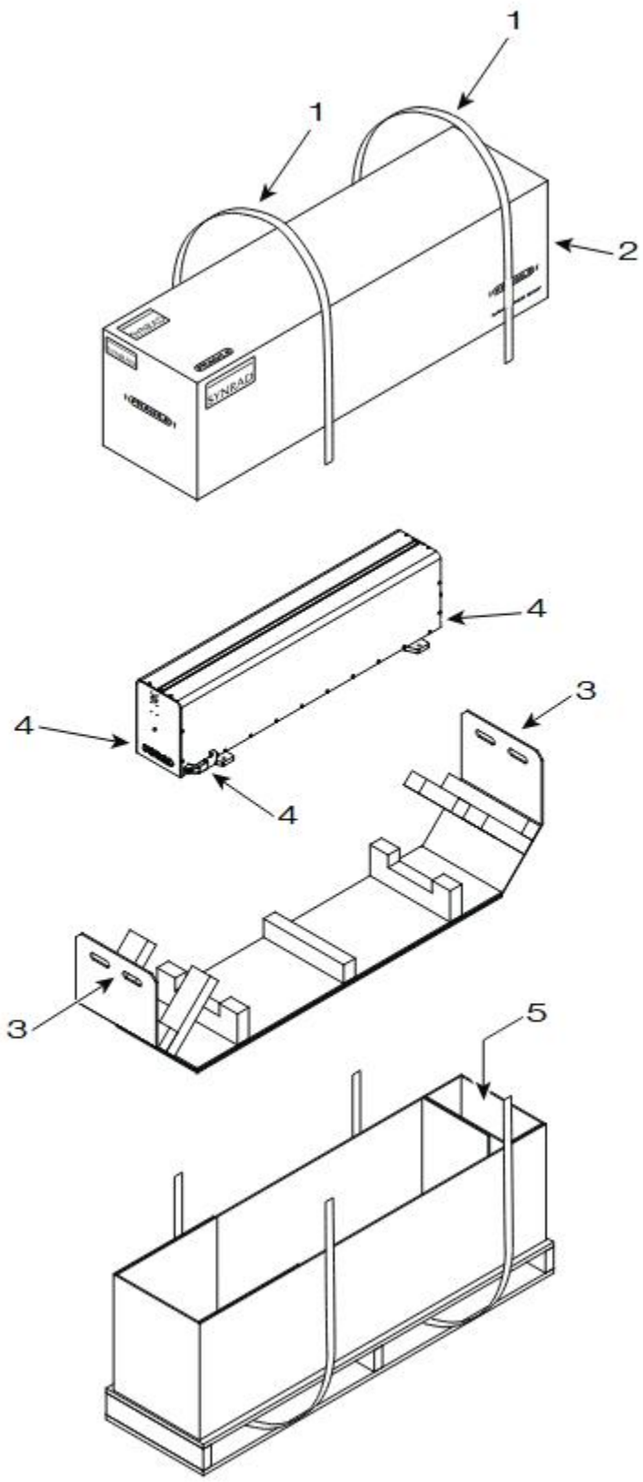
To unpack the i Series laser, refer to Figure 3.2.4 and perform the following steps. The numbered items in Figure 3.2.4 correspond to the step numbers in the following procedure.

Caution: Possible Equipment Damage

Do not lift or support the i Series laser using the cooling fittings. Lift the laser by the lifting handles or baseplate only.

1. Carefully cut the shipping straps wrapped around the shipping container.
2. Remove the upper lid and set it aside.
3. Carefully lift or hoist the sling containing the i Series laser out of the container and place it on a solid surface. To prevent injury to personnel or damage to the laser, always use at least two people to lift and move the sling.
4. Lift or hoist the i Series laser out of the container using the three lifting handles. To prevent injury to personnel or damage to the laser, always use at least two people to handle the i Series laser.
5. After removing the laser, pull out all accessory items and paperwork packaged behind the laser in the shipping container's accessory compartment.
6. Save the shipping container and sling. Use these specialized packaging materials when shipping the laser to another location.

3.2.4 Figure: Unpacking the i Series laser

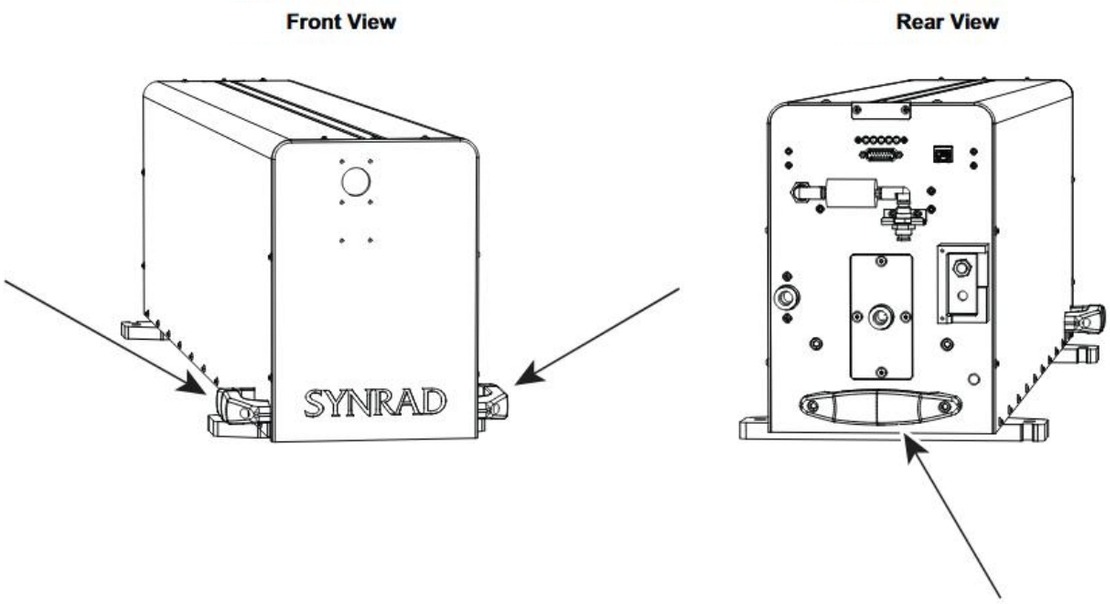


3.2.5 Removing the Lifting Handles

Once you have placed the i Series laser in its final mounting location, perform the following steps to remove the lifting attachments.

1. Remove the 1/4–20 × 5/8" capscrews from two locations on each of the three handles as shown in Figure 3.2.6.
2. Save the lifting handles and capscrews so the handles can be reinstalled if the i Series is moved to another location.

3.2.6 Figure: Removing the i Series lifting handles



3.2.7 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 4.9.3) 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 4.9.3) may void the warranty. Customers may incur additional repair charges for shipping damage caused by improper packaging.

3.2.8 Table: i Series Shipment Inventory

Contents	Qty	Additional Information
i Series Laser	1	For cutting, welding, drilling, and marking a wide variety of products and materials.
Customer Communication Flyer	1	Follow the instructions on the flyer to access the latest manual on the Novanta website.
Cooling Kit	1	Contains adapter fittings: Two straight 12mm male to ½" female 90° fittings and two 12mm male to 12mm female 90° fittings.
Cooling Tubing	1	Carries cooling water from the chiller to the laser and back. This clear polyethylene tubing is 12 mm O.D. by 30 feet and must be cut to length.
Gas purge Kit	1	Provides a filtering and connection point to the laser from your facility's gas purge system.
Ethernet Crossover cable	1	Provides the communications link between a host and the laser for accessing operating parameters via a TCP/IP web-based interface.
BNC Control Cable	1	Coaxial cable carries the PWM Command signal from the UC-2000 Controller to the laser's Quick Start Plug.
DC Power Cables	1	A pair of cables, to carry DC power from the 48 V power supply to your laser. Standard cable length is 2.0 meters (6.5 feet).
Spare Fuse	4	40 ampere fast-blow fuses protect the internal RF circuitry.
Quick Start Plug	1	Connects to laser's User I/O connector. Jumpers are built into the plug to enable laser interlock circuits for initial start-up and testing.

3.3 Mounting

The i Series base plate is designed so that the laser is easily mounted in various configurations as described in the subsections below. Refer to the i Series package outline drawing in the Technical Reference chapter for mounting locations and dimensions.

When mounting your i Series laser, you can choose between different mounting schemes, the four-point mount with feet, the four-point mount without feet and the three-point mount without feet. Read through the mounting sections below to determine which mounting scheme is required for your application.

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 4.9.3) may void the warranty. Customers may incur additional repair charges due to shipping damage caused by improper packaging.

3.3.1 Four-point mount with feet

Use this scheme to mount the laser to a horizontal or vertical surface (or to a surface that will move dynamically in multiple axes) using the factory-installed mounting feet. To use a four-point mount, the variation in mounting surface flatness must not exceed 1.02 mm (0.040").

Note:

Each mounting foot also contains a 9.65 mm (0.380") dowel pin guide (labeled "B" in Figure 3.3.1.1.) for applications that require precision positioning for alignment purposes.

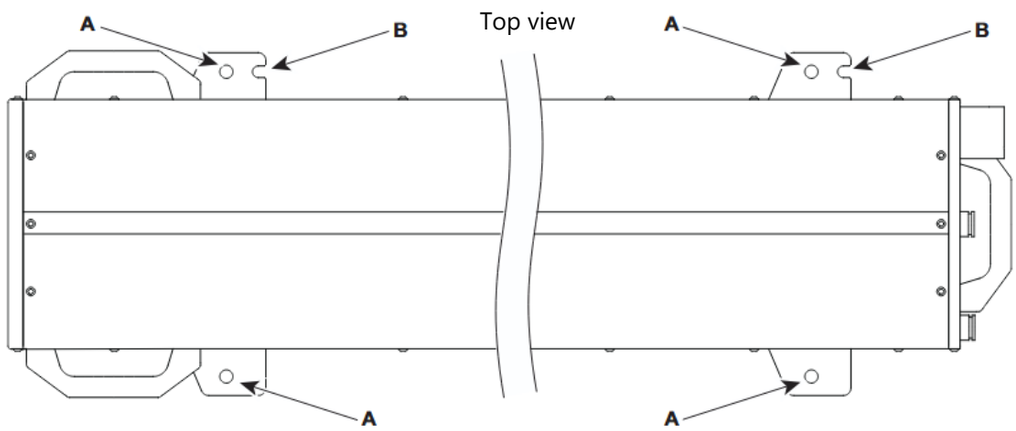
To install a laser (with feet) using the four-point mounting method, perform the following steps:

1. Determine whether you will use metric (ISO) or inch (SAE) fasteners to mount the laser. Four M10 (metric) capscrews and M10 flat/split washers are included in the ship kit.
2. Refer to the i Series outline and mounting drawing (Sheet 1 of 2) for Option 'A' mounting dimensions, then drill and tap four M10 × 1.5 or four 3/8" (UNC or UNF) holes into your mounting surface. These holes should correspond with the holes labeled "A" shown in Figure 3.3.1.1.
3. Carefully place the i Series laser on the mounting surface so the holes in the mounting feet line up over the threaded holes in the mounting surface.
4. Place a split washer and flat washer on each capscrew and insert the fasteners through the feet into the mounting surface. Turn the screws by hand until the threads fully engage.
5. Evenly tighten all four fasteners to a torque of 40 Nm (29 ft-lb).

Note:

After the laser is fastened into position, remove the lifting handles if necessary.

3.3.1.1 Figure: Mounting locations for four-point mount with feet



3.3.2 Four-point mount without feet

Use this scheme to mount the laser to a horizontal or vertical surface (or to a surface that will move dynamically in multiple axes) by fastening directly into the laser's base plate. To use a four-point mount, the variation in mounting surface flatness must not exceed 1.02 mm (0.040").

Caution: Possible Equipment Damage

When removing the mounting feet, raise the laser by placing support blocks under the base plate. Do not lay or place the laser on its side or top, even temporarily, because the sheet metal covers are not designed to support the weight of the laser. Always support and mount the laser using the mounting feet or base plate to avoid damaging the laser.

Note:

The i Series base plate contains two 6.40 mm × 12.70 mm (0.252" × 0.500") dowel pin slots (labeled "D" in Figure 3.3.2.1) and a 6.40 mm (0.252") dowel pin hole for applications that require precision positioning of the laser.

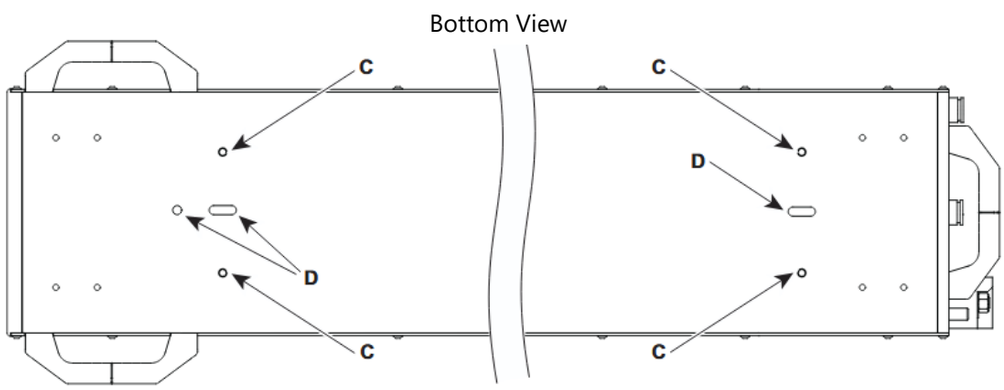
Important Note:

Verify the correct fastener length for your mounting application. The M10 × 1.5 × 35 mm capscrews from the ship kit are for use with the factory-installed mounting feet. When fastening the i Series laser to your mounting surface from the bottom up, **use M10 × 1.5 mounting screws with a length of 30 mm ± 2 mm plus the thickness of the mounting plate and any washers between the bolt head and the mounting plate.**

To install an i Series laser (without feet) using the four-point mounting method, perform the following steps:

1. Raise the i Series laser and place support blocks under the base plate.
2. Unscrew the four M10 capscrews fastening the feet to the bottom of the i Series laser and remove the factory-installed mounting feet.
3. Refer to the i Series outline and mounting drawing (Sheet 2 of 2) for Option 'B' mounting dimensions, then drill four 10.6 mm (close fit) or 11.2 mm (normal fit) holes in your mounting surface. These holes should correspond with the fastener locations labeled "C" shown in Figure 3.3.2.1.
4. Carefully place the i Series laser on the mounting surface so the M10 threaded holes in the base plate line up over the thru holes in the mounting surface.
5. Place a split washer and flat washer on each capscrew and insert the fasteners through the mounting surface into the laser base plate. Turn the screws by hand until the threads fully engage.
6. Evenly tighten all three fasteners to a maximum torque of 40 Nm (29 ft-lb).

3.3.2.1 Figure: Mounting locations for four-point mount without feet



3.3.3 Three-point mount without feet

Use this scheme to mount the laser to a static horizontal surface only by fastening directly into the laser's base plate. A three-point mount is required when the variation in mounting surface flatness exceeds 1.02 mm (0.040").

Caution: Possible Equipment Damage

When removing the mounting feet, raise the laser by placing support blocks under the base plate. Do not lay or place the i Series laser on its side or top, even temporarily, because the sheet metal covers are not designed to support the weight of the laser. Always support and mount the laser using the mounting feet or base plate to avoid damaging the laser.

Important Note:

The single rear fastener must be located at position "E" shown in the bottom view illustration in Figure 3.3.3.1. This mounting point is designed to accommodate the full load of the laser without distorting the chassis.

Important Note:

Verify the correct fastener length for your mounting application. The M10 × 1.5 × 35 mm capscrews from the ship kit are for use with the factory-installed mounting feet. When fastening the i Series laser to your mounting surface from the bottom up, **use M10 × 1.5 mounting screws with a length of 30 mm ± 2 mm plus the thickness of the mounting plate and any washers between the bolt head and the mounting plate.**

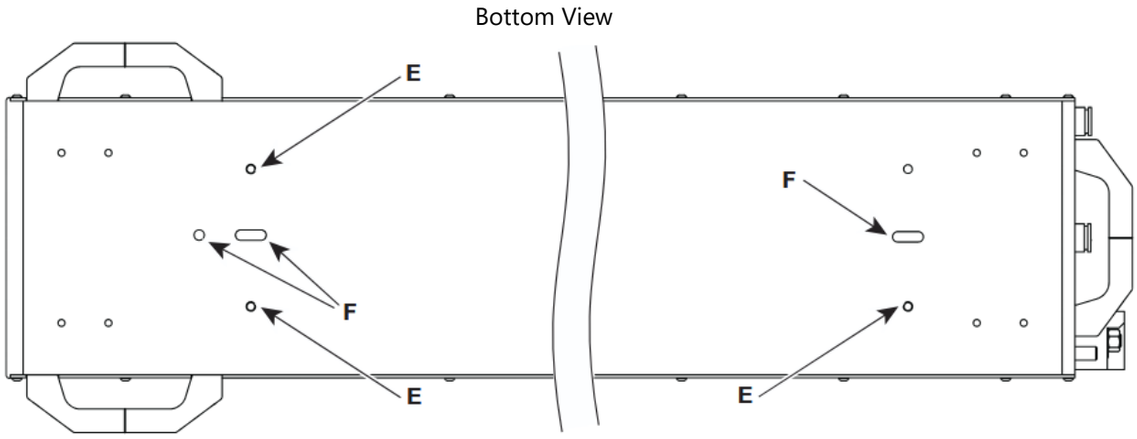
Note:

The i Series base plate contains two 6.40 mm × 12.70 mm (0.252" × 0.500") dowel pin slots (labeled "F" in Figure 3.3.3.1) and a 6.40 mm (0.252") dowel pin hole for applications that require precision positioning of the laser.

To install an i Series laser (without feet) using the three-point mounting method, perform the following steps:

1. Raise the i Series laser and place support blocks under the base plate.
2. Unscrew the four M10 capscrews fastening the feet to the bottom of the i Series laser and remove the factory-installed mounting feet.
3. Refer to the i Series outline and mounting drawing (Sheet 2 of 2) for Option 'B' mounting dimensions, then drill four 10.6 mm (close fit) or 11.2 mm (normal fit) holes in your mounting surface. These holes should correspond with the fastener locations labeled "E" shown in Figure 3.3.3.1.
4. Carefully place the i Series laser on the mounting surface so the M10 threaded holes in the base plate line up over the thru holes in the mounting surface.
5. Place a split washer and flat washer on each capscrew and insert the fasteners through the mounting surface into the laser base plate. Turn the screws by hand until the threads fully engage.
6. Evenly tighten all three fasteners to a maximum torque of 40 Nm (29 ft-lb).

3.3.3.1 Figure: Mounting locations for three-point mount without feet



3.4 Cooling

The i Series laser is only available as 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.

3.4.1 Cooling Fitting Adaptors

The i Series cooling fittings are designed to accept 12 mm polyethylene tubing. If your integrated system uses 1/2" cooling tubing, you have two options: One is to install metric-to-imperial tubing adaptors on the existing 12 mm fittings. The second option is to remove the 12 mm Tri Thread fittings from the laser's cooling manifold and install 1/2" Tri Thread fitting. The Tri Thread fittings used on i Series lasers (from Pneuforce.com) are designed to seal on the face of the O-ring, which allows them to seal properly even when re-used. When replacing Tri Thread fittings, turn the fitting by hand until the O-ring touches the face of the cooling manifold and then use a wrench to tighten the fitting an additional ¼ turn clockwise.

Caution: Possible Equipment Damage

DO NOT over-tighten Tri Thread fittings as this may deform or damage the O-ring seal and cause coolant leakage.

DO NOT install any other type of fitting into the cooling manifold as this may damage the manifold threads and/or cause coolant leakage.

3.4.2 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.

3.4.3 Chiller Preparation

You must provide fittings to adapt the laser's 12mm 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 i Series' factory-installed fittings and tubing are metric (12 mm), do not use ½" size tubing or fittings unless you have installed the appropriate adaptors. Mixing inch and metric tubing/fittings will lead to coolant leaks or may allow the pressurized tubing to blow off the fitting.

3.4.4 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: brass, copper, Delrin®, PBT, polyethylene, stainless steel, and Viton®.

Ensure that coolant flow is 4 GPM (15.1 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.

3.4.5 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.

- Use the Gas purge port to introduce nitrogen or dry filtered air into the laser housing.
- 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).
- Refer to Table 3.4.5.1 and gradually increase coolant temperature until it is above the dew point temperature and condensation disappears. Do not exceed a coolant temperature of 28°C (82°F).

Table: Dew Point Temperatures (3.4.5.1) provides dew point temperatures for a range of air temperature and relative humidity values. Remember that the laser's coolant temperature must be set above the dew point temperatures given in the chart; **however, for best results and performance, use a coolant temperature in the range of 18 –22°C (64–72°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).

3.4.5.1 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).

	Relative Humidity															
Air Temp °F/°C	**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 and 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 if 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.

3.4.6 Cooling Tubing Connections

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

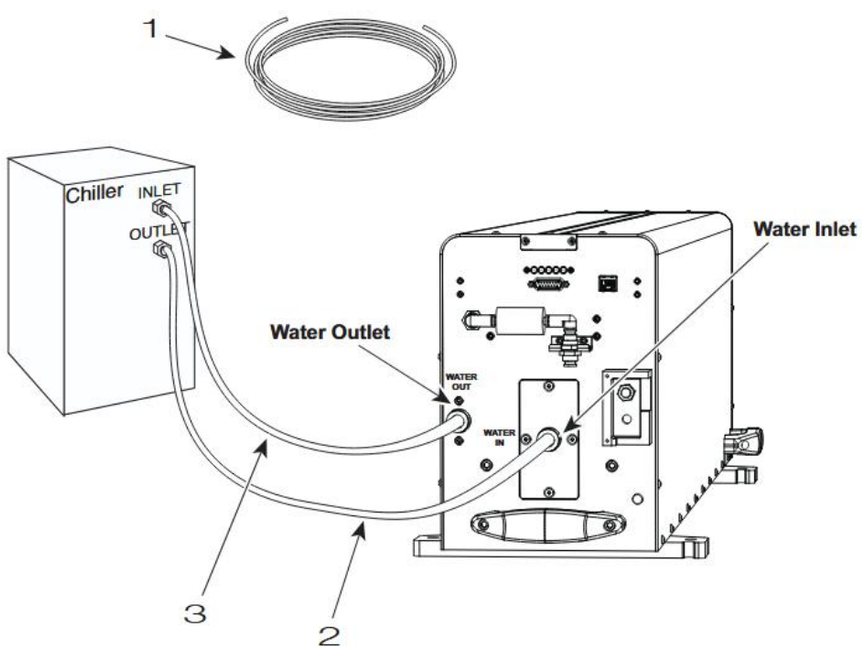
> **Note:**
>
> Every i Series laser is equipped with fittings for 12 mm tubing. If your integrated system uses 1/2" O.D. coolant tubing, you must install 12 mm to 1/2" tubing adaptors between the laser and other equipment in your processing system or install 1/2" Tri Threads fittings on the laser's cooling manifold.

To connect cooling tubing to your laser, perform the following step. The numbered items in Figure 3.4.7 correspond to the step numbers in the following procedure.

1. Locate the 12 mm O.D. polyethylene cooling tubing in the ship kit.
2. Cut and connect a length of 12 mm 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 4 GPM (15.1 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).

3.4.7 Figure: i Series cooling connections



3.5 Electrical Connections

The following procedures describe how to complete electrical connections to the i Series lasers. The i401 laser requires a DC power source capable of supplying a minimum of 135 A at 48 VDC. The i501 laser requires a DC power source capable of supplying a minimum of 175 A at 48 VDC. A supply with remote sense capability that can compensate for a minimum load lead loss (round trip) of 1.0 V is highly recommended. For all i Series lasers, we recommend the Novanta PS-401 DC power supply, which can provide a maximum of 145 A at 48 VDC. AC input requirements for the PS-401 supply are 180–264/342–528 VAC, three-phase (3Ø), 30 A max per phase, 50–60 Hz.

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.

3.5.1 PS-401 DC Power Supply

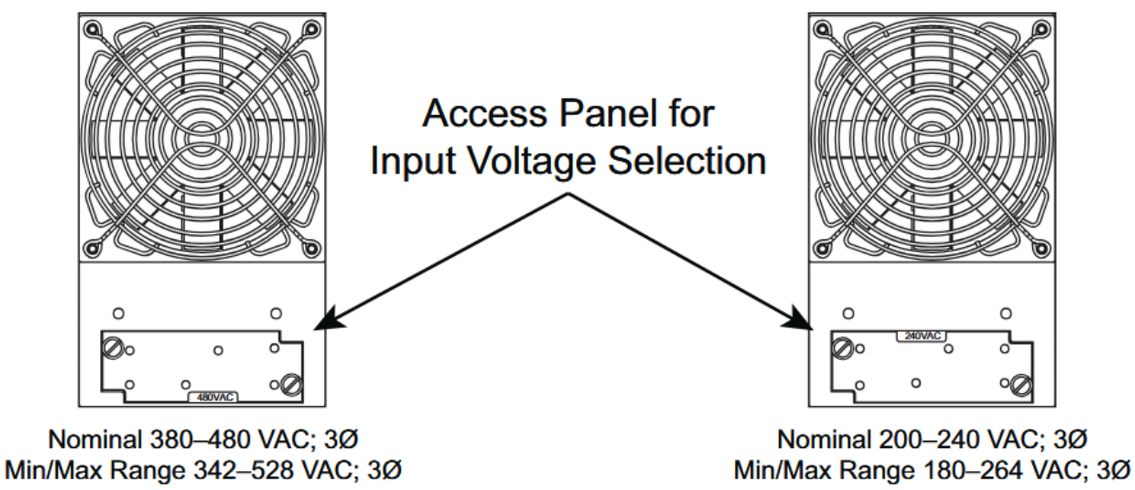
3.5.1.1 Input Voltage Selection

The PS-401 supply is shipped with the default AC input voltage range set to 480 VAC, which is used for high-range 3Ø input voltages between 342–528 V with the nominal range being 380–480 VAC.

To operate the PS-401 DC supply on a low-range 3Ø voltage between 180–264 V with the nominal range being 200–240 VAC, perform the following steps to reconfigure the unit:

1. Verify that input AC power to the DC power supply is physically locked out or disconnected.
2. Refer to Figure 3.5.1.2 for the location of the voltage selection assembly on the front of the PS-401 supply.
3. Unscrew the knurled thumbscrews fastening the voltage selection assembly to the PS-401 chassis.
4. Pull the voltage selection assembly out of the chassis and rotate it 180° so the notch is now facing upwards.
5. Carefully insert the voltage selection assembly back into the power supply chassis and make sure it is firmly seated into the connector. The words "240VAC" should appear in the cutout area as seen in Figure 3.5.1.2.
6. Securely tighten the thumbscrews fastening the selection assembly to the PS-401 chassis.

3.5.1.2 Figure: PS-401 voltage selection access panel



3.5.1.3 AC three-phase connection

Caution: Possible Equipment Damage

All AC input wiring and fusing to the DC power supply must be sized and connected in accordance with applicable local, state, and national requirements.

Local, state, and national code requirements (like NEC, CSA, and IEC 60364) supersede any recommendations provided in this manual.

The following table provides recommendations for three-phase input wiring and fusing.

3.5.1.4 Table: AC three-phase electrical recommendations

Parameter	Recommendation
Input voltage Range (3 Ø)	342 V–528 VAC; 380 V–480 V nominal 180 V–264 VAC; 200 V–240 V nomina
Input current, max.	25A per phase
Wire gauge	10 AWG
Fuse/circuit breaker	30 Amps

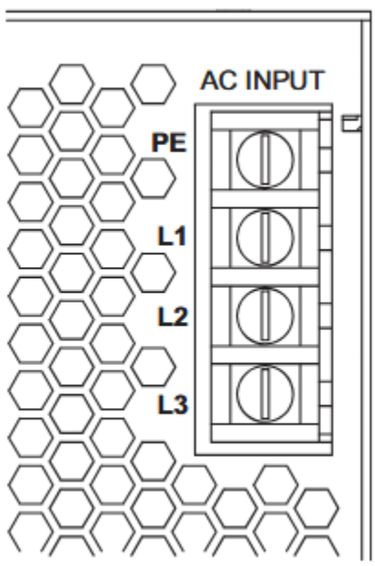
To connect three-phase AC input power, refer to Figure 3.5.1.5 and perform the following steps:

Note:

Because AC input connections and requirements vary from facility to facility, customers must provide the AC power cable or wiring. AC input connections to the PS-401 DC power supply are made using a four-position terminal strip with M4 screw terminals on 13.0 mm centers.

1. Follow your facility's Lockout/Tagout procedures and verify that input AC voltage to the DC power supply is physically locked out or disconnected.
2. Connect the ground (earth) wire, typically green, to the input terminal labeled PE.
3. Connect the first three-phase hot wire, typically black, to the input terminal labeled L1.
4. Connect the second three-phase hot wire, typically red, to the input terminal labeled L2.
5. Connect the third hot wire, typically blue, to the input terminal labeled L3.

3.5.1.5 Figure: PS-401 input section



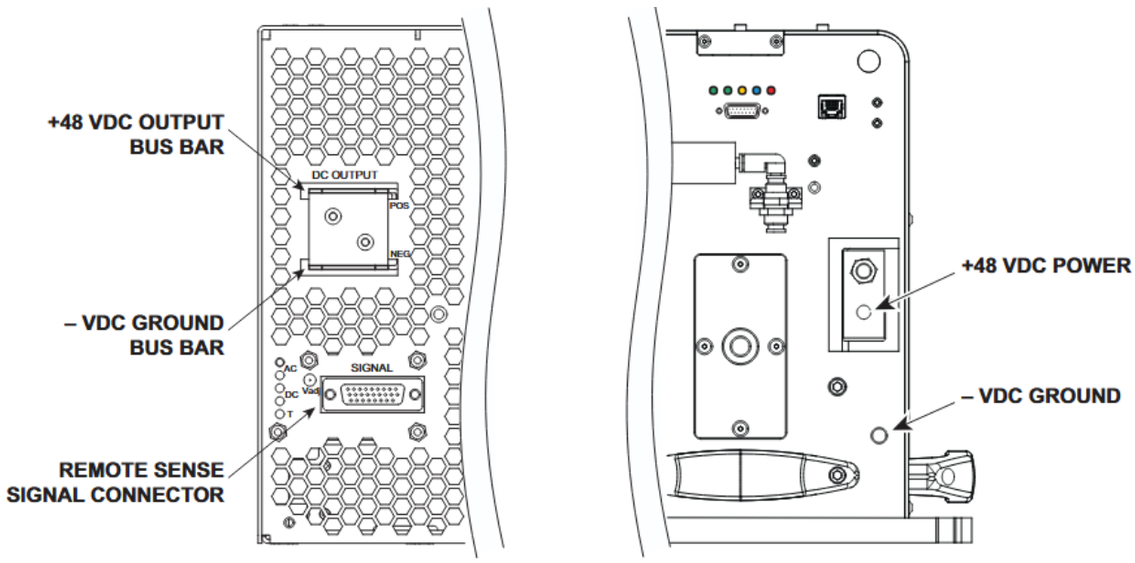
3.5.2 DC power/DC voltage sense cables

To connect DC power and the DC voltage sense cables between your i Series laser and PS-401 DC power supply, refer to Figure 3.5.3 and Figure 3.5.4 and perform the following steps.

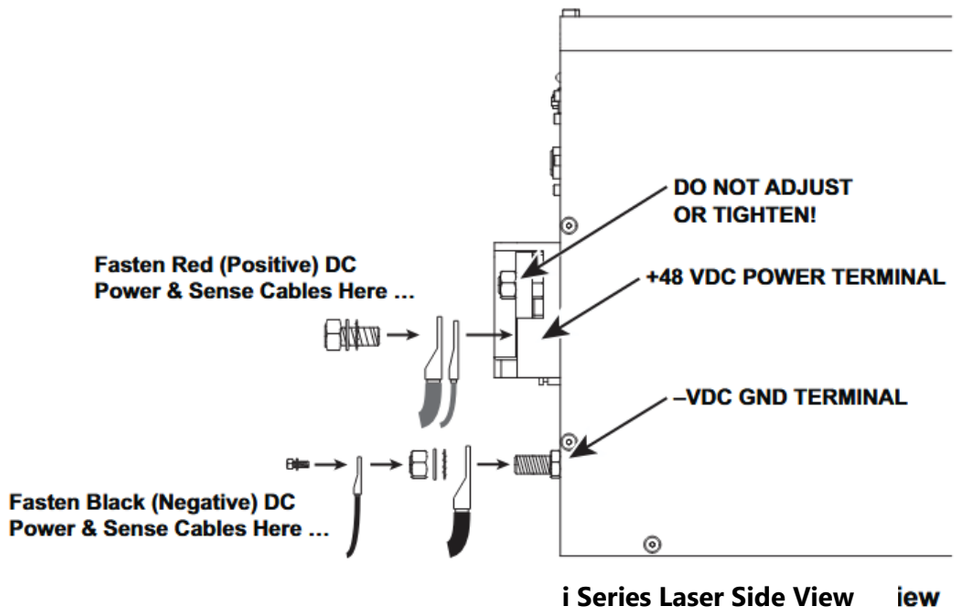
Caution: Possible Equipment Damage

Do not reverse polarity when connecting the DC power or DC sense cables to your DC power source. Reversed DC polarity may damage the laser's internal RF power supply. Carefully follow the directions below to ensure that DC power cables are properly connected to the correct DC output terminals.

3.5.3 Figure: DC power connection locations – rear view



3.5.4 Figure: DC power connection locations - side view



3.5.4.1 Laser connections

Note:

A DC Voltage Sense Cable is only included with the purchase of the Novanta PS-401 DC power supply. When using a power supply other than the PS-401, fabricate a DC voltage sense cable to match your supply's DC sense connections. In either case, attach the sense cable as described below.

1. Locate DC Power Cables and DC Voltage Sense Cable in the i Series and PS-401 ship kits.
2. Remove the two 6–32 capscrews and acrylic shield covering the +48V POWER terminal block on the rear of the laser.
3. Remove the M10 bolt, flat washer, and external star washer from the +48V POWER terminal block.
4. Remove the M10 hex nut, flat washer, and external star washer from –VDC GND terminal on the rear of the laser.
5. Slide the black (negative) DC power cable over the –VDC GND terminal followed by the M10 external star washer, flat washer, and hex nut (see Figure 3.5.4).
6. Tighten the M10 hex nut to a torque of 20 Nm (15 ft-lb) maximum using two wrenches. While tightening the outer nut, hold the inner nut, the one against the laser's rear plate, so that it does not move.
7. Place the black (negative) DC voltage sense lead on the end of the –VDC GND terminal and fasten using an M4 capscrew and flat washer. Carefully tighten the M4 screw to a torque value of 1.8 Nm (1.3 ft-lb) maximum.
8. Fasten the red (positive) DC power cable and red DC sense lead to the +48V POWER terminal on the rear of the laser using the M10 bolt, flat washer, and star washer as shown in Figure 3.5.4. Carefully tighten the M10 bolt to a torque of 7.4 Nm (5.5 ft-lb) maximum.
9. Replace the acrylic cover on the +48V POWER terminal block and fasten it in place using two 6–32 capscrews.

Note:

Do not overtighten the M10 fastener into +48V POWER terminal on the laser because this may damage the threads.

3.5.4.2 DC power supply connections

Note:

If you are not using a PS-401 DC supply, we highly recommend installing a DC power supply with remote sense capability that can compensate for a minimum load lead loss (round trip) of 1.0 V.

1. Verify that input AC voltage to the DC power supply is physically locked out or disconnected.
2. Attach the black (negative) DC power cable to the –VDC Ground Bus Bar on the PS-401 power supply using M6 (or ¼") fasteners (Figure 3.5.3).
3. Attach the red (positive) DC power cable to the +48 VDC Output Bus Bar on the PS-401 power supply using M6 (or ¼") fasteners.
4. Connect the 26-pin connector on the DC Voltage Sense Cable into the Remote Sense Signal Connector on the rear of the PS-401 power supply. In addition to completing the DC voltage sense circuit, the 26-pin connector also jumpers the PS-401's Output Inhibit and Output Interlock inputs to enable DC output.

If using another type of DC power supply, connect DC sense cables per the manufacturer's recommendations.

3.6 Control Connections

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

3.6.1 Quick Start Plug

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.

Caution: Possible Equipment Damage

Turn off DC power before installing or removing any plug or cable from the DB-15 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.

For your i Series laser to properly operate, several input signals must be applied to the DB-15 User I/O connector before lasing is enabled. Voltage must be applied to Remote Interlock (Pin 3) and Shutter Open Request (Pin 10) inputs before the laser becomes ready to fire. In applications where the lasers are integrated into automated systems and safety interlocks are required, these input signals must be provided by the customer's control system. The Quick Start Plug included in the ship kit has factory-installed shorting jumpers wired into it to enable these inputs. Connect the Quick Start Plug to the User I/O connector when performing initial start-up and testing of your laser. For further information about the User I/O connector, see User I/O connections in the Technical Reference chapter for User I/O pinouts and signal descriptions. For detailed instructions on integrating the lasers safety features, like keyswitch, shutter, and remote interlock functions with automated control systems, see also the Technical Reference chapter.

3.6.2 UC-2000 Universal Laser Controller

Warning: Serious Personal Injury

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

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.

Note:

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

Note:

The i Series laser 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.

3.7 Other Connections

3.7.1 Gas purge port

A gas purge is highly recommended when operating the laser. Purging the laser creates positive pressure inside the laser housing that prevents dirt and debris from accumulating on optical surfaces inside the laser housing. In condensing atmospheres, a gas purge helps to reduce the potential for condensation damage.

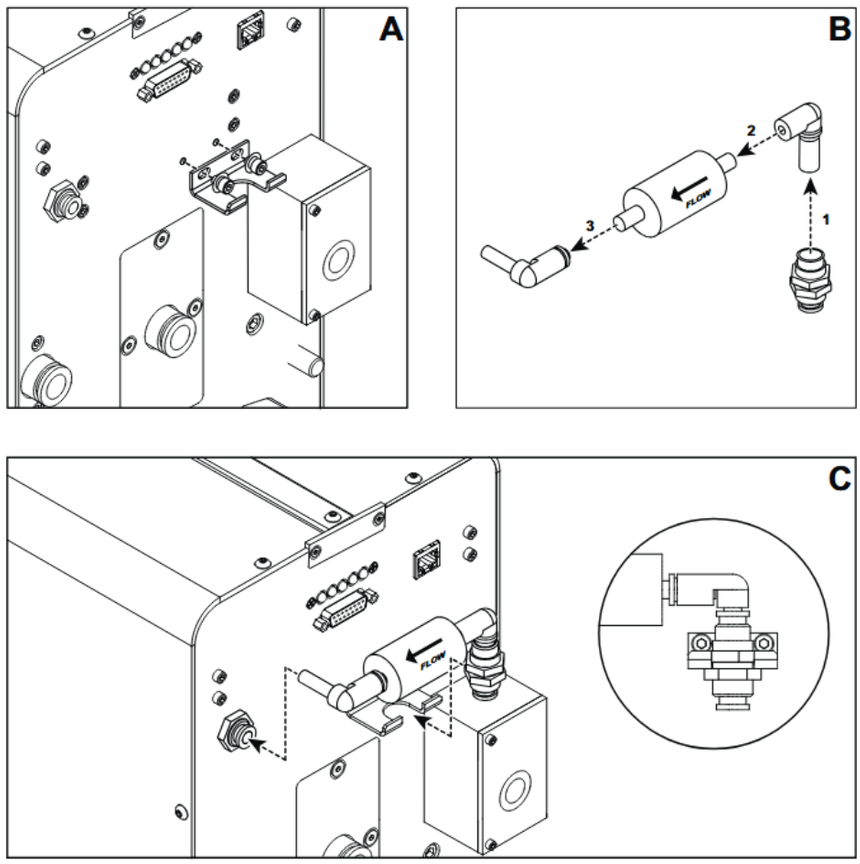
Caution: Possible Equipment Damage – for i501 only

The gas purge is mandatory for the i501 to ensure the proper operation of the laser.

To connect the i Series gas purge port, refer to Figure 3.7.2 and perform the following steps:

1. Locate the Gas Purge Kit in the i Series ship kit. The kit consists of two each male/female 90° quick-disconnect fittings, a straight fitting, a low-flow gas filter, and a support bracket with fasteners.
2. Refer to Figure 3.7.2 A and fasten the filter support bracket to the rear of the i Series laser using the 6–32 Allen capscrews and # 6 flat washers provided in the kit.
3. Assemble the two 90° fittings, straight fitting, and filter as shown in Figure 3.7.2 B. Be sure to orient the directional arrow on the filter as shown.
4. Loosen the two jam nuts on the straight fitting so it will slide into the support bracket.
5. Refer to Figure 3.7.2 C and plug the filter assembly into the Gas Purge port connector.
6. Adjust the jam nuts on either side of the support bracket to hold the filter assembly in position.
7. Connect nitrogen or breathing-grade air to the straight connector using 1/4" plastic tubing.

3.7.2 Figure: Gas purge kit assembly



Note:

To disconnect gas purge tubing, 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.

Caution: Possible Equipment Damage

Do not exceed a gas purge pressure of 34.5 kPa (5 PSI). Excessive pressure may damage the purge assembly or other internal laser components.

Do not use argon as a purge gas. Use only nitrogen or clean, dry air as described in Table 3.7.3 Purge gas specifications.

8. Set a purge pressure between 13.8–34.5 kPa (2–5 PSI). This provides just enough positive airflow to prevent dust from entering the laser. If a flowmeter is available, set a flow rate of 0.85–1.7 m^3/h (30–60 SCFH, Standard Cubic Feet per Hour) at a pressure not to exceed 34.5 kPa (5 PSI).
9. When purge gas is flowing, access the i Series web page and monitor the *Relative Humidity* value. The measured value should drop to 0% (± 10%) within 10–15 minutes. If the relative humidity never drops below approximately 10%, then increase the flow rate slightly.

The Gas Purge port on the i Series laser must be connected to a source of nitrogen or clean, dry air only; do not use any other gases for purging. Purge gas specifications are listed in Table 3.7.3 below.

3.7.3 Table: Purge gas Specifications

Purge Gas	Specification	
Air	Breathing Grade	≥ 99.9996% purity; filtered to ISO Class 1 particulate level
Air	Compressed	Instrument-grade air filtered and dried to ISO 8573-1:2010 Class 1, 2, 1 (≤ 10 1.0 - 5.0µm particles/m^3; ≤ -40°F dew point; ≤ 0.01 mg/m^3 oil vapor)
Nitrogen	High Purity Grade	≥99.9500% purity; filtered to ISO Class 1 particulate level

3.7.4 Ethernet port

A connection to the i Series Ethernet port is not required for normal operation; however, we strongly recommend that you setup the i Series web page and verify its functionality as part of the initial start-up procedure. This will ensure an i Series web connection is available for troubleshooting purposes if necessary, during preliminary testing of the laser.

3.7.4.1 Set-up the web page

The i Series lasers are pre-configured with a fixed IP address that allows a simple Ethernet connection between the laser and a host. To connect your host computer to the i Series laser using a peer-to-peer Ethernet connection, perform the steps in the following sections:

Important Note:

Connection to a local network is permitted as long as the laser's fixed IP address is unique to your network, otherwise a peer-to-peer connection is required. When connecting to a local network, use a straight-thru Ethernet cable between the laser and your Ethernet router or hub.

Note:

The procedure may require the assistance of your IT Department if your facility's Ethernet settings are determined automatically using Dynamic Host Configuration Protocol (DHCP). The i Series peer-to-peer Ethernet connection must be connected to a computer with a static IP address that is not connected to a local network.

Set your computers static IP address

> **Note:**
>
> The exact steps may vary depending on your operating system.

1. Disconnect the computer from your local network by removing any networking cables.
2. Open the Windows Settings and select Network & Internet.
3. Click the Change Adapter Option.
4. Right-click the Ethernet option and select Properties.
5. In the Ethernet Properties dialog select Internet Protocol Version 4 (TCP/IPv4) and click the Properties button.
6. In the Internet Protocol Version 4 (TCP/IPv4) Properties dialog, select "Use the following IP address:" and enter the following information:
   IP Address: 192.168.50.100
   Subnet Mask: 255.255.255.0

Connect to the i Series laser

1. Remove DC power from the laser.
2. Locate the Ethernet crossover cable in the ship kit.
3. Connect the crossover cable between your computer and the i Series' Ethernet port

> **Important Note:**
>
> The Ethernet cable included in the laser's ship kit is a shielded crossover cable. If your network application requires a straight-thru (patch) cable or you supply your own crossover cable, be sure the Ethernet cable is an industrially shielded CAT 5e or CAT 6 cable.

4. Follow the initial start-up procedure in the Operation chapter and proceed with Step 5 below when DC power is applied to the laser.
5. Launch your web browser, type "http://192.168.50.50" (without the quotes,) and then press Enter. The i Series home page should appear as shown in Figure 4.5.3.

> **Note:**
>
> The web page is not compatible with Google Chrome browser.

To use the i Series web page capability to monitor various operating or service parameters, see the i Series web interface section in the Technical Reference chapter for additional information. If you have problems connecting to the web page, refer to the Troubleshooting –Web interface section in the Maintenance/Troubleshooting chapter.

3.8 Controls and Indicators

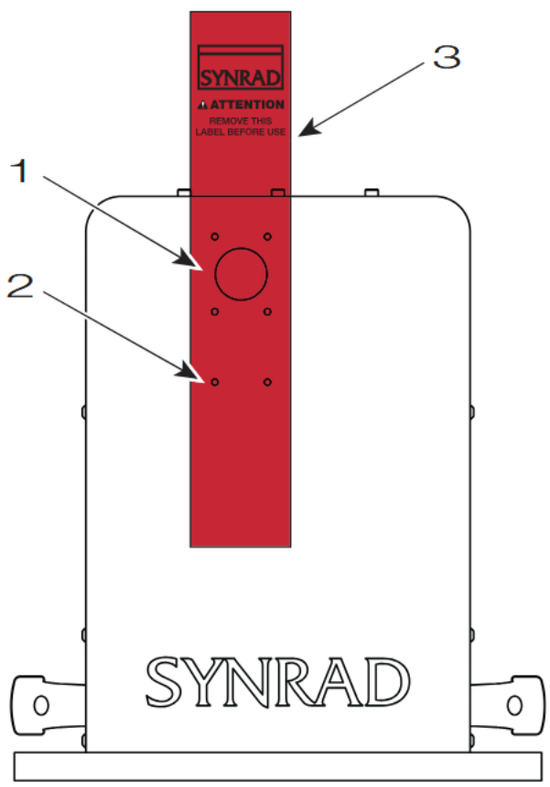
Use information in this chapter to familiarize yourself with the i Series controls and indicators on the front and rear panels of the laser.

3.8.1 i Series Front Panel

The front panel contains the following features, also shown in Figure 3.8.2.

1. Aperture Seal – prevents dust from damaging laser optics during shipping. Remove the self-adhesive label before applying power to the laser.
2. 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 i Series outline and mounting drawings in the Technical Reference section for mounting dimensions.
3. Laser Aperture – provides an opening in the i Series' front panel from which the beam exits.

3.8.2 Figure: i Series Front Panel



Important Note:

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

Important Note:

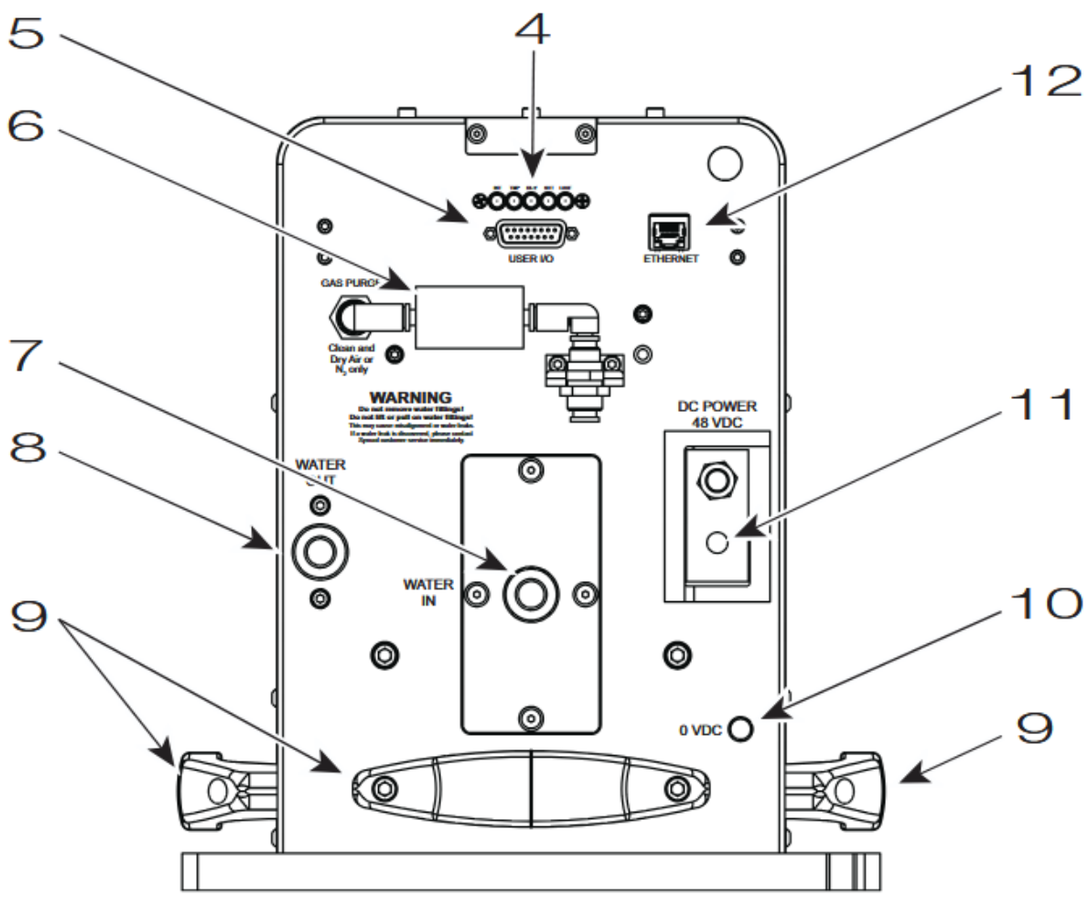
To prevent damage when mounting optical components to the i Series lasers, the 8–32 UNC fasteners must extend no further than 4.8 mm (0.19") into the laser's faceplate.

3.8.3 i Series Rear Panel

The rear panel contains the following features, also shown in Figure 3.8.4*:*

4. Status Indicators - LED indicators display i Series laser status. From left to right:
   - INT (Remote Interlock) Indicator illuminates green to indicate that a remote interlock circuit is closed, and that lasing may be enabled; The INT indicator is red and lasing is disabled if the interlock input is open.
   - TMP (Temperature) Indicator illuminates green to indicate that laser temperature is within limits and that lasing may be enabled; the LED is red and lasing is disabled if coolant temperature or flow rate is outside operating limits.
   - 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.
   - SHT (Shutter) Indicator illuminates blue to indicate the electromechanical shutter is Open and lasing is enabled. The SHT LED is off and lasing is disabled if the shutter is Closed.
   - LASE Indicator – illuminates red to indicate that the laser is actively lasing.
5. 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.
6. Gas Purge Port Assembly – provides a low pressure nitrogen (or pure air) connection to prevent dust and debris from damaging electronic or optical components inside the housing.
7. WATER IN Port (water-cooled models only) – labeled IN, provides a 12 mm inlet connection to the laser's cooling system for 12 mm O.D. cooling tubing
8. WATER OUT Port (water-cooled models only) – labeled OUT, provides a 12 mm outlet connection to the laser's cooling system for 12 mm O.D. cooling tubing
9. Lifting Handles – allow you to safely lift and move the laser. After laser installation, all three handles can be removed if additional clearance is necessary.
10. GND (–) Terminal – M10 × 1.5 threaded stud provides connection point for negative (ground) side of the 48 VDC power supply
11. 48V POWER Terminal Block – receives +48 VDC from the 48 VDC power supply. Fasten the positive DC Power Cable using the supplied M10 × 1.5 bolt at the indicated connection point.
12. Ethernet Port – provides the connection point for a TCP/IP web-based interface between your computer or network and the i Series laser.

3.8.4 Figure: i Series Rear Panel



3.9 Initial Start-Up

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

Danger: Serious Personal Injury

Any Class 4 CO_2 laser product that emits invisible infrared laser radiation in the 9–11 µm wavelength band can seriously burn human tissue. Do not allow the laser beam to contact a person.

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.

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

Warning: Serious Personal Injury

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

Warning: Serious Personal Injury

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

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

Important Note:

For safety reasons, the i Series laser contains an internal electromechanical shutter assembly that is controlled by the Shutter Open Request input signal (Pin 10 on the DB-15 User I/O connector). The shutter opens only when a Shutter Open Request signal is applied and the RDY LED is on (Remote Interlock input active and no over-temperature fault exists).

Use the interlock input to provide maximum operator safety. When the Remote Interlock input is opened (voltage source removed), the internal shutter automatically closes to block the beam path, the RDY LED turns Off, the SHT LED turns Off (regardless of the state of the Shutter Open Request input), and all DC power is removed from the RF boards.

To initiate lasing, apply a voltage in the range of ±5–24 VDC to the Remote Interlock input. This causes the INT LED to turn green, the RDY indicator to turn yellow, and sends DC power to the laser's RF boards, allowing internal tickle pulses to reach the tube. Apply a Shutter Open Request signal (a voltage in the range of ±5–24 VDC) to open the physical shutter assembly (it takes approximately 30 ms for the electromechanical shutter to fully open) and then apply a PWM Command signal to begin lasing.

Removing the Shutter Open Request signal causes the shutter to close and block the beam path while simultaneously disabling the PWM signal, leaving internal tickle enabled to supply tickle signals as required to maintain tube readiness.

3.9.1 Status Indicators

The i Series LED indicators, also mirrored as output signals on the User I/O connector, provide status information to the user. Table 3.9.2 shows the laser's 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 DC power-up of an i Series laser, the RDY lamp illuminates yellow when INT and TMP indicators illuminate green. After the RDY indicator illuminates, internal tickle is enabled and a five-second delay begins before lasing is permitted. When a Shutter Open Request signal is applied, the internal shutter opens, the SHT LED illuminates blue, and application of a PWM Command signal causes the LASE indicator to illuminate red as lasing begins.

For safety reasons, the shutter function on i Series lasers is dependent on the state of the Remote Interlock input, which is reflected by the state of INT and RDY indicators. Although a Shutter Open Request signal may be applied, the SHT LED will not illuminate while the INT LED is red (RDY LED Off). Therefore, no power is applied to the RF boards until the INT indictor is green (and the RDY LED is yellow).

3.9.2 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

3.9.3 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 0.5 meters (20”) from the laser aperture to prevent the beam from traveling beyond the work area.
4. Turn on the chiller and set the temperature setpoint between 18 °C–22 °C. Verify that the chiller is delivering a flow rate of 15.1 lpm (4 GPM) at less than 414 kPa (60 PSI) of pressure. Examine all cooling connections carefully and ensure that they do not leak.
5. Start purge gas flow at a rate of 0.85–1.7 m^3/h (30–60 SCFH, Standard Cubic Feet per Hour) at a pressure not to exceed 34.5 kPa (5 PSI) If a flowmeter is not available, set a purge pressure between 13.8–34.5 kPa (2–5 PSI).

> **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.

6. 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.

7. Turn on the +48 VDC power supply.
   If the factory-wired Quick Start Plug is installed, the INT indicator will illuminate green, the SHT indicator will illuminate blue, and the RDY LED will illuminate yellow. The TMP indicator will illuminate green if laser temperature is within safe operating limits.

Starting your i Series Laser

> **Important Note:**
>
> The SHT LED on i Series lasers is dependent on the state of the RDY indicator. Although a Shutter Open Request signal is applied, the SHT LED will not light while the RDY LED is Off. Therefore, no power is applied to the RF boards until the RDY indicator is illuminated.

> **Important Note:**
>
> Each time an i Series OEM laser is powered up, a five-second delay occurs between the time the RDY indicator illuminates and the laser is permitted to lase. After the five-second delay (and while the SHT LED is off), tickle is applied to maintain the laser in a ready state. Once a Shutter Open Request signal is applied, and the SHT LED illuminates, apply PWM Command signals to begin lasing.

> **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.

1. Press the UC-2000's Lase On/Off button. The Lase indicator on the UC-2000 should illuminate.
2. 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.
3. Press the UC-2000's Lase On/Off button to stop lasing. LASE indicators on the UC-2000 and the laser should turn off.
4. If you are connected to the i Series' Ethernet port, access the i Series web page to verify operating conditions and functionality. See the Getting Started or Technical Reference chapters for details on accessing the i Series web page.
   While purge gas is flowing, check the Relative Humidity value. The measured value should drop to 0% (± 10%) within 10–15 minutes. If the relative humidity never drops below approximately 10%, then increase the flow rate slightly.
5. Remove DC power from laser
6. Shut off the chiller or otherwise stop coolant flow through the laser.
7. Shut off gas purge flow to the laser. In dirty or dusty environments; however, it may be necessary to purge the laser continuously to prevent contamination of internal optics.

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

3.9.4 Without a UC-2000 Controller

In 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 laser's User I/O connector. Refer to User I/O connections in the Technical Reference chapter for connector pinouts and see Controlling laser power in the Technical Reference chapter for Command signal descriptions.

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

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 0.5 meters (20") from the laser aperture to prevent the beam from traveling beyond the work area.
4. Turn on the chiller and set the temperature setpoint between 18 °C–22 °C. Verify that the chiller is delivering a flow rate of 15.1 lpm (4 GPM) at less than 414 kPa (60 PSI) of pressure. Examine all cooling connections carefully and ensure that they do not leak.
5. Start purge gas flow at a rate of 0.85–1.7 m^3/h (30–60 SCFH, Standard Cubic Feet per Hour) at a pressure not to exceed 34.5 kPa (5 PSI) If a flowmeter is not available, set a purge pressure between 13.8–34.5 kPa (2–5 PSI).
6. Ensure that your PWM controller is set to zero percent output (0.0%).
7. Turn on the +48 VDC power supply.
   If the factory-wired Quick Start Plug is installed, the INT indicator will illuminate green, the SHT indicator will illuminate blue, and the RDY LED will illuminate yellow. The TMP indicator will illuminate green if laser temperature is within safe operating limits.

Starting your i Series Laser

> **Important Note:**
>
> The SHT LED on i Series lasers is dependent on the state of the RDY indicator. Although a Shutter Open Request signal is applied, the SHT LED will not light while the RDY LED is Off. Therefore, no power is applied to the RF boards until the RDY indicator is illuminated.

> **Important Note:**
>
> Each time an i Series OEM laser is powered up, a five-second delay occurs between the time the RDY indicator illuminates and the i Series laser is permitted to lase. After the five-second delay (and while the SHT LED is off), tickle is applied to maintain the laser in a ready state. Once a Shutter Open Request signal is applied, and the SHT LED illuminates, apply PWM Command signals to begin lasing.

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.

1. Apply a PWM Command signal (+5 VDC, 5 kHz square wave of 4 µs duration) between PWM Input (Pin 9) and PWM Return (Pin 1) on the laser's User I/O connector.
2. Slowly increase the duty cycle of the square wave. The LASE indicator illuminates red when PWM signal pulses are long enough to produce laser output (typically 7–10 µs at 5 kHz). The spot where the beam hits the beam block increases in brightness, indicating an increasing power output.
3. Remove the PWM Command signal from the User I/O connector. The LASE indicator turns off.
4. If you are connected to the i Series' Ethernet port, access the i Series web page to verify operating conditions and functionality. See the Getting Started or Technical Reference chapters for details on accessing the i Series web page.
   While purge gas is flowing, check the Relative Humidity value. The measured value should drop to 0% (± 10%) within 10–15 minutes. If the relative humidity never drops below approximately 10%, then increase the flow rate slightly.
5. Remove DC power from the laser.
6. Shut off the chiller or otherwise stop coolant flow through the laser.
7. Shut off gas purge flow to the laser. In dirty or dusty environments; however, it may be necessary to purge the laser continuously to prevent contamination of internal optics.

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 i Series laser.

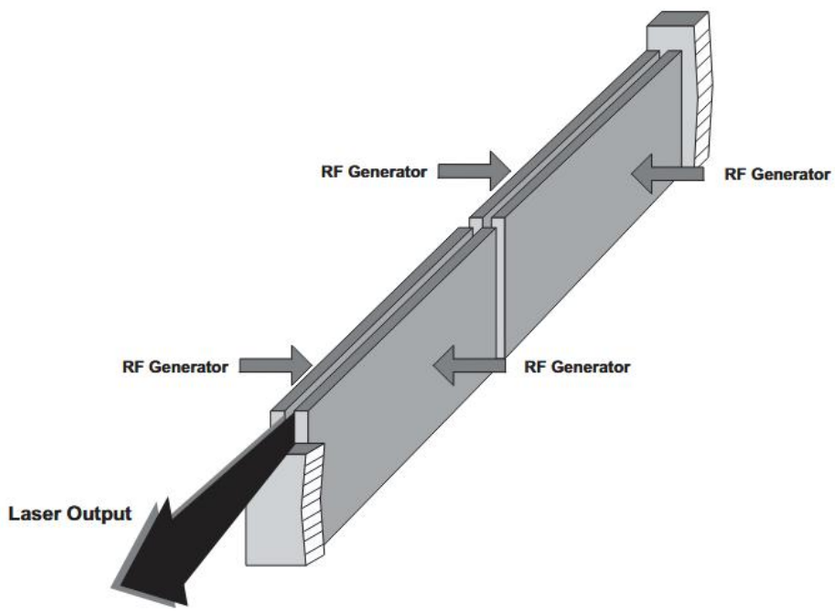
4.1 Technical Overview

4.1.1 Laser Design

4.1.1.1 Optical resonator

The i Series laser was developed using new technology patented by Novanta, Inc. This new technology, based on a hybrid waveguide/unstable resonator design (Figure: 4.1.1.2), 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. The unique extruded aluminum envelope offers excellent heat transfer, long gas life, and low operating costs in contrast to other laser tube technologies. Besides 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.

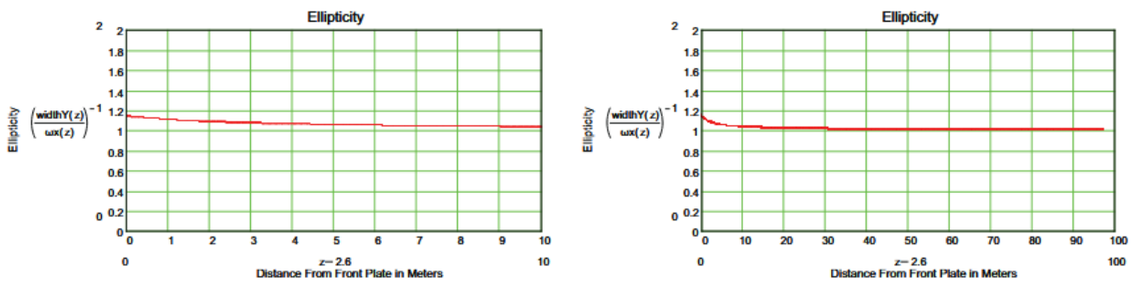
4.1.1.2 Figure: Hybrid waveguide/unstable resonator design



The optical resonator, in conjunction with the electrodes and the gas mixture, generates the laser beam. The i Series laser's 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 structure of the resonator and internal beam conditioning optics combine to produce a near Gaussian mode quality (M2 factor) of < 1.2. Beam waist diameter is typically 6.7 mm at the output aperture and full-angle divergence due to diffraction is approximately 2.5 milliradians (a 2.5 mrad divergence means that beam diameter increases 2.5 mm over every one meter distance traveled). Beam ellipticity measures approximately < 1.2 as it exits the resonator, but becomes closer to 1.0 in the far field (or at the point of focus). An example of the beam ellipticity for the i401 laser is shown in Figure 4.1.1.3.

4.1.1.3 Figure: i401 beam ellipticity example



4.1.1.4 Heat removal

Heat generated by excited CO_2 molecules is transferred to the bore walls by diffusion. Collected heat is transferred to the water in the cooling tubes by conduction of the electrodes and aluminum envelope. The coolant path is directed through corrosion-resistant copper alloy tubing to regulate laser temperature for maximum stability.

4.1.1.5 Beam conditioning

The i Series laser incorporates a novel beam conditioning system that first converts the beam to a circular profile, cleans up the beam to remove side lobes and improve beam quality, and then rotates the polarization through 45 degrees as an aid in applications where a circular polarizer is used. To do this, the laser beam exits the resonator and is turned back on itself through a front folding block that directs the beam into a cylindrical lens located about 0.63 m (25") away from the resonator output. The cylindrical lens converts the beam into a round beam which is then focused by a spherical focusing mirror through a water-cooled aperture (to remove any side lobes) and then onto another spherical mirror that collimates the beam. This beam then passes the shutter mechanism and through the rear folding mirror/beam rotator assembly which rotates the beam 45 degrees before exiting through the output aperture.

Polarization

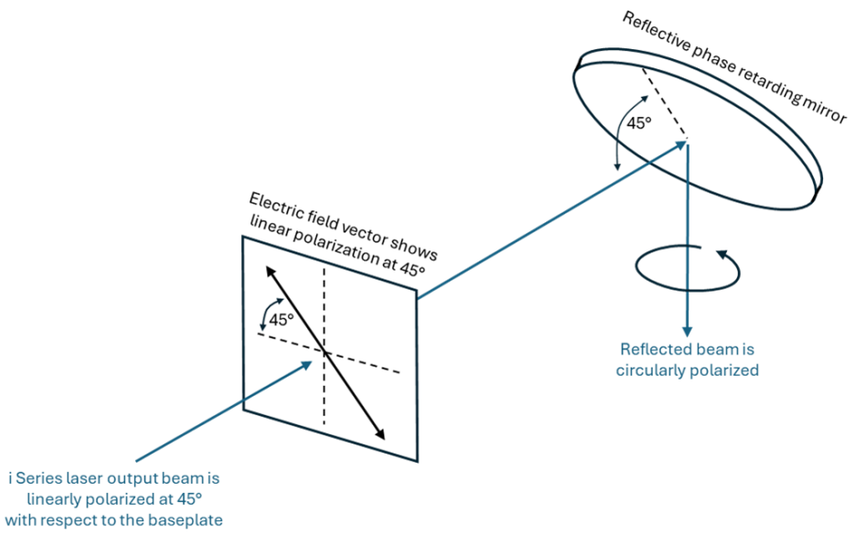
Polarization is important in achieving the best cut quality from a laser and this is usually achieved with linear polarization aligned with the cut direction; however, in most applications where two axes of cut are required, linearly polarized light can lead to differences in cut quality depending on the orientation of the polarization with respect to the cutting direction.

Converting the laser polarization from linear to circularly polarized light gives uniform cut quality in both axes. Circularly polarized light can be generated without significant power loss by using a circular polarizer (also known as a cut quality enhancer or CQE) or a simple phase retarding mirror.

For the simplest and most cost-effective solution, a reflective phase retarder, laser polarization must be rotated by 45°. Because most lasers have horizontally or vertically polarized outputs with the cutting or welding substrate placed horizontally, this rotation of the polarization is usually done by mounting the laser at 45° to the horizontal or by using two or more mirrors. Mounting the laser at 45° is often not practical while the addition of extra mirrors in the beam path adds cost and complexity and can reduce reliability.

To reduce the complexity and cost of beam delivery components, the i Series laser was designed with the beam polarized at 45° to the base plate (see Figure 4.1.1.6 for details). This design allows the use of a simple reflective phase retarder and eliminates the need for additional mirrors or complex mounting schemes. To use a reflective phase retarding mirror, the linearly polarized beam must make a 45° angle with the plane of incidence as shown in Figure 4.1.1.6.

4.1.1.6 Figure: Converting 45° linear polarization to circular polarization



4.1.2 RF Power Supply

The i Series lasers are driven by four compact RF modules mounted internally in the laser chassis. Each RF module converts 48 VDC input power into a radio frequency (RF) signal that is then amplified and routed to its corresponding electrode structure in the laser tube where it excites the gas mixture in the tube to produce lasing.

Control circuity built into the laser interrupts operation if any critical parameter is violated. Switches and sensors on the control board monitor various conditions and parameters that, if exceeded, pose a risk of potential damage to the laser. Additionally, laser operation is interrupted in response to the following conditions:

(A) the electromechanical shutter is closed

(B) the Shutter Open Request input signal is missing

(C) an over temperature or low coolant flow condition occurs

(D) the Remote Reset/Start Request input signal is enabled

(E) the Remote Interlock input signal is missing

(F) any fault is present

4.1.3 Optical Setup

After selecting a laser for a CO_2 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.

4.1.3.1 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.

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.

4.1.3.2 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 important issue affecting performance; a dirty or scratched lens will underperform and exhibit a vastly shortened lifetime. When the laser application requires air 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.

4.1.3.3 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 - 5.0µm particles/m^3; ≤ -40°F dew point; ≤ 0.01 mg/m^3 oil vapor)
Argon	Welding	High Purity Grade	> 99.998% purity; filtered to ISO Class 1 particulate level
Helium	Welding	High Purity Grade	> 99.997% purity; filtered to ISO Class 1 particulate level
Nitrogen	Cutting/Drilling	High Purity Grade	> 99.9500% purity; filtered to ISO Class 1 particulate level
Oxygen	Cutting/Drilling	Ultra-pure Grade	> 99.9998% purity; filtered to ISO Class 1 particulate level

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 PWM Command signals to the i 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 i 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. 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).

The i Series lasers are designed to operate at Command signal base frequencies up to 100 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 100 kHz maximum.

4.2.1.3 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 i 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.

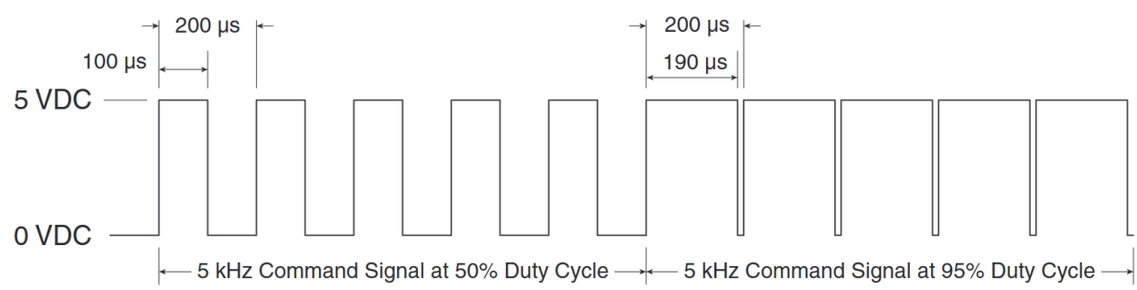
Base frequency, the second parameter, is the repetition rate of the PWM input signal. The standard base frequency is 5 kHz, which has a period of 200 µs. Maximum PWM frequency is 100 kHz.

The third Command signal parameter, PWM duty cycle, is the percentage of the period that the Command signal is high. If the Command signal's amplitude (at 5 kHz) is high for 100 µs and low for 100 µs, it has a 50% duty cycle. If the amplitude is high for 190 µs and low for 10 µs, it has a 95% duty cycle. Figure 4.2.1.4 illustrates PWM Command signal parameters.

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.

4.2.1.4 Figure: PWM Command Signal Waveform



The i Series User I/O PWM input consists of a high-speed optoisolator LED with a forward voltage drop (Vf) of 1.5 VDC. The PWM input frequency can range from DC (0 Hz) to 100 kHz. Table 4.2.1.5 provides minimum, maximum, and nominal PWM signal specifications.

4.2.1.5 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 (3 mA)	+5.0 VDC	+6.7 VDC (10 mA), continuous
Frequency Range	0 Hz (DC)	5 kHz	100 kHz
Duty Cycle	1%		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 i 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 i 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 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.

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. Continuous operation at 99% duty cycle may lead to thermal instability and optical degradation.

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

4.2.2.5 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 i 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.

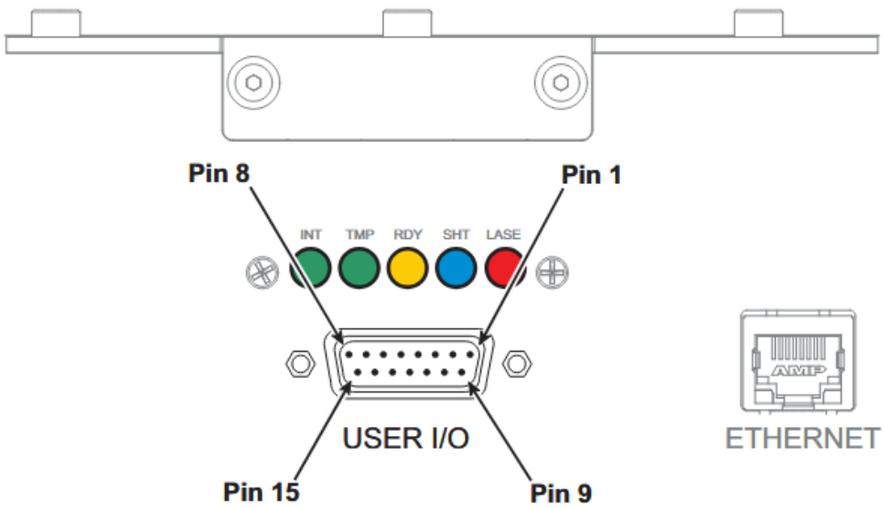
4.3 DB-15 I/O Connections

4.3.1 DB-15 I/O Connection Summary

The i 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 PWM Command signal and all input/output (I/O) control signals are connected to the User I/O port, a 15-pin female D-type subminiature connector, on the i Series' rear panel. Figure 4.3.2 below illustrates the pin arrangement of the User I/O connector and the corresponding Table 4.3.3 provides a quick reference summary to the User I/O connections.

4.3.2 Figure: DB-15 I/O Connector Pinouts



4.3.3 Table: DB-15 I/O Pin Descriptions

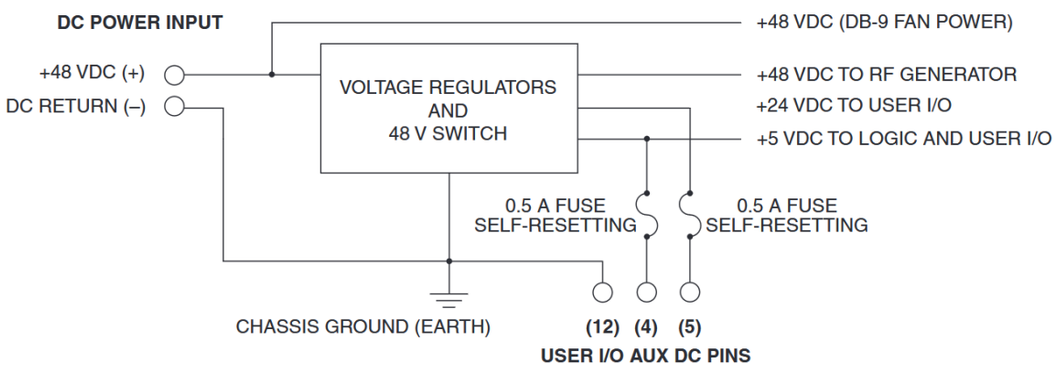
Pin	Description	Function
1	PWM Return	This input provides the negative, or return, side of the optoisolated PWM Command signal referenced to PWM Input (Pin 9).
2	Remote Reset/Start Request input	Apply a positive or negative voltage (±5–24 VDC) with respect to Pin 11, Input Common, to reset or remote 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).
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). The shutter will not activate until a voltage is also applied to the Remote Interlock input (INT LED illuminated green and RDY LED On).
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 0.3 A self-resetting fuse.
14	Shutter Open output	This bi-directional switched output is internally connected to Pin 13, Output Common, when Remote Interlock and Shutter Open Request signals are present (RDY indicator illuminated yellow and SHT indicator blue) to indicate that the shutter is open and lasing is enabled This output is open (high impedance) 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 i 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 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 i 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. Note that throughout this manual, input voltage levels are specified with respect to their corresponding return line.

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 4.3.3.8 for input circuit specifications.
2	Remote Reset/Start Request input	Apply a positive or negative voltage (±5–24 VDC) with respect to Pin 11, Input Common, to disable the laser. The laser remains disabled while voltage is applied. Removing voltage from the Remote Reset/Start Request pin causes the laser's RDY indicator to illuminate and 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. **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. 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. Remote Interlock faults (INT LED illuminates red) are not latched. Re-applying a voltage to Pin 3 enables the RDY indicator and lasing is possible after the five-second delay, provided that the SHT indicator is also lit. Use the interlock function to provide maximum operator safety. When the Remote Interlock input is opened (voltage source removed), the internal shutter automatically closes to block the beam path, the RDY LED turns Off, the SHT LED turns Off (regardless of the state of the Shutter Open Request input), and all DC power is removed from the RF boards.
9	PWM Input	Connect your PWM Command signal (+5 VDC, 5 kHz nominal, 100 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
10	Shutter Open Request input	Apply a positive or negative voltage (±5–24 VDC) with respect to Pin 11, Input Common, to open the internal electromechanical shutter assembly (when the Remote Interlock input is active). If your system does not supply a Shutter Open Request signal, then this pin must be connected to a voltage source in the range of ±5–24 VDC. Refer to Figure 3-7 for a diagram showing how the Shutter Open Request input is factory-jumpered on the Quick Start Plug. See Table 4.3.3.8 for input circuit specifications. **Note**: Shutter Open Request and Remote Interlock inputs are dependent control functions. The internal shutter mechanism will not activate (open) until a voltage is also applied to the Remote Interlock input (causing INT LED to illuminate green and RDY LED to turn On).
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.

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.

4.3.3.6 Figure: Quick Start Plug wiring diagram

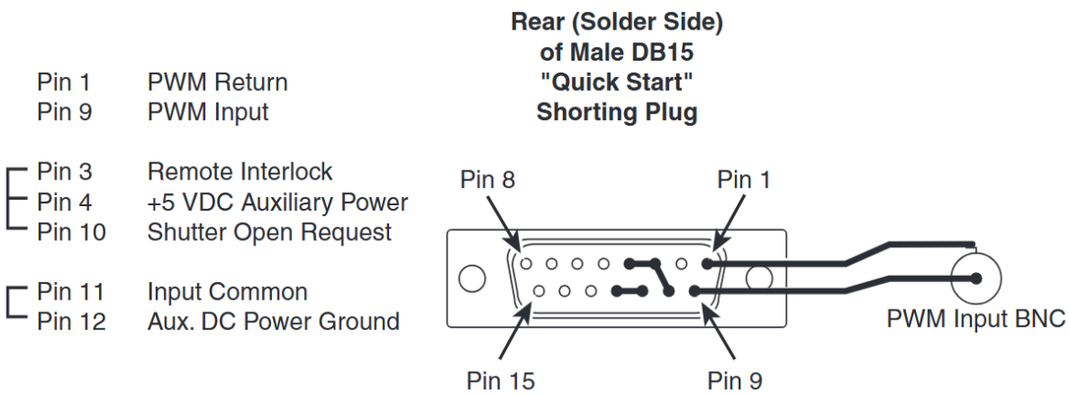
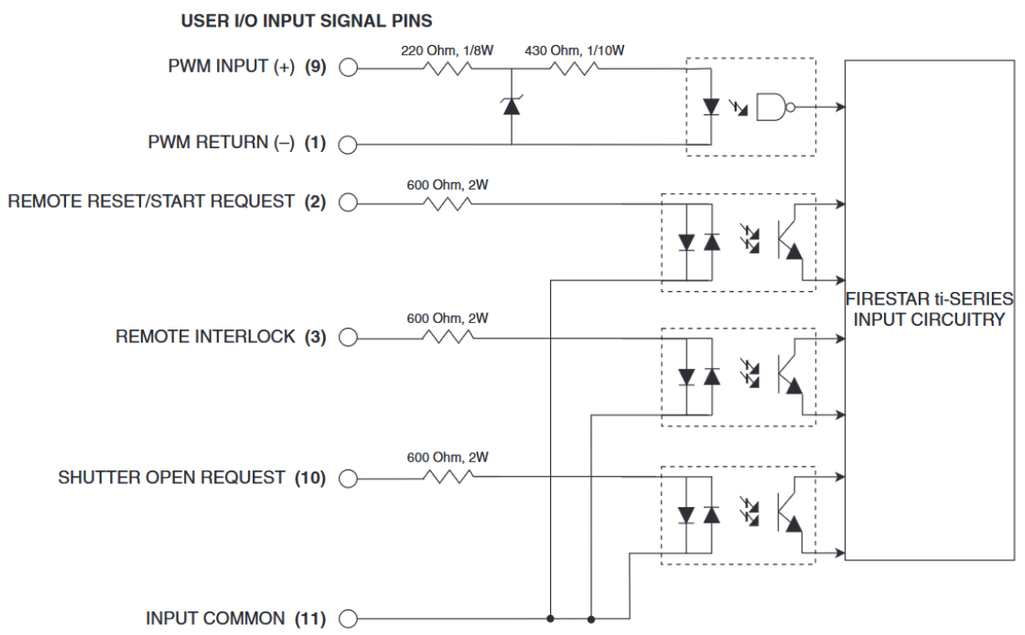


Figure 4.3.3.7 illustrates the input circuit's equivalent internal schematic while Table 4.3.3.8 provides i Series input circuit specifications.

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. 100 kHz
Remote Reset/Start Remote Interlock Shutter Open Request	Bidirectional optoisolator LED, forward voltage drop (Vf) 1.15 VDC Off state Vmax < 1.0 VDC On state Vmin +5.0 VDC @ 7 mA On state (continuous) Vmax +24.0 VDC @ 40 mA

Note:

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

4.3.3.9 Output Signals

The i 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 i 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:

Interlock Open and Shutter Open output signals are dependent control functions. The Shutter Open output will not close (SHT LED On) until a Shutter Open Request signal is applied and the Interlock Open output opens (causing INT LED to illuminate green and RDY LED to turn On).

4.3.3.10 Table: Output Signal Pin description

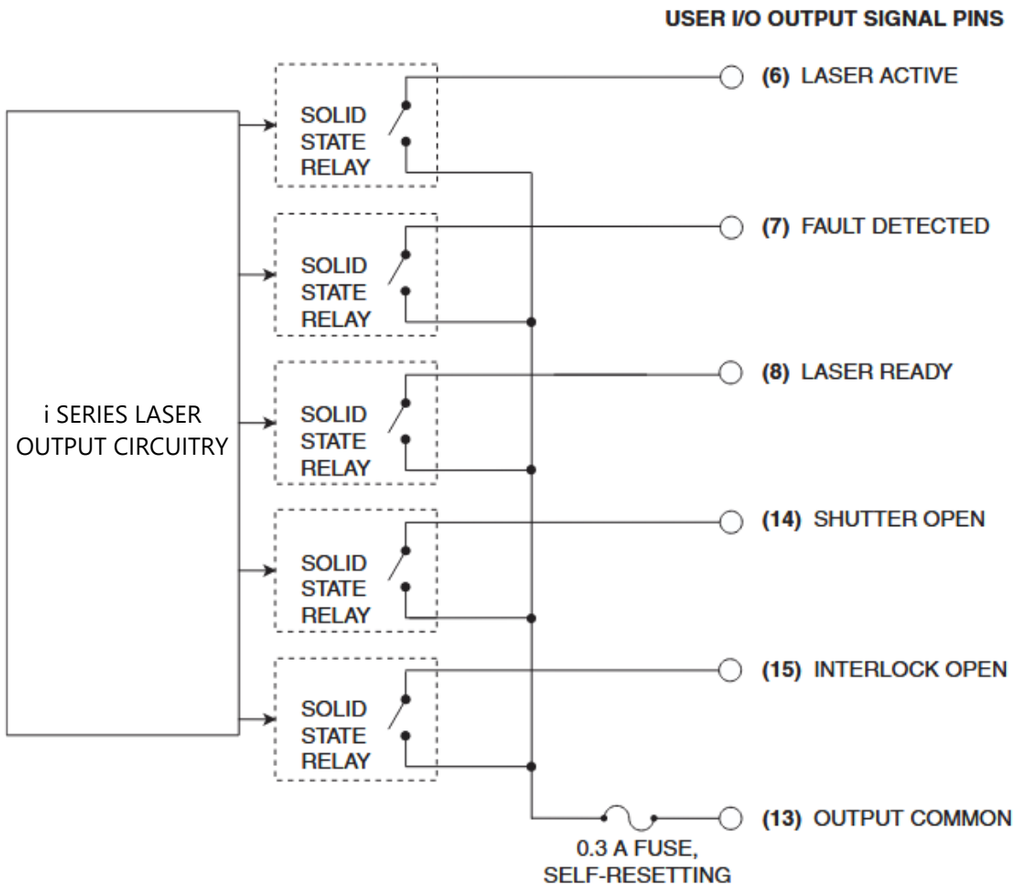
Pin	Description	Function
6	Laser Active output	This bi-directional switched output is internally connected to Pin 13, Output Common, when the laser is actively lasing (LASE indicator red). This output is open, in a high-impedance state, when no beam is being emitted (LASE indicator Off). Refer to Table 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 (1) an over-temperature fault (TMP LED is red) or (2) a No-Strike condition (blue SHT indicator is flashing) has occurred. 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 Remote Interlock and Shutter Open Request signals are present (SHT LED blue and RDY LED yellow), indicating that lasing is enabled. 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). When this output is initially switched open, there is a five-second delay during which lasing is inhibited. Refer to Table 4.3.3.11 for output circuit specifications.

Figure 4.3.3.12 illustrates the output circuit's equivalent internal schematic and Table 4.3.3.11 provides the i Series 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

4.3.3.12 Output equivalent schematic



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 i 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

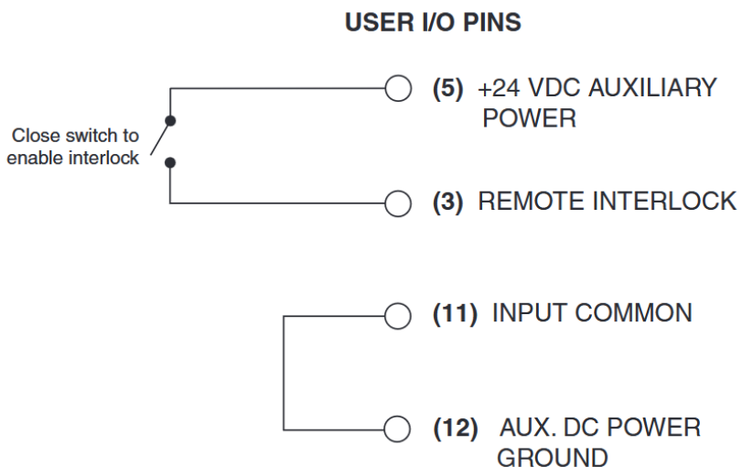
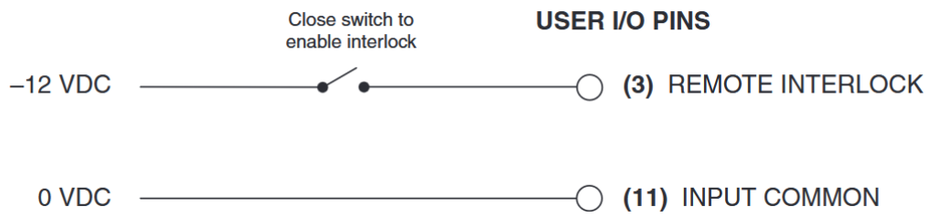


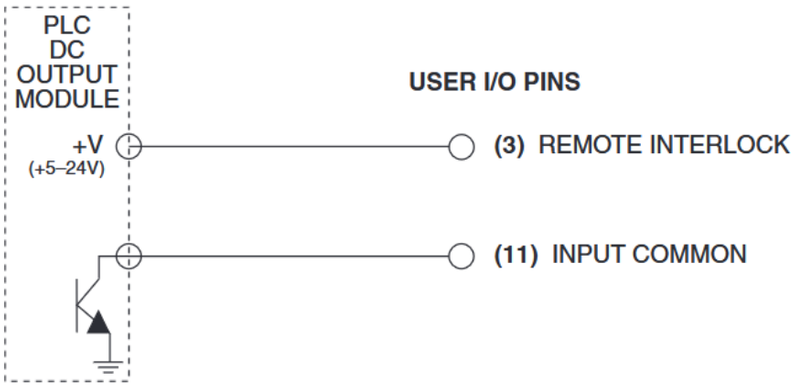
Figure 4.3.4.3 shows another variation for supplying a Remote Interlock signal to the laser. In this case, the customer is using a switch and supplying a negative voltage to drive the laser's input circuit.

4.3.4.3 Figure: Customer supplied interlock, negative voltage



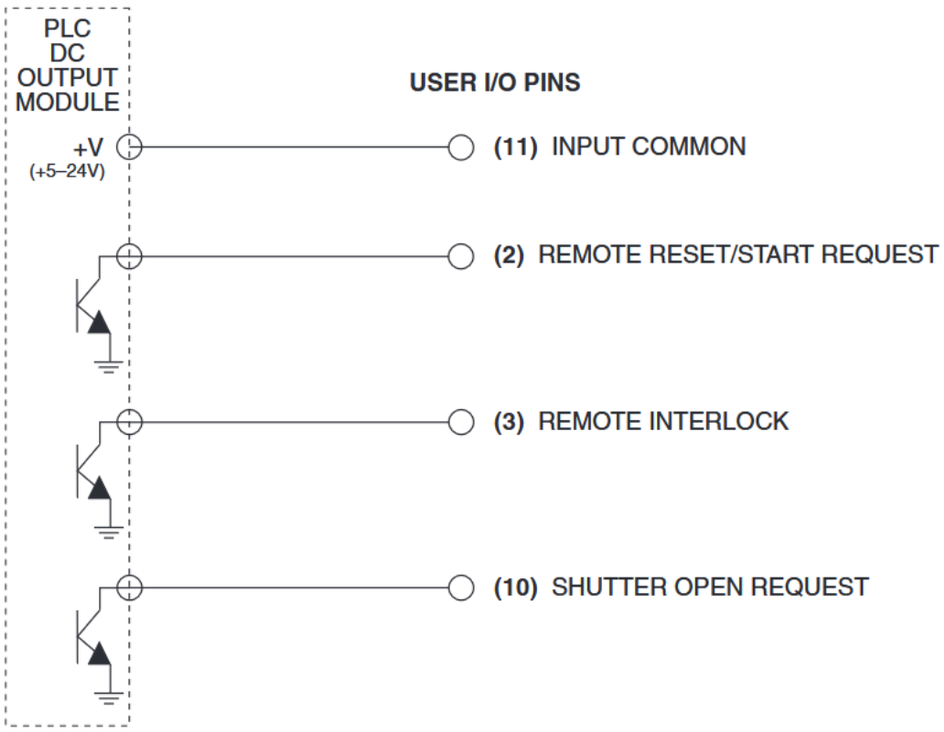
A Programmable Logic Controller (PLC) can also drive i Series inputs. The Figure below shows a typical method for connecting to a PLC input module when only one laser input is used.

4.3.4.4 Figure: PLC driven interlock signal



When multiple PLC inputs are required, connect the i 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.

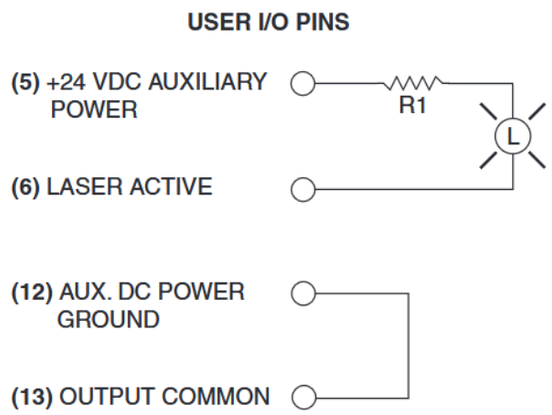
4.3.4.5 Figure: Multiple PLC driven inputs



4.3.4.6 Sample Outputs

The i 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: i 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 i Series outputs.

4.3.4.8 Figure: i Series output driving a relay

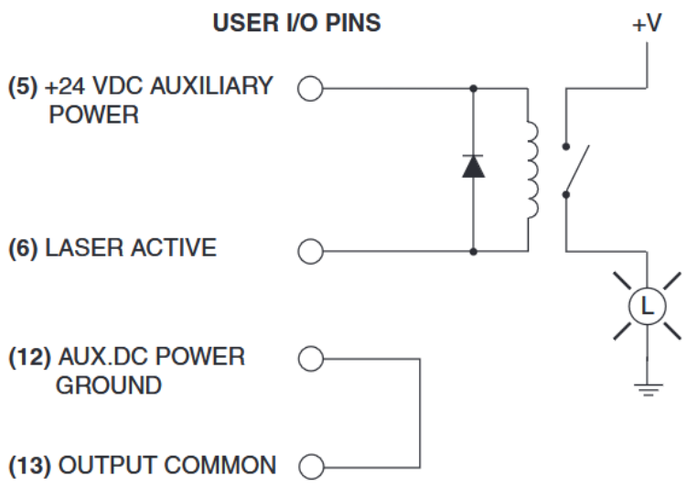
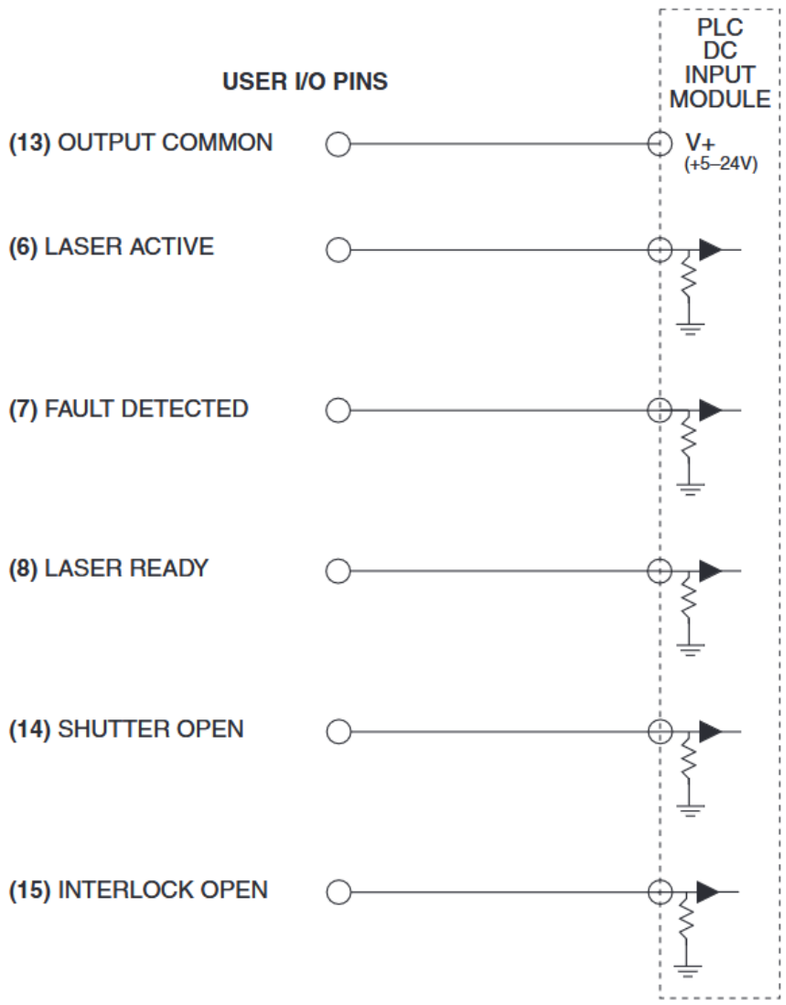


Figure 4.3.4.9 illustrates how i Series' outputs can drive the DC Input Module of a Programmable Logic Controller (PLC). By supplying voltage (+VDC) to Pin 13, Output Common, each output is independently switched to activate individual PLC inputs.

4.3.4.9 Figure: i Series outputs driving PLC input module



4.4 DC power/ DC sense cable

4.4.1 DC power cables

The DC power cables shipped with i Series lasers are manufactured with 1/0 AWG wire to a standard length of 2.0 m (6.5 ft) or an optional length of 5.0 m (16 ft). Nominal finished O.D. is 14.9 mm (0.586") so the minimum bend radius must be greater than 12 cm (4.7 in). Terminals on the laser end of the cables fit the laser's M10 studs while terminals on the power supply ends are sized to fit M6 (0.25") bolts.

When using a power supply other than the PS-401, we recommend using remote sensing so the power supply output remains at a constant voltage over varying load conditions. Choose a DC supply that can compensate for a minimum load lead loss (round trip) of 1.0 V.

Important Note:

If you lengthen the DC Power Cables shipped with the i Series laser, you must calculate and measure the additional voltage drop to ensure that 48.0 VDC is available at the laser's +48V POWER terminal under full-load conditions. Depending on the additional length required, you may need to use larger gauge (2/0) wire.

4.4.2 DC voltage sense cable

The DC voltage sense cable shipped with the i Series laser is matched to the length of the DC power cable - either the standard length of 2.0 m (6.5 ft) or an optional length of 5.0 m (16 ft). The laser end of the voltage sense cable is finished with an M10 ring terminal to fit the +48 VDC POWER terminal and an M4 spade terminal to fit the end of the –VDC GND terminal. The power supply end of the sense cable is terminated with a 26-pin high-density D-subminiature connector that connects to the PS-401 DC power supply. In addition to remote sensing connections, the 26-pin HD connector includes jumpers to enable the PS-401's Output Inhibit and Output Interlock inputs.

When using a power supply other than the PS-401, you can fabricate your own DC voltage sense cable or you can remove the 26-pin HD D-subminiature connector and terminate the sense cable to match your power supply's DC voltage sense connections.

4.5 i Series web interface

4.5.1 Accessing the i Series web page

Important Note:

The web interface is not compatible with the Google Chrome browser.

The i Series lasers are pre-configured with a fixed IP address that allows a simple Ethernet connection between the laser and a host. To connect your host computer to the i Series laser using a peer-to-peer Ethernet connection, perform the steps in the following sections:

Important Note:

Connection to a local network is permitted as long as the laser's fixed IP address is unique to your network, otherwise a peer-to-peer connection is required. When connecting to a local network, use a straight-thru Ethernet cable between the laser and your Ethernet router or hub.

Note:

The procedure described below may require the assistance of your IT Department if your facility's Ethernet settings are determined automatically using Dynamic Host Configuration Protocol (DHCP). The peer-to-peer Ethernet connection must be connected to a computer with a static IP address that is not connected to a local network.

4.5.1.1 Set your computers static IP address

Note:

The exact steps may vary depending on your operating system.

1. Disconnect the computer from your local network by removing any networking cables.
2. Open the Windows Settings and select Network & Internet.
3. Click the Change Adapter Option.
4. Right-click the Ethernet option and select Properties.
5. In the Ethernet Properties dialog select Internet Protocol Version 4 (TCP/IPv4) and click the Properties button.
6. In the Internet Protocol Version 4 (TCP/IPv4) Properties dialog, select "Use the following IP address:" and enter the following information:
   IP Address: 192.168.50.100
   Subnet Mask: 255.255.255.0

4.5.1.2 Connect to the i Series laser

1. Remove DC power from the laser.
2. Locate the Ethernet crossover cable in the ship kit.
3. Connect the crossover cable between your computer and the i Series' Ethernet port.

Important Note:

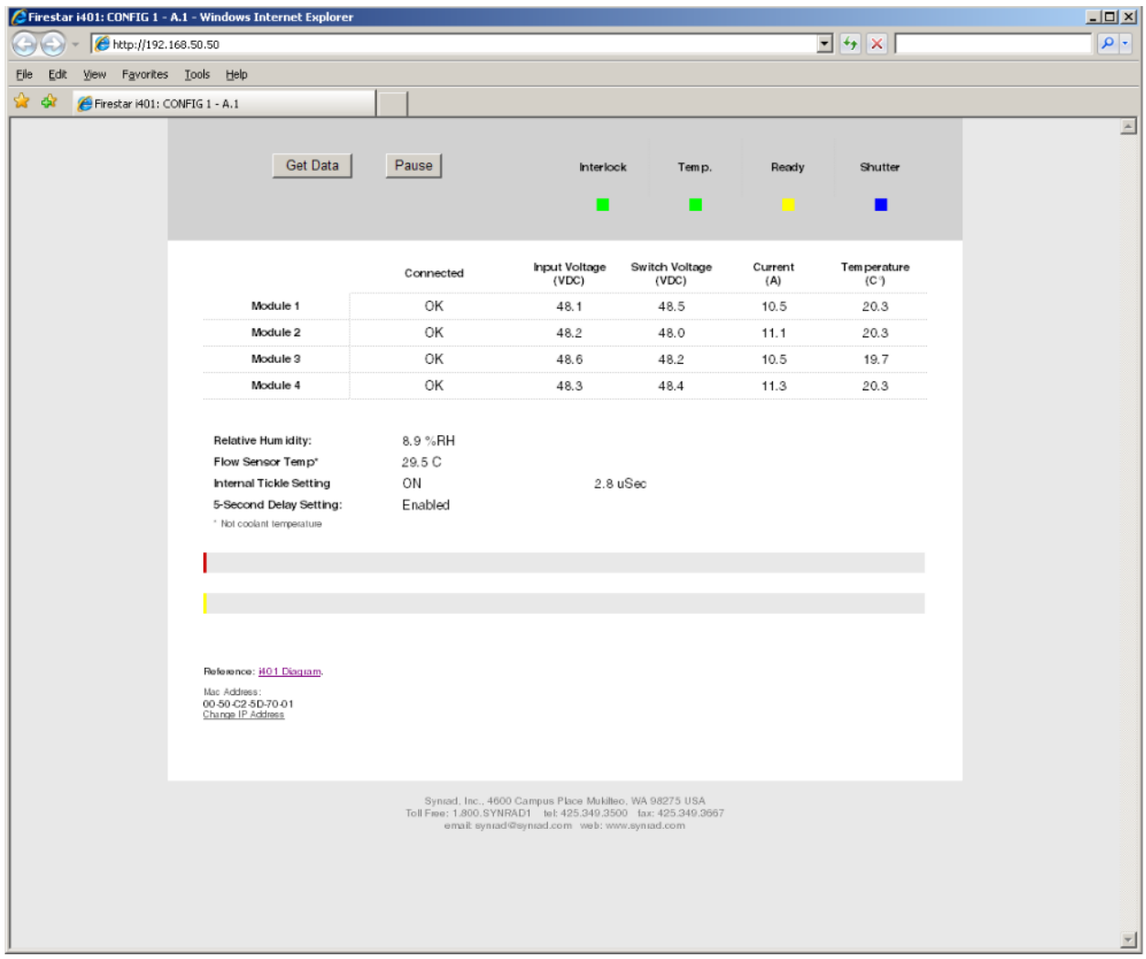
The Ethernet cable included in the laser's ship kit is a shielded crossover cable. If your network application requires a straight-thru (patch) cable or you supply your own crossover cable, be sure the Ethernet cable is an industrially shielded CAT 5e or CAT 6 cable.

4. Follow the initial start-up procedure in the Operation chapter and proceed with Step 5 below when DC power is applied to the laser.
5. Launch your web browser, type "http://192.168.50.50" (without the quotes,) and then press Enter. The home page should appear as shown in Figure 4.5.3.

4.5.2 Home page layout

The i Series lasers feature a web-based Internet interface that allows you to access read-only information about LED and RF module status–including voltage, current, and temperature measurements—using a standard web browser as shown in Figure 4.5.3.

4.5.3 Figure: i Series home page



Note:

On initial power-up of the laser, allow five seconds for the web interface to load before accessing the web page.

When the home page opens, the i Series laser begins sending status data based on the laser's current condition. Once the initial data is loaded, the "Get Data" button becomes active. Click this button to begin updating the static home page once a second. Click the "Pause" button to halt updating. If a fault should occur while the home page is active, the updating process will automatically halt and an error message is displayed. Displayed data values are accurate to within ±0.25 units.

The Interlock, Temp, Ready, and Shutter status LED icons on the web page display the current state of the laser's status LEDs.

Note:

Because the home page is a static web page, Ready and Shutter icons will not flash fault codes; however, the gray Error messages section will display the fault.

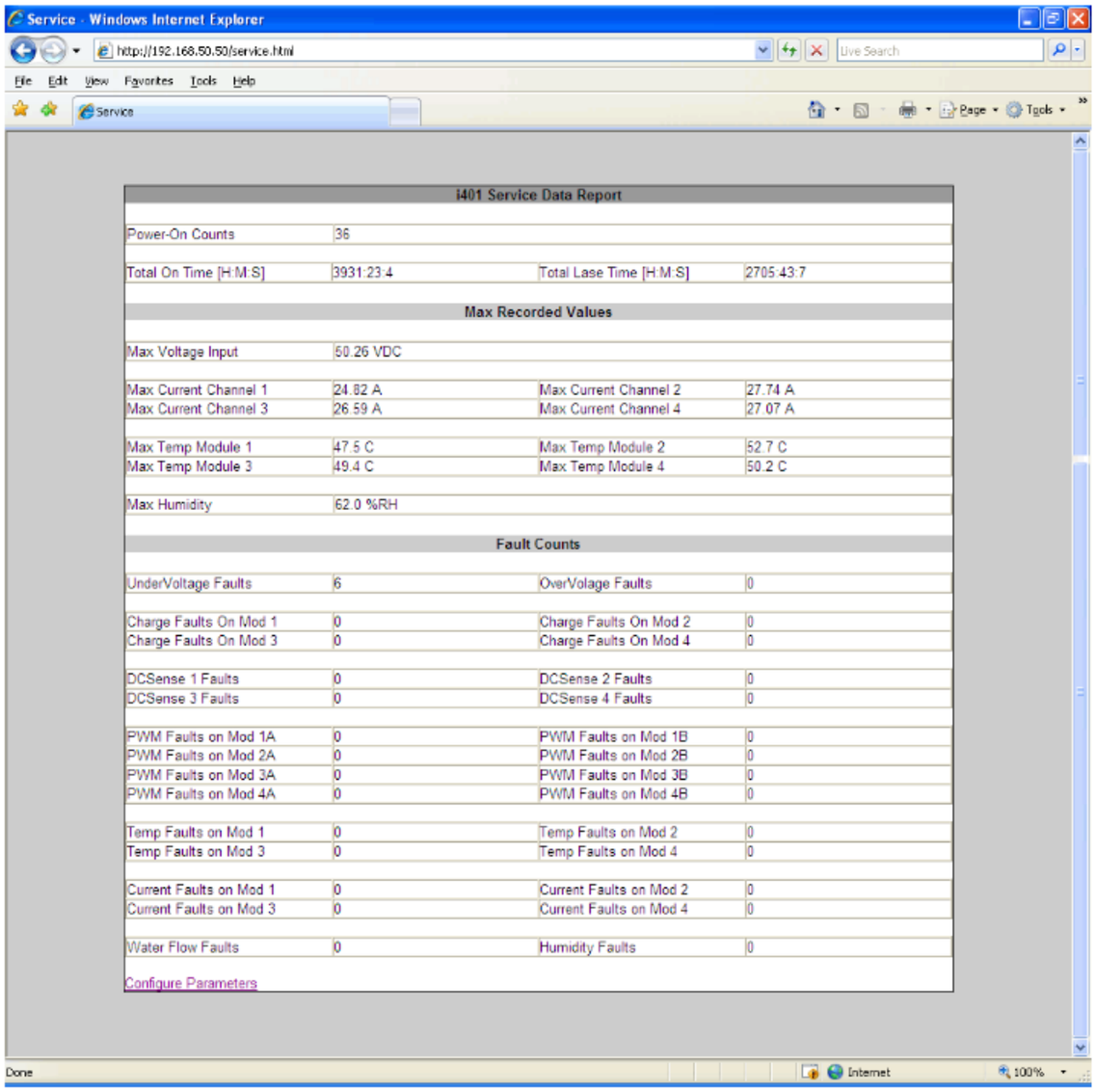
4.5.4 Table: Home page data overview

Data	Function
RF module data	This section displays operating conditions for each of the i Series four RF modules.
Connected	'OK' means that the RF module is connected to the Control module. 'NC' means the Control module does not sense a connection to the RF module
Input Voltage (VDC)	Displays the DC voltage level measured at the input of the Power module.
Switch Voltage (VDC)	Displays the DC voltage level measured at the input of the RF module.
Current (A)	Displays DC current (Amperage) being drawn by each RF module.
Temperature	Displays the heat sink temperature of each RF module.
Relative Humidity	Displays the measured relative humidity (RH) within the i Series laser housing. When purge gas is flowing, the RH value should drop to 0% (± 10%) within 10–15 minutes. If the relative humidity never drops below approximately 10%, then slightly increase the purge gas flow rate.
Flow Sensor Temp	Displays cooling system temperature measured after the RF amplifier modules. **Note**: The Flow Sensor Temp value is not a measurement of coolant temperature and should not be used to adjust the chiller's setpoint!
Internal Tickle Setting	Indicates that tickle is active (ON) and displays the actual tickle setting.
5 Second Delay Setting	Indicates that the five-second delay is active (Enabled).
Error message Area	Hard faults (those that require a power cycle), are annunciated in the upper (red) error message area while warnings are described in the lower (yellow) message area. If a fault occurs before the web interface is active, the fault or warning message is displayed; however, no other operating data is archived or displayed.
Reference: laser diagram	Hyperlink to an illustration showing various modules and their location inside the laser housing.
Configure IP Adress link	Click this link to change the laser's factory-default IP address (192.168.50.50). See the Changing the i Series IP address section for details.

4.5.5 Event log page layout

To access the i Series' event log page (Figure 4.5.6), open your web browser, type "http://192.168.50.50/service.html" (without the quotes,) and then press Enter. The event log page opens and displays information recorded over the life of the laser. This information includes power-on cycles as well as total on-time/total lase time; maximum values for voltage, current, temperature, and humidity; and the number of times that various fault conditions have occurred. Refer to the home page for a display of currently active faults, if any exist.

4.5.6 Figure: i Series event log page



i401 Service Data Report

Power-On Counts	36		
Total On Time [H:M:S]	3931:23:4	Total Lase Time [H:M:S]	2705:43:7
Max Recorded Values			
Max Voltage Input	50.26 VDC		
Max Current Channel 1	24.82 A	Max Current Channel 2	27.74 A
Max Current Channel 3	26.59 A	Max Current Channel 4	27.07 A
Max Temp Module 1	47.5 C	Max Temp Module 2	52.7 C
Max Temp Module 3	49.4 C	Max Temp Module 4	50.2 C
Max Humidity	62.0 %RH		
Fault Counts			
UnderVoltage Faults	6	OverVolage Faults	0
Charge Faults On Mod 1	0	Charge Faults On Mod 2	0
Charge Faults On Mod 3	0	Charge Faults On Mod 4	0
DCSense 1 Faults	0	DCSense 2 Faults	0
DCSense 3 Faults	0	DCSense 4 Faults	0
PWM Faults on Mod 1A	0	PWM Faults on Mod 1B	0
PWM Faults on Mod 2A	0	PWM Faults on Mod 2B	0
PWM Faults on Mod 3A	0	PWM Faults on Mod 3B	0
PWM Faults on Mod 4A	0	PWM Faults on Mod 4B	0
Temp Faults on Mod 1	0	Temp Faults on Mod 2	0
Temp Faults on Mod 3	0	Temp Faults on Mod 4	0
Current Faults on Mod 1	0	Current Faults on Mod 2	0
Current Faults on Mod 3	0	Current Faults on Mod 4	0
Water Flow Faults	0	Humidity Faults	0

Configure Parameters

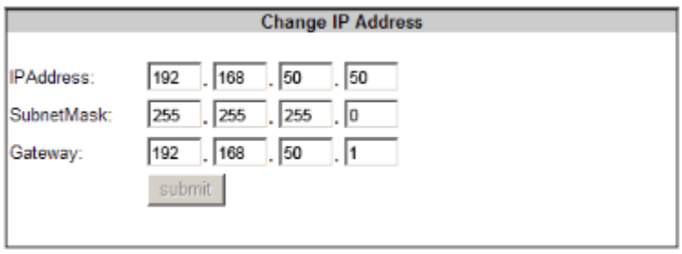
4.5.7 Changing the lasers IP address

To change the i Series' factory-default IP address, perform the following steps:

> **Important Note:**
>
> You must carefully record and store the new IP address for future reference. After the factory-default IP address is changed, it cannot be remotely reset.

1. From the i Series web page, click the *Configure IP Address* link.
2. The Change IP Address page loads (Figure 4.5.8), displaying the factory default IP Address, Subnet Mask and Gateway addresses.
3. Change the IP Address, Subnet Mask and Gateway addresses as required. Be sure to record these address changes in a safe location and then click the Submit button.
   To revert back to the factory default IP settings, simply click Submit when the Change IP Address page opens.
4. Remove DC power from the laser, wait 30 seconds, and then re-apply 48 VDC power.
5. Launch your web browser, type the new IP address (http://xxx.xxx.xxx.xxx), and then press Enter. The i Series home page will appear as shown back in Figure 4.5.3. To reach the event log page, enter "http://xxx.xxx.xxx.xxx/service.html" (without the quotes); where xxx.xxx.xxx.xxx is the new IP address.

4.5.8 Figure: i Series Change IP address page



4.5.9 Alternate Ethernet Connection

In situations where it is necessary to isolate the laser from your internal IT network, but still access the i Series web page from a networked control computer, you can connect the laser to the networked computer using a USB to Ethernet adapter. Devices like the TRENDnet TU2-ET100 USB to 10/100 Mbps Adapter allow your networked computer to access the i Series web page over the computer's USB port, which isolates the laser from your computer network. In this case, use a crossover Ethernet cable between the i Series laser and the USB to Ethernet adapter.

4.6 i Series Firmware upgrade

4.6.1 Required material/equipment

The following materials and equipment is required to upgrade the firmware in an i Series laser:

- Firmware upgrade file (i401_Firmware_Upgrade.zip) from Novanta
- Ethernet crossover cable
- Windows®-based personal computer

4.6.2 Firmware upgrade procedure

Important Note:

The firmware upgrade must be performed using a peer-to-peer connection between the laser and host computer as described below.

Note:

The i Series web interface is not compatible with Google Chrome browsers.

Disable your computer's firewall

1. If your computer's firewall is enabled, notify your IT Administrator and disable the firewall before continuing with this procedure.

Enable your computer's TFTP Client

Note:

By default, the TFTP Client is disabled on Windows® operating systems. Follow the steps in this subsection to enable the TFTP Client feature.

1. In the Windows Control Panel, click on Programs.
2. Select Programs and Features.

3. In the Programs and Features dialog on the left, click the Turn Windows Features On or Off option.
4. In the Windows Features dialog window, check “TFTP Client” and then click OK.
5. A progress bar window will appear while the TFTP Client feature is being activated. When the window closes, continue with the next section.

Set your computers static IP address

> **Note:**
>
> The exact steps may vary depending on your operating system.

1. Disconnect the computer from your local network by removing any networking cables.
2. Open the Windows Settings and select Network & Internet.
3. Click the Change Adapter Option.
4. Right-click the Ethernet option and select Properties.
5. In the Ethernet Properties dialog select Internet Protocol Version 4 (TCP/IPv4) and click the Properties button
6. In the Internet Protocol Version 4 (TCP/IPv4) Properties dialog, select “Use the following IP address:” and enter the following information:
   IP Address: 192.168.50.100
   Subnet Mask: 255.255.255.0

> **Note:**
>
> The Default Gateway field can be left blank.

7. Click OK to submit the changes.

Prepare the upgrade files

1. Double-click the “i401_Firmware_Upgrade.zip” file and extract the enclosed firmware upgrade folder to the computer’s desktop.
2. Double-click the firmware upgrade folder to open it.

Connect to the laser

1. Remove DC power from the laser.
2. Locate the Ethernet crossover cable in the ship kit and connect it between your computer and the laser’s Ethernet port.
3. Remove the Quick Start Plug from the laser’s User I/O connector.
4. Apply 48 VDC power to the laser and wait 15 seconds for the firmware to initialize.
5. If you have changed the laser’s IP address (the factory default is 192.168.50.50), you must change it back. If not, proceed to the next section, Perform the firmware upgrade.
   a. Launch your web browser, type the laser’s IP address, and then press Enter.
   b. When the home page appears as shown in Figure 4.5.3., click the Configure IP Address link at the bottom of the page.
   c. When the Change IP Address page loads showing the default IP address (Figure 4.5.8), click the Submit button. This resets the laser’s IP address to 192.168.50.50

Perform the Firmware upgrade

1. In the firmware upgrade folder, double-click the Update.bat file.
2. Wait until the batch file dialog displays the "Done! Press any key to continue..." message.
3. Press any key to exit the batch file.
4. Remove DC power from the laser, wait 15 seconds, and then re-apply 48 VDC power.
5. Launch your web browser, type: "http://192.168.50.50" (without the quote symbols) and then press Enter.
6. When the i Series Home page appears, check the label on the web browser's tab. It should read: Firestar i401: CONFIG 2 – X.X to indicate the laser is running upgraded firmware.
7. If necessary, click the Configure IP Address link at the bottom of the web page and reset the default IP address to the specific address required for your application.

Re-enable your computer's firewall

1. If your computer's firewall was disabled for this procedure, notify your IT Administrator and reenable the firewall.

4.7 Integrating i Series safety features

The i 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 CO_2 gas to remain in a zero-energy state. The i Series status indicators provide users with a quick visual indication of the laser's operational status. All power to the laser's RF board is removed when the RDY indicator is Off (Laser Ready output open).

4.7.1 Keyswitch functions

4.7.1.1 OEM lasers

On OEM lasers, the RDY LED illuminates on DC power-up (when the Remote Interlock input is enabled) and five seconds later, DC power is applied to the RF driver. When the Shutter Open Request input is inactive (SHT indicator Off) only tickle pulses are applied to the laser. PWM Command signals are enabled only when voltage is applied to both Shutter Open Request and Remote Interlock inputs (INT LED green, RDY LED On, and SHT LED On). Over temperature faults are reset by removing and then re-applying 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 five seconds later lasing is enabled.

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 begins a five-second countdown after which lasing is enabled (RDY LED illuminates yellow). The RF driver is disabled as long as voltage is applied to Pin 2.

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

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.

4.7.2 Shutter functions

An internal electromechanical shutter is installed on all i Series lasers. Lasing is enabled when the shutter is open (SHT LED illuminated blue) and disabled when the shutter is Closed (SHT LED off).

For i Series OEM lasers in automated systems, shutter actuation is provided by the Shutter Open Request signal via Pin 10 on the User I/O connector. To use this feature, 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 (provided the RDY indicator is On) and opens the physical shutter to allow lasing. Removing voltage from the Shutter Open Request input causes the physical shutter to close and block the beam path, extinguishing the SHT lamp and allowing only tickle signals to reach the tube.

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 Open Request signal is present (SHT LED illuminated blue) and the Laser Ready output is closed (RDY LED is On). The output is open (SHT LED Off) when the Shutter Open Request signal is removed or the Laser Ready output is open (RDY LED is Off).

4.7.3 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 the RDY LED is illuminated and a Shutter Open Request signal is applied. Lasing is 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. Remote interlock functionality is provided by the Remote Interlock signal via Pin 3 on the User I/O connector.

To use the remote interlock feature to initiate lasing, 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, the RDY indicator to turn yellow, and sends DC power to the RF driver boards. After a five-second delay, a tickle signal is applied to the tube. When a Shutter Open Request signal is present, PWM Command signals are enabled to begin lasing. Removing voltage stops DC power from reaching the RF driver, causing the INT LED to turn red and the RDY LED to turn Off. Lasing remains disabled until a voltage 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 the interlock circuitry is closed.

4.8 General Specifications

4.8.1 i Series General Specifications

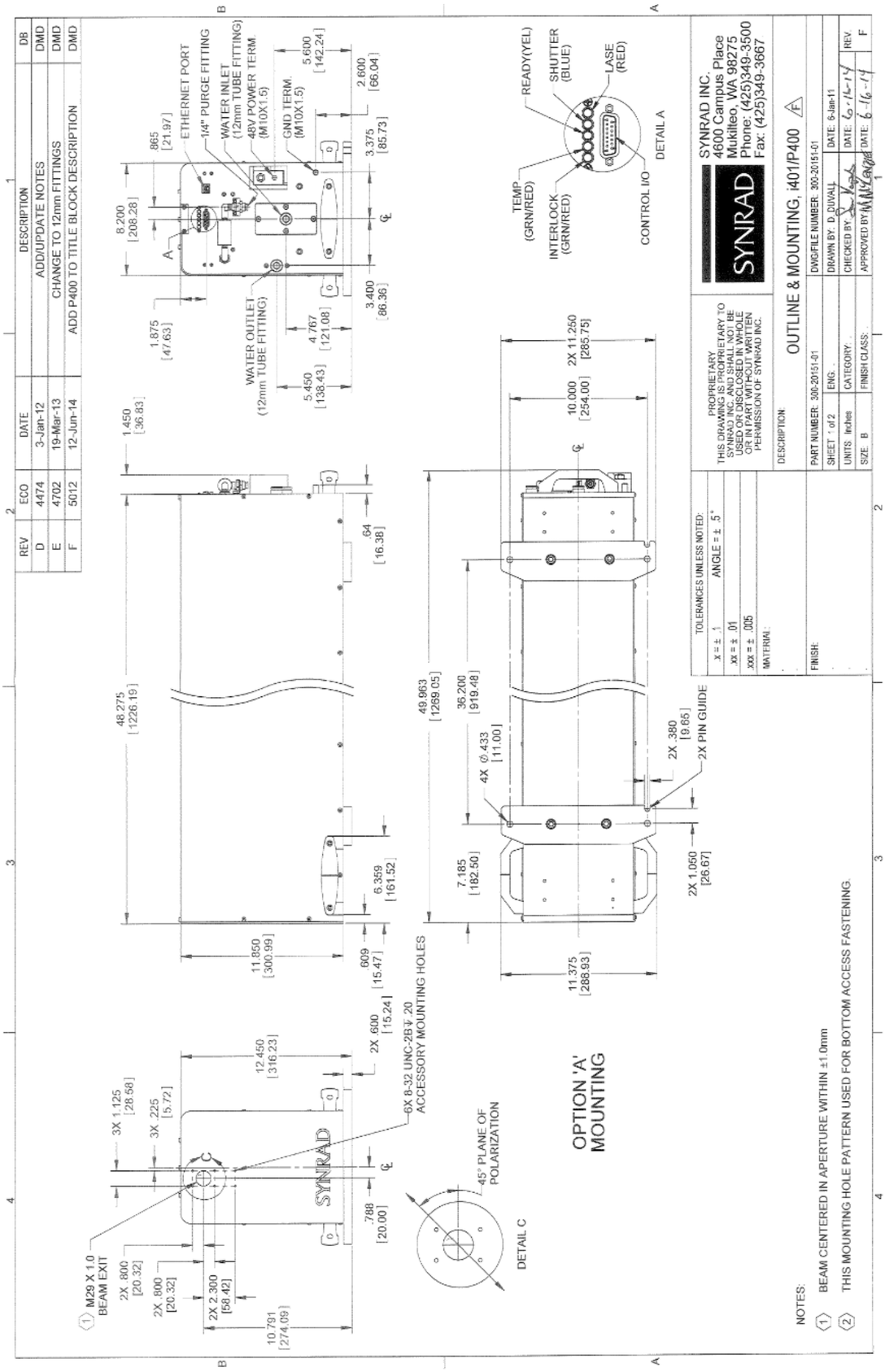
Model	i401	i501
Laser		
Wavelength	10.2 µm, 10.6 µm	
Output Power [1]	> 400 W	> 500 W
Power Stability [2] (cold start)	± 7%	
Power Stability (typical, after 3 minutes)	± 5%	
Beam Quality (M^2)	< 1.2	
Beam Waist Diameter at $1/e^2$ [3]	6.7 mm ± 0.7 mm	
Beam Divergence, full angle	2.5 mrad ± 0.3 mrad	
Ellipticity	< 1.2	
Polarization	Linear (45°)	
Rise/ Fall time	<100 µs	
Operating Frequency	0 – 100 kHz	
Power Supply		
Voltage	48 V ± 1.0 VDC	
Maximum Current	125 A	175 A
Cooling		
Maximum Heat Load	6000 W	8500 W
Coolant Temperature	18 – 22° C (water)	
Minimum Flow Rate	4.0 GPM, < 60 PSI	4.2 GPM, < 60 PSI
Environmental		
Operating Ambient Temperature	15 – 40° C	
Maximum Humidity	95%, non-condensing	
Physical		
Length	48.3 in / 1227 mm	
Width	8.2 in / 208 mm	
Height	11.8 in / 300 mm	
Weight	130 lb / 59.0 kg	142 lb / 64.5 kg

* Specifications subject to change without notice.

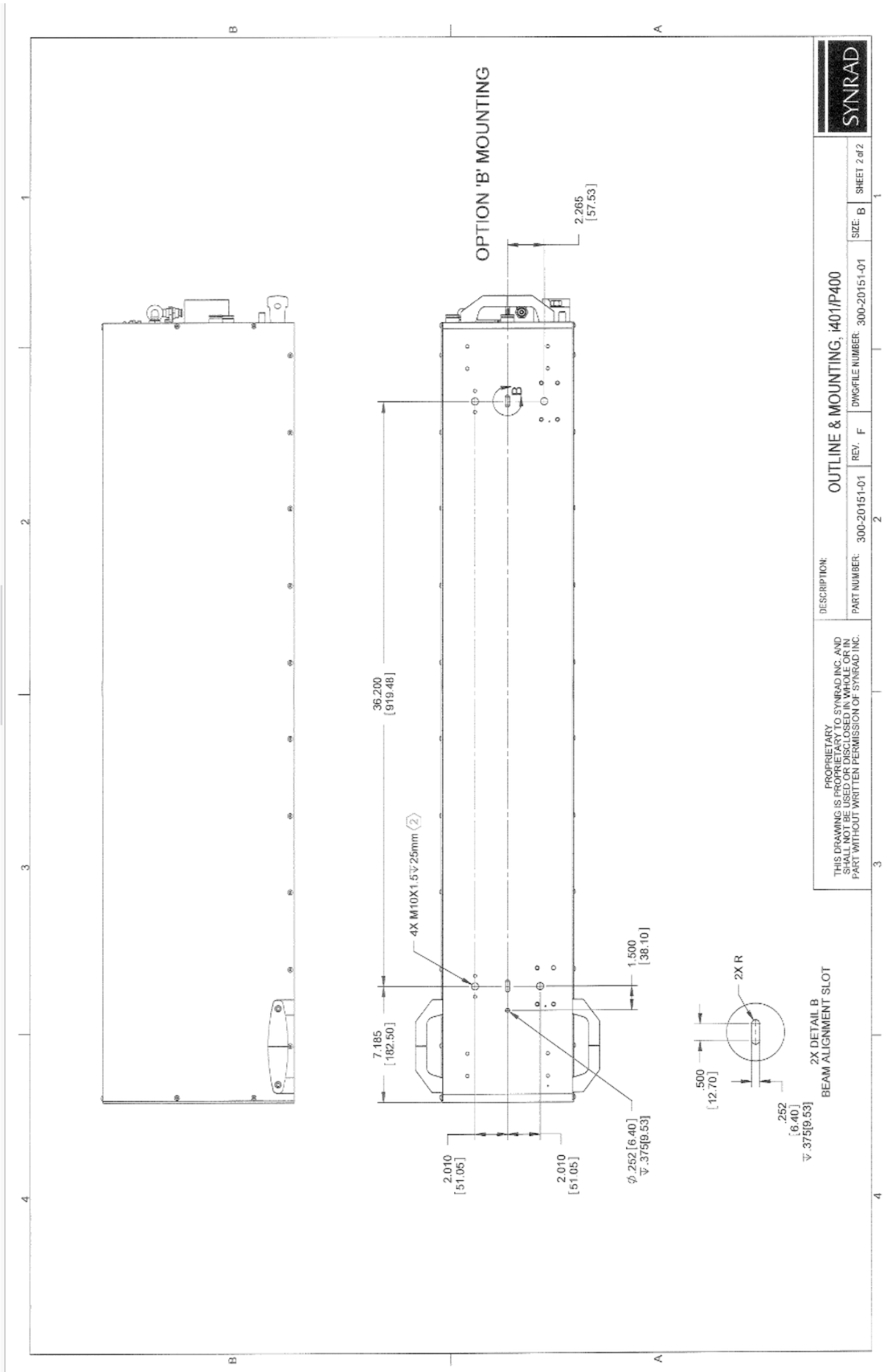
1 Power level guaranteed for 2 years from date of shipment, regardless of operation hours, within recommended coolant flow rate and temperature range.
2 Measured from cold start as $\pm(P_{max}-P_{min})/(P_{max}+P_{min})$.
3 Measured $1/e^2$ diameter at laser output.

4.9 Outline and Mounting Drawings

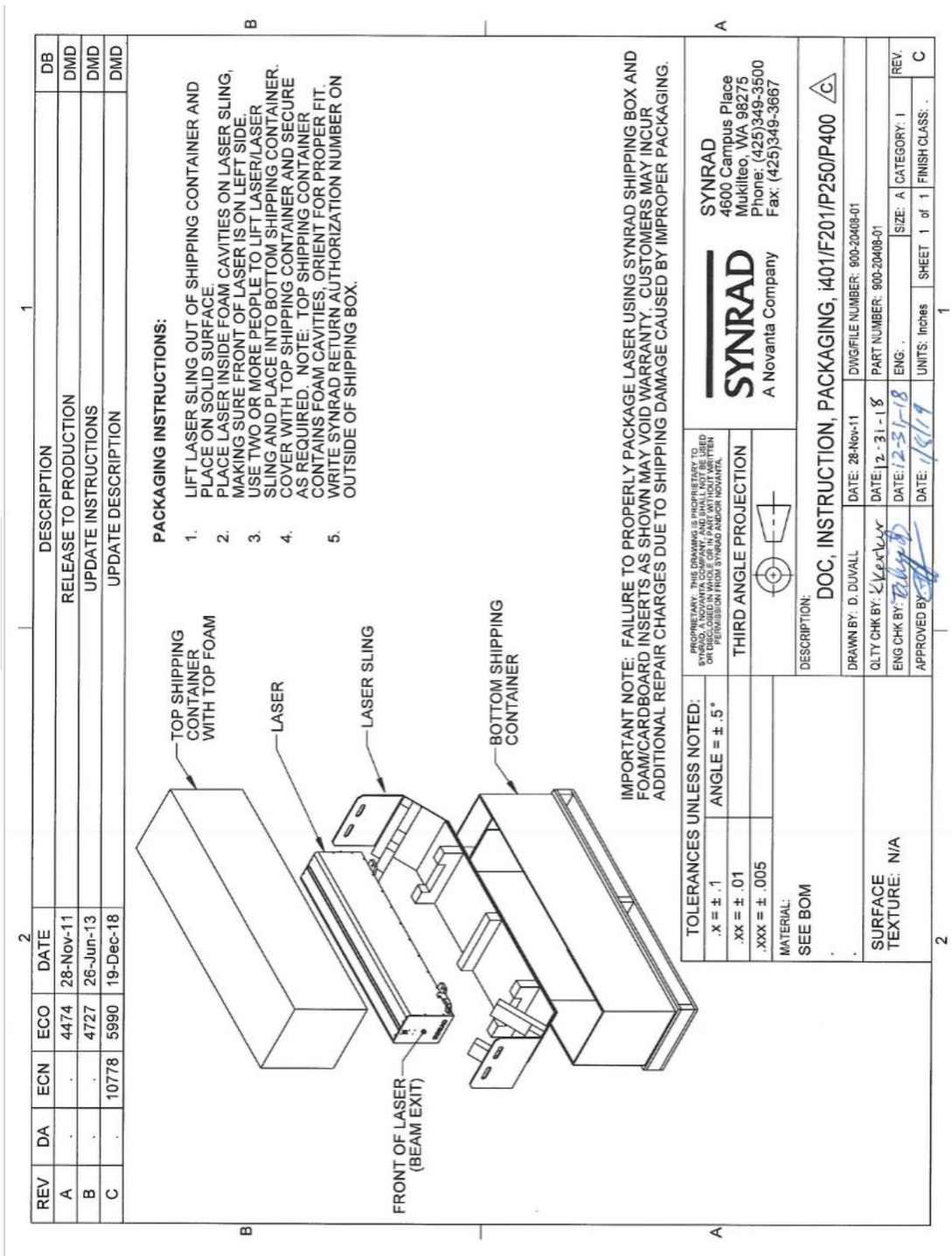
4.9.1 Figure: i Series outline & mounting dimensions



4.9.2 Figure: i Series outline & mounting dimensions (mounting feet removed)



4.9.3 Figure: i Series packaging instructions



5 Maintenance and Troubleshooting

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

5.1 Maintenance

5.1.1 Disabling the Laser

Before performing any maintenance on your i 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 i 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 for detail on preventing condensation.
2. When using compressed air as a purge gas on your i Series laser, empty water traps and oil separators on each filter and/or dryer between the laser and your compressed air source. Compressed air purity must meet the gas purity specifications shown in Table 3.7.3 in the Getting Started 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 i 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 CO_2 laser radiation is emitted through the aperture. Corneal damage or blindness may result from exposure to the laser radiation.

Caution: Possible Equipment Damage

Even small amounts of contamination on optics in the beam path can absorb enough energy to 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.

Important – i Series lasers have several beam conditioning optics between the output aperture and the faceplate. To prevent dust and debris from damaging these optical surfaces, always connect nitrogen or filtered air to the laser's Gas Purge port.

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 i 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 CO_2 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 CO_2 radiation when in the same area as an exposed laser beam. Eyewear protects against scattered energy but is not intended to protect against direct viewing of the beam – never look directly into the laser output aperture or view scattered laser reflections from metallic surfaces.

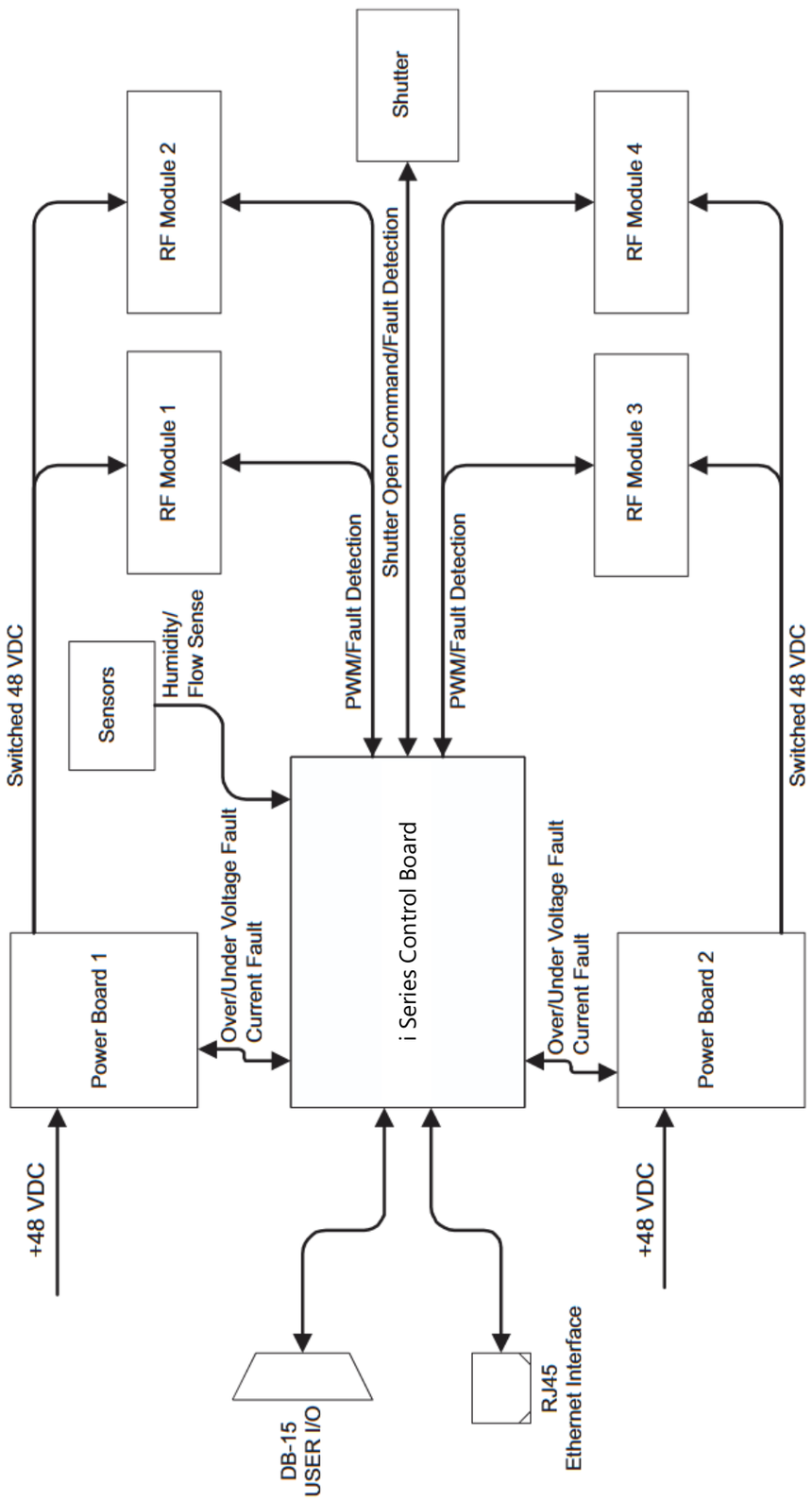
Do not contact the laser beam. This product emits an invisible laser beam that is capable of seriously burning human tissue. Always be aware of the beam's path and always use a beam block while testing.

Caution: Possible Equipment Damage

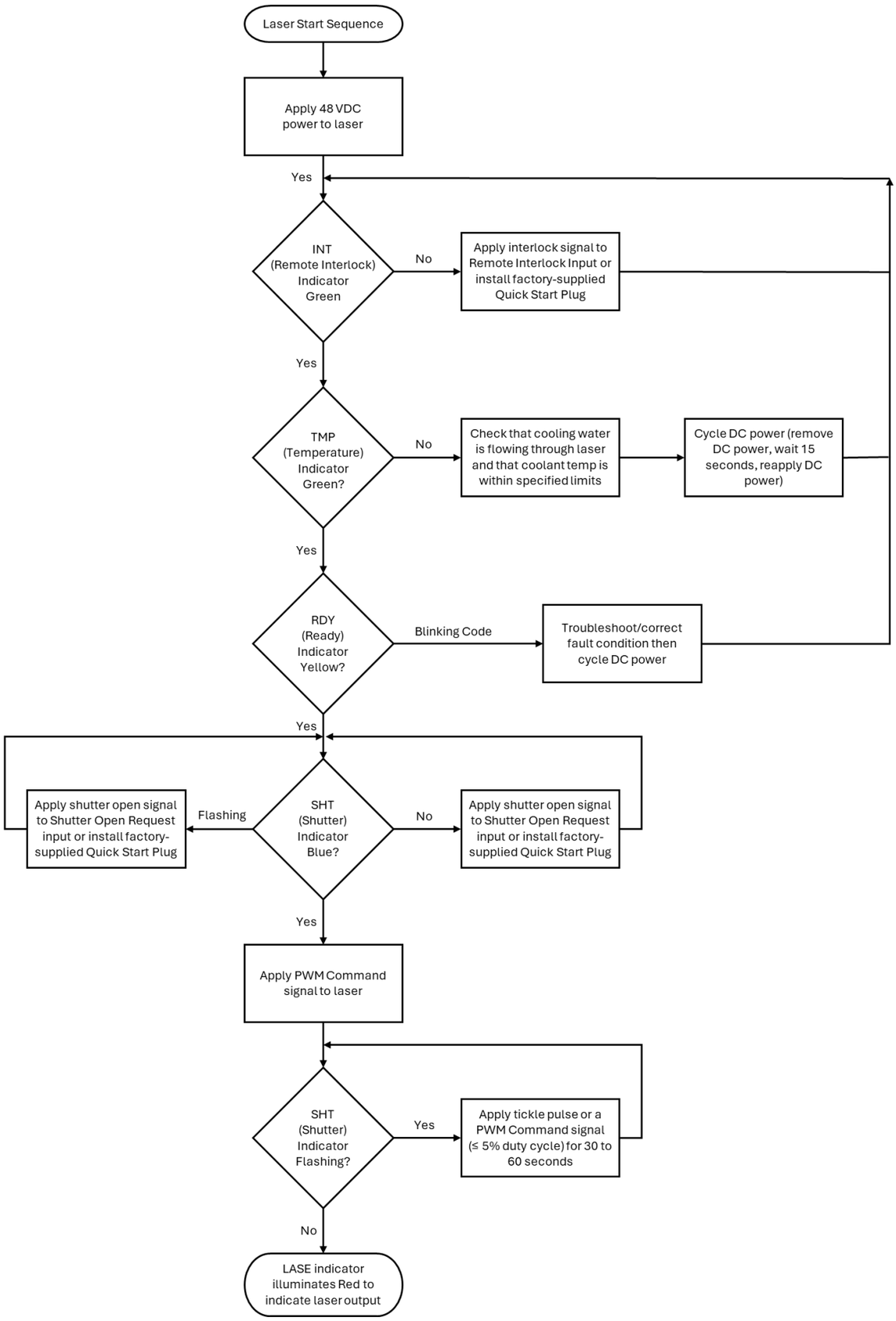
Attempting repair of a Novanta laser without the express authorization of Novanta will void the product warranty.

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

5.2.2 Figure: i Series functional block diagram



5.2.3 Figure: Operational flowchart



5.2.4 Status LEDs

The LED indicators, also mirrored as output signals on the User I/O connector, provide status information to the user. User I/O outputs are Closed when the state indicated by the signal name is logically True.

On DC power-up of an i Series laser, the RDY lamp illuminates yellow when INT and TMP indicators illuminate green. After the RDY indicator illuminates, internal tickle is enabled and a five-second delay begins before lasing is permitted. When a Shutter Open Request signal is applied, the internal shutter opens, the SHT LED illuminates blue, and application of a PWM Command signal causes the LASE indicator to illuminate red as lasing begins.

For safety reasons, the shutter function on i Series lasers is dependent on the state of the Remote Interlock input, which is reflected by the state of INT and RDY indicators. Although a Shutter Open Request signal may be applied, the SHT LED will not illuminate while the INT LED is red (RDY LED Off). Therefore, no power is applied to the RF boards until the INT indictor is green (and the RDY LED is yellow).

Table 5.2.5 illustrates the dependencies of various operating parameters based on the state of the Remote Interlock input. The conditions shown in bold are those required for lasing to be enabled.

5.2.5 Table: Effect of Remote Interlock input on operating parameters

Parameter	**Remote Interlock Input Inactive (No V+)**		**Remote Interlock Input Active (V+ Applied)**	
INT LED Interlock Open Output	Red Closed		**Green** **Open**	
RDY LED (if TMP LED Green) Laser Ready output (if FD output Open)	Off Open	Off Open	**Yellow** **Closed**	**Yellow** **Closed**
Shutter Open Request input SHT LED Shutter Open output	Inactive Off Open	Active Off Open	Inactive Off Open	**Active** **Blue** **Open**
Physical shutter position DC power to RF boards Signal input RF boards	Closed Off None	Closed Off None	Closed On Tickle	**Open** **On** **Tickle/PWM**

5.2.6 Laser Fault Indications

The i 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 fault conditions.

5.2.7 Table: i Series LED and I/O Status States

LASER CONDITION / FAULT	INPUT STATUS: Remote Interlock	INPUT STATUS: Remote Reset / Start Request	INPUT STATUS: Shutter Open Request	INPUT STATUS: PWM	LED STATUS: INT	LED STATUS: TMP	LED STATUS: RDY	LED STATUS: SHT	LED STATUS: LASE	OUTPUT STATUS: Interlock Open	OUTPUT STATUS: Fault Detected	OUTPUT STATUS: Laser Ready	OUTPUT STATUS: Shutter Open	OUTPUT STATUS: Laser Active	COMMENTS
DC Power Off	x	x	x	x	Off	Off	Off	Off	Off						No RF to tube
DC Power Applied, Laser Disabled	0 x x	x 1 x	x x 0	x x x	Red	Green	Off	Off	Off	C					No RF to tube
DC Power Applied, Laser Enabled	1	0	1	0	Green	Green	Yellow	Blue	Off			C	C		Tickle applied to tube for 5 seconds, then laser may fire
Laser Firing	1	0	1	(pulse train)	Green	Green	Yellow	Blue	Red			C	C	C	Normal laser operation
Interlock Open	0	0	1	x	Red	Green	Off	Off	Off	C					No RF to tube
Over Temperature	1	0	1	x	Green	Red	Off	Off	Off		C				Cooling problem
Electromechanical Shutter Not Open	1	0	1	x	Green	Green	Yellow	Off	Off			C			No RF to tube
Under Voltage	1	x	1	x	Green	Green	Blinking (1)	Blue	Off				C		Voltage below 46VDC
Over Voltage	1	x	1	x	Green	Green	Blinking (2)	Blue	Off				C		Voltage over 50VDC
RF Drive Switch Fault	1	x	1	x	Green	Green	Blinking (3)	Blue	Off				C		Laser service required
PWM Drive Fault	1	x	1	x	Green	Green	Blinking (4)	Blue	Off				C		Laser service required
DC Pre-Charge Fault	1	x	1	x	Green	Green	Blinking (5)	Blue	Off				C		Laser service required
Internal Humidity; Laser Quits Lasing	1	0	1	x	Green	Green	Off	Off	Off						>95% Relative Humidity inside laser chassis
No Strike Fault	1	0	1	x	Green	Green	Yellow	Blinking (C)	Off		C	C	C		Output limited to 5%

TABLE KEY:

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

RDY (1): Blinking LED; number represents blink sequence
SHT (C): Blinking LED; "C" represents continuous blinking sequence

C : Closed

5.2.8 Web page fault annunciation

The i Series web interface displays errors and warnings in real-time on the home page in either the error message area or the warning message area. Hard faults that require a DC power cycle are always shown in the error message area. Operating data is not archived or displayed if the web interface is inactive when the fault occurs. The event log page displays fault information recorded over the life of the laser. See the i Series web interface section in the Technical Reference chapter for web page access details.

5.2.9 Resetting Faults

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

Remote interlock condition

A remote interlock condition occurs when the Remote Interlock input opens (the INT indicator changes from green to red). The internal shutter mechanism closes (even when the Shutter Open Request input is active) and lasing is halted immediately.

On i Series lasers, a remote interlock condition is not latched. Re-establish the Remote Interlock signal input (INT LED changes from red to green and the Interlock Open output Opens) to enable the RDY indicator and begin lasing after the five-second delay.

Over temperature fault

Over-temperature faults occur when coolant temperature or flow limits in the laser are exceeded (the TMPLED changes from green to red and the Fault Detected output Closes).

To reset an over temperature fault, lower coolant temperature below 28°C and then cycle DC power to the laser. Once the TMP indicator turns green (Fault Detected output Opens) and the RDY lamp is illuminated, lasing is possible after the five-second delay.

Under voltage fault

An under voltage fault occurs when DC input voltage falls below a preset limit of 46.5 VDC. This fault is indicated by the RDY LED flashing 1 blink. To reset an under voltage fault, first correct the voltage problem and ensure that 48 VDC is measured at the laser's DC power terminals under full-load conditions. Next, cycle DC power off and then on again. When the RDY LED illuminates, lasing is enabled after a five-second delay.

Over voltage fault

An over voltage fault occurs when DC input voltage rises above a preset limit of 49.5 VDC. This fault is indicated by the RDY LED flashing 2 blinks. To reset an over voltage fault, first correct the voltage problem and ensure that 48 VDC is measured at the laser's DC power terminals under full-load conditions. Next, cycle DC power off and then on again. When the RDY LED illuminates, lasing is enabled after a five-second delay.

RF Drive Switch fault

An RF Drive Switch fault occurs on power-up when the tube fails to breakdown or a fault occurs in the RF Driver's 48-volt switching circuitry. In this case, the RDY LED flashes 3 blinks. If an RF Drive Switch fault occurs, contact Novanta Customer Service or a Novanta Authorized Distributor.

PWM Drive fault

A PWM Drive fault indicates a problem in the laser's internal RF circuitry and causes the RDY LED to flash 4 blinks. If a PWM Drive fault appears, the laser requires service—contact Novanta Customer Service or a Novanta Authorized Distributor.

No-Strike condition

When a No-Strike condition occurs, lasing is limited to a maximum 5% duty cycle (at a PWM Command frequency of 5 kHz). This fault is annunciated by the SHT indicator flashing continuously and an error message appears on the i Series' web page. To clear the No-Strike condition, 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 at the commanded power level without cycling DC power. If the No-Strike condition persists, contact Novanta or a Novanta Authorized Distributor.

Common causes of No-Strike (gas breakdown) issues are environmental conditions–like cold overnight temperatures when the laser is powered down. In situations like this, it may take 30 to 60 seconds for gas breakdown to occur so the laser can begin normal daily operation.

5.2.10 General laser fault conditions

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

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

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

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

- **Possible Causes:** Coolant temperature is above 28 °C (82 °F) or there is inadequate coolant flow through the laser.

  Check that the chiller is maintaining a coolant temperature between 18 °C–28 °C (64 °F–82 °F) at a flow rate of 15.1 lpm (4.0 GPM).

  If water temperature is OK, check the flow rate. The simplest way to do this, if a flow meter is not available, is to disconnect the cooling tubing from the chiller inlet (or the drain) and run the cooling water for 30 seconds into a five-gallon bucket; you should have close to two gallons of water. If there is much less than two gallons of coolant, check the cooling path for kinked or pinched cooling tubes or check the chiller for a clogged or dirty filter.

  On i Series lasers, the over-temperature fault (indicated by the TMP indicator turning red) is latched. This means that if an over-temperature condition occurs the TMP indicator will turn red, the Fault Detected output will Close, the RDY light goes out, and lasing is disabled. Because of its latched condition, the TMP indicator will remain red even after the laser has cooled sufficiently to begin operation. To reset an over-temperature fault, lower coolant temperature below 28 °C and then cycle DC power (remove DC power, wait 30 seconds, reapply DC power). When the RDY indicator illuminates, lasing is enabled after the five- second delay. If the TMP indicator remains red after cycling power, continue to flow cooling water through the laser for a few more minutes and/or verify the coolant flow rate and then cycle DC power again.

- **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 or 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.

  When this occurs while a PWM signal is applied, laser output is limited to a PWM duty cycle of approximately 5%. 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	Laser Active output	= Open

- **Possible Causes:** No Shutter Open Request signal on Pin 10 of the User I/O connector.

  Check to see that a positive or negative voltage in the range of ±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, wire a male DB-15 connector to the User I/O 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).

  When a Shutter Open Request signal is applied to the laser, it takes approximately 30 ms for the electro-mechanical shutter to fully open. Although tickle signals are applied to RF circuitry during this interval, PWM Command signals are inhibited until the shutter is fully open. When the Shutter Open Request signal is removed from Pin 10, PWM Command signals are inhibited immediately; however, the electro-mechanical shutter takes approximately 120 ms to fully close.

- **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 internal shutter automatically closes to block the beam path, the RDY LED turns Off, the SHT LED turns Off (regardless of the state of the Shutter Open Request input), and all DC power is removed from the RF boards. However, if the interlock circuit closes again, the INT indicator changes from red to green, the Interlock Open output Opens, the RDY light illuminates, the SHT LED turns On, the internal shutter opens, and five seconds later lasing is enabled.

- **Possible Causes**: Electrical noise on the Remote Reset/Start Request input has momentarily disabled the laser.

  If you are operating in an industrial environment and experience brief intervals where the laser is commanded to lase, but does not, this behavior may be the result of noise-induced voltage transients on the Remote Reset/Start Request input. When a typical noise-induced voltage transient occurs, the duration can be long enough to cause input circuitry to disable lasing, but short enough that the RDY LED (and Laser Ready output) appear to remain switched on. When this transient noise occurs, lasing is disabled until the mandatory five-second delay has timed out.

  Electrical noise can unintentionally inhibit lasing because of (1) improperly shielded or grounded I/O wiring or (2) excessive electrical noise generation around the laser; for example from an improperly shielded or grounded variable-frequency drive (VFD) or other electrically-noisy device.

- **Symptom:** Your i Series OEM laser has quit lasing. A PWM Command signal is being applied and no faults are indicated, but the following status LEDs and I/O states exist:

INT LED =	Green	Interlock Open output	= Open
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 internal humidity sensor has detected a Relative Humidity (RH) reading inside the laser chassis that is greater than 95%

  Because relative humidity readings above 95% may indicate a condensing atmosphere, leading to catastrophic laser damage, lasing is halted when this threshold is exceeded. If you are connected to the laser's Ethernet port, access the web page to verify the fault condition. If you are not connected to the i Series web page, refer to the Getting Started or Technical Reference chapters for details on accessing the web page.

  To reset the laser, you must lower the RH level below 95% and then cycle DC power off and back on. The best method for lowering humidity is to connect a source of nitrogen or clean, dry air to the laser's Gas Purge port as described in the Getting Started chapter.

  During laser operation, monitor information on the i Series' web page, including the Relative Humidity value. When properly conditioned purge gas is flowing, the measured RH value should drop below 10% within 10–15 minutes. If the relative humidity never drops below approximately 10%, then increase the gas flow rate slightly. If the RH value exceeds 85% during operation, a warning is displayed in the web page's lower (yellow) error message section. If the RH value continues to rise and reaches 95%, lasing is halted and a fault is displayed in the upper (red) error message section of the web page.

Important Note:

Novanta highly recommends the use of purge gas to keep the internal humidity level below 10%. See the Getting Started chapter for connection details and gas quality specifications

- **Symptom**: DC power is applied, but the i Series web interface cannot be accessed.
- **Possible Causes:** The peer-to-peer connection was made using a straight-thru Ethernet cable.

  Use an Ethernet crossover cable for a peer-to-peer connection between the laser and the computer. Use a straight-thru cable when connecting to a network using a network router, switch, or hub.
- **Possible Causes:** The factory-default IP address was changed.

  The i Series lasers are pre-configured at the factory with a fixed IP address of 192.168.50.50. If this address was changed in the field, then you must locate the new IP address, it cannot be remotely reset.

- **Symptom**: The i Series laser is connected to a network; however, the web interface does not open or locks up while receiving data from the laser.
- **Possible Causes:** The laser was connected to the network using a crossover cable.

  A straight-thru cable is required if connecting an i Series laser to a network via a network router, switch, or hub.

- **Possible Causes:** Java script is not enabled in the web browser.

  Locate your browser's Internet Options menu and configure it to enable Java script. The Java feature is located on the Internet Options dialog's Advanced tab (under Tools/Internet Options). The dialog boxes in your particular browser may appear differently.

- **Possible Causes:** Multiple i Series lasers are connected to the same network with identical IP addresses.

  Make sure only one laser is connected to the network at a time or, if multiple lasers are connected, be sure they have distinct IP addresses to prevent IP addressing conflicts.

- **Possible Causes**: The laser's IP address is not recognized as an authorized site on your local intranet network or a trusted site on the Internet.

  Add the laser's IP address to the list of authorized and/or trusted websites. In your browser, locate the Internet Options dialog's Security tab. The dialog boxes in your particular browser may appear differently. To authorize the i Series web page on a local intranet, click the Local intranet icon and then click the Sites button. In the Local intranet dialog, click Advanced. In the Add this website to the zone: text box, type the laser's IP address and click Add. Click Close and then click OK twice.

  To add the i Series web page as a trusted web site, click the Trusted sites icon and then click the Sites button. In the Trusted sites dialog, type the laser's IP address in the Add this website to the zone: text box, and then click Add. Click Close and then click OK twice.

- **Symptom**: It is necessary to isolate the laser from the IT network, but still important to access the web page from a networked control computer.
- **Possible Causes:** Use a USB to Ethernet adapter to isolate your i Series laser from the network.

  In situations where it is necessary to isolate the laser from your internal IT network, but still access the i Series web page from a networked control computer, you can connect the laser to the networked computer using a USB to Ethernet adapter. Devices like the TRENDnet TU2-ET100 USB to 10/100 Mbps Adapter allow your networked computer to access the i Series web page over the computer's USB port, which isolates the laser from your computer network. In this case, use a crossover Ethernet cable between the laser and the USB to Ethernet adapter.

5.2.11 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 CO_2 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*** CO_2 laser radiation is emitted through the aperture. Corneal damage or blindness may result from exposure to laser radiation.

Shut down the laser and carefully inspect each optic in the beam delivery path, including the laser's output coupler. Remember that optics are fragile and must be handled carefully. 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 i 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 (4.1.3.3) in the Technical Reference chapter for filtering and drying specifications.

6 Appendix

6.1 Declaration of Incorporation

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Declaration of incorporation within the meaning of the Machinery Directive 2006/42/EC Annex II 1B

Product	Firestar™ OEM i401 Laser FSi401SB (*OEM)		
Manufacturer	Novanta Corporation 4600 Campus Place Mukilteo, WA 98275 USA	The person authorized to compile the relevant technical documentation	Justin Ryser (Laser Scientist) Novanta Corporation 4600 Campus Place Mukilteo, WA 98275 USA

The manufacturer declares that the above-named product is an incomplete machine within the meaning of the Machinery Directive. The product is exclusively intended to be incorporated into a machine or an incomplete machine and therefore does not comply with all the requirements of the Machinery Directive.

A list of the essential requirements of the Machinery Directive that apply to this product and with which it complies can be found in the Annex to this declaration.

Commissioning of the product is prohibited until it has been established that the machine into which the above-named product is incorporated complies with all essential requirements of the Machinery Directive and the safety requirements and measures of standard DIN EN ISO 60825-1:2014, *Safety of Laser Products*.

The special technical documentation in accordance with Machinery Directive 2006/42/EG Annex VII Part B has been created. The person authorized to compile the technical documentation undertakes to send the documentation to the national authorities in response to a reasoned request. The documentation is sent by post in paper format or by electronic media.

The above-named product fulfills the requirements of the following EC Directives:

- Electromagnetic Compatibility Directive 2014/30/EU
- RoHS Directive 2011/65/EU, including (EU) 2015/863

Additionally, the product meets the protection objectives of the Low Voltage Directive 2014/35/EU.

The following harmonized European standards have been applied:

[1] Before commissioning the subsystem, the integrator is responsible for ensuring that the complete machine complies with the safety requirements and measures of the DIN EN ISO 60825-1:2014 standard.

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- DIN EN 61010-1:2010 Safety requirements for Electrical Equipment of Measurement, Control, and Laboratory Use – Part 1: General requirements
- DIN EN 61000-6-4:2007 Radiated Emissions, Group 1, Class A
- DIN EN 61000-6-4:2007 Conducted Emissions, Group 1, Class A
- DIN EN 61000-6-2:2005 Electrostatic Discharge Immunity
- DIN EN 61000-6-2:2005 RF Electronic Fields Immunity
- DIN EN 61000-6-2:2005 Electrical Fast Transient/burst Immunity
- DIN EN 61000-6-2:2005 Conducted RF Disturbances Immunity

Mukilteo, 2025-01-23 Justin Ryser

Justin Ryser (Laser Scientist)

Annex to the declaration of incorporation

List of the essential health and safety requirements for the design and construction of machinery that apply to the product specified on page 1 and with which it complies.

Number Annex I	Heading	applicable	complied with	Comment
1	ESSENTIAL HEALTH AND SAFETY REQUIREMENTS	–	–	–
1.1.2	Principles of safety integration	Yes	Yes	
1.1.3	Materials and products	Yes	Yes	The product contains zinc selenide. Appropriate safety measures must be taken by the integrator.
1.1.4	Lighting	No	-	-
1.1.5	Design of machinery to facilitate its handling	Yes	Yes	Handles provided for 2-person lifting when moving.
1.1.6	Ergonomics	No	-	-
1.1.7	Operating positions	No	-	-
1.1.8	Seating	No	-	-
1.2	CONTROL SYSTEMS	--	--	-
1.2.1	Safety and reliability of control systems	Yes	No	No control systems included.[1]
1.2.2	Control devices	No	-	-

[1] Before commissioning the subsystem, the integrator is responsible for ensuring that the complete machine complies with the safety requirements and measures of the DIN EN ISO 60825-1:2014 standard.

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Number Annex I	Heading	applicable	complied with	Comment
1.2.3	Starting	Yes	No	Machine will start immediately after power up.[1]
1.2.4	Stopping	–	–	No stop functionality included.[1]
1.2.4.1	Normal stop	No	-	
1.2.4.2	Operational stop	No	-	
1.2.4.3	Emergency stop	No	-	
1.2.4.4	Assembly of machinery	No	-	
1.2.5	Selection of control or operating modes	No	-	
1.2.6	Failure of the power supply	No	-	
1.3	PROTECTION AGAINST MECHANICAL HAZARDS	–	–	–
1.3.1	Risk of loss of stability	No	-	-
1.3.2	Risk of break-up during operation	Yes	Yes	See Laser Manual
1.3.3	Risks due to falling or ejected objects	No	-	-
1.3.4	Risks due to surfaces, edges, or angles	Yes	Yes	-
1.3.5	Risks related to combined machinery	No	-	-
1.3.6	Risks related to variations in operating conditions	No	-	-
1.3.7	Risks related to moving parts	Yes	Yes	Mechanical shutter is fully enclosed within Laser
1.3.8	Choice of protection against risks arising from moving parts	–	–	–
1.3.8.1	Moving transmission parts	No	-	-
1.3.8.2	Moving parts involved in the process	No	-	-
1.3.9	Risks of uncontrolled movements	No	-	-
1.4	REQUIRED CHARACTERISTICS OF GUARDS AND PROTECTIVE DEVICES	–	–	–
1.4.1	General requirements	No	-	-
1.4.2	Special requirements for guards	–	–	–
1.4.2.1	Fixed guards	No	-	-
1.4.2.2	Interlocking movable guards	No	-	-
1.4.2.3	Adjustable guards restricting access	No	-	-
1.4.3	Special requirements for protective devices	No	-	-
1.5	RISKS DUE TO OTHER HAZARDS	–	–	–
1.5.1	Electricity supply	Yes	No	Electrical safety for complete machine must be fulfilled.
1.5.2	Static electricity	Yes	Yes	-
1.5.3	Energy supply other than electricity	No	-	-
1.5.4	Errors of fitting	Yes	Yes	See Laser Manual
1.5.5	Extreme temperatures	Yes	Yes	-
1.5.6	Fire	Yes	Yes	Flammables are fully enclosed in metal
1.5.7	Explosion	No	-	-
1.5.8	Noise	Yes	No	Noise must be considered in the complete machine.
1.5.9	Vibrations	No	-	-
1.5.10	Radiation	Yes	Yes	Laser performance characteristics meet or exceed the requirements of EMC Directive 2014/30/EU. See Laser Manual
1.5.11	External radiation	No	-	-

[1] Before commissioning the subsystem, the integrator is responsible for ensuring that the complete machine complies with the safety requirements and measures of the DIN EN ISO 60825-1:2014 standard.

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Number Annex I	Heading	applicable	complied with	Comment
1.5.12	Laser radiation	Yes	No	Laser radiation must be considered in the complete machine.
1.5.13	Emissions of hazardous materials and substances	Yes	No	Particles and fumes as process-product must be considered in the complete machine.
1.5.14	Risk of being trapped in a machine	No	-	-
1.5.15	Risk of slipping, tripping, or falling	No	-	-
1.5.16	Lightning	No	-	-
1.6	MAINTENANCE	–	–	–
1.6.1	Machinery maintenance	No	-	-
1.6.2	Access to operating positions and servicing points	No	-	-
1.6.3	Isolation of energy sources	No	-	-
1.6.4	Operator intervention	No	-	-
1.6.5	Cleaning of internal parts	No	-	-
1.7	INFORMATION	–	–	–
1.7.1	Information and warnings on the machinery	Yes	No	To be complied with in the completed machine.
1.7.1.1	Information and information devices	No	-	-
1.7.1.2	Warning devices	No	-	-
1.7.2	Warning of residual risks	No	-	-
1.7.3	Marking of machinery	Yes	Yes	Necessary marking is present as far as applicable.
1.7.4	Instructions	Yes	Yes	Instructions for installation of the incomplete machine are available in the product manual.
1.7.4.1	General principles for the drafting of instructions	Yes	Yes	
1.7.4.2	Contents of the instructions	Yes	Yes	
1.7.4.3	Sales literature	Yes	Yes	
2	SUPPLEMENTARY ESSENTIAL HEALTH AND SAFETY REQUIREMENTS FOR CERTAIN CATEGORIES OF MACHINERY	No	–	
3	SUPPLEMENTARY ESSENTIAL HEALTH AND SAFETY REQUIREMENTS TO OFFSET HAZARDS DUE TO THE MOBILITY OF MACHINERY	No	–	
4	SUPPLEMENTARY ESSENTIAL HEALTH AND SAFETY REQUIREMENTS TO OFFSET HAZARDS DUE TO LIFTING OPERATIONS	No	–	
5	SUPPLEMENTARY ESSENTIAL HEALTH AND SAFETY REQUIREMENTS FOR MACHINERY INTENDED FOR UNDERGROUND WORK	No	–	
6	SUPPLEMENTARY ESSENTIAL HEALTH AND SAFETY REQUIREMENTS FOR MACHINERY PRESENTING PARTICULAR HAZARDS DUE TO THE LIFTING OF PERSONS	No	–	

[1] Before commissioning the subsystem, the integrator is responsible for ensuring that the complete machine complies with the safety requirements and measures of the DIN EN ISO 60825-1:2014 standard.

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