# i401 Laser

User Manual


Novanta

ENGINEERED BY SYNRAD

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# Important Information

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

### Safety Symbols

**DANGER:** Indicates a hazardous situation which, if not avoided, will result in serious injury or death. Its use should be limited to the most extreme situations.

**WARNING:** Indicates a hazardous situation which, if not avoided, could result in serious injury or death.

**CAUTION:** Indicates a hazardous situation which, if not avoided, could result in minor or moderate injury.

Important: Indicates information considered important but not directly hazard related (e.g., security, hygiene, or equipment or property damage).

Safety Labels

**DANGER:** Laser radiation can cause severe retinal and corneal burns, burns on the skin, and may pose a fire risk. To avoid injury and reduce risk of fire, please follow the control measures and safety guidelines provided by the laser's manufacturer, and those established by your Laser Safety Officer (LSO), Radiation Safety Officer (RSO), or safety department of your business or institution.

**ESD Warning**

MOVIA scan heads are electrostatic discharge-sensitive devices (ESD). The equipment should remain sealed until the user is located at a proper static control station; improper handling could cause damage to these electronics.

A proper static control station should include:

A soft grounded conductive tabletop or grounded conductive mat on the tabletop.

A grounded wrist strap with the appropriate (1 MΩ) series resistor connected to the tabletop mat and ground.

An adequate earth ground connection, such as a water pipe or AC ground.

Conductive bags, trays, totes, racks, or other storage.

Properly grounded power tools.

Personnel handling ESD items should wear ESD protective garments and ground straps.

Important: Equipment returned to the factory must be shipped in anti-static packaging.

Important: Customers assume all responsibility for maintaining a laser-safe working environment. Original equipment manufacturer (OEM) customers assume all responsibility for CDRH (Center for Devices and Radiological Health) certification.

## Customer Support

Before contacting Novanta for assistance, review appropriate sections in the manual that may answer your questions.

After consulting this manual, please contact one of our worldwide offices between 9 AM and 5 PM local time.

### Americas, Asia Pacific

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## Introduction

This section outlines the following information:

- Trademark, Copywrite & Warranty information
- Guidelines and contents description
- i401 Nomenclature

**Important Note:** This Operation Manual explains operation activities related to i401 lasers. If you cannot operate the unit using the information described in this manual, contact Novanta®

(+1.425.349.3500) or an authorized Novanta Distributor.

Do not lift or support the laser by its cooling fittings.

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

Before beginning any maintenance or inspections of your i401 laser, be sure to completely disable the laser by disconnecting the DC Power cable (or cables) from the rear of the laser.

**Caution: Possible Equipment Damage**

Novanta does not recommend vertical or head down configurations.

Please contact the factory for limitations as a vertical orientation increases the risk of damage to the laser's optics.

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

If you operate your laser dirty or dusty environments, contact Novanta about the risks of doing so and precautions you can take to increase the longevity of your laser, marking head, and associated

## Trademark, Warranty & Copywrite

Novanta and I401 are registered trademarks of Novanta, Inc.

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



## Warranty Information

This is to certify that ® i401 lasers are guaranteed by Novanta, Inc. to be free of all defects in materials and workmanship for a period of one year from the date of purchase. This warranty does not apply to any defect caused by negligence, misuse (including environmental factors), accident, alteration, or

improper maintenance. 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, Inc. of any shortage or damage. If no discrepancies are reported, Novanta shall assume the shipment was delivered complete and defect-free.

If, within one year from the date of purchase, any part of the I401 laser should fail to operate, contact the Novanta Customer Service department at 1. 800.NOVANTA1 (outside the U.S. call 1.425.349.3500) and report the problem. When calling for support, please be prepared to provide the date of purchase, model number and serial number of the unit, and a brief description of the problem. When returning a unit for service, a Return Authorization (RA) number is required; this number must be clearly marked on the outside of the shipping container 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 I401 laser fails within the first 45 days after purchase, Novanta, Inc. 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. In order to maintain your product warranty and to ensure the safe and efficient operation of your i401 laser, only authorized Novanta replacement parts can be used. This warranty is void if any parts other than those provided by Novanta, Inc. are used.

Novanta, Inc. and Novanta Authorized Distributors have the sole authority to make warranty statements regarding Novanta products. Novanta, Inc. and its Authorized Distributors neither assumes nor authorizes any representative or other person to assume for us any other warranties in connection with the sale, service, or shipment of our products. Novanta, Inc. reserves the right to make changes and improvements in the design of our products at any time without incurring any obligation to make equivalent changes in products previously manufactured or shipped. Buyer agrees to hold 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

## Worldwide Headquarters

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

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Outside the U.S.: **+1.425.349.3500**

Fax: **+1.425.349.3667**

E-mail: Novanta@Novanta.com

## Sales & Application

Novanta Regional Sales Managers work with customers to identify and develop the best CO2 laser solution for a given application. Because they are familiar with you and your laser application, use them as a first point of contact when questions arise. Regional Sales Managers also serve as the liaison between you and our Applications Lab in processing material samples per your specifications. To speak to the Regional Sales Manager in your area, call Novanta at 1.800. NOVANTA1.

## Customer Service

For assistance with order or delivery status, service status, or to obtain a Return Authorization (RA) number, contact Novanta at 1. 800.NOVANTA1 and ask to speak to a Customer Service representative, or you can email us by sending a message to customercare@Novanta.com.

## 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 e-mail questions to the Technical Support Group by sending your message to Novanta tech support@ Novanta.com.

## Reference Materials

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

## EU Headquarters

For assistance in Europe, contact Novanta® European subsidiary, Novanta Europe, at:

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# Getting Started

Use information in this section to prepare your i401 laser for operation. The or-der of information presented in this section is the same as the order of tasks that you will need to perform. The best way to get your laser ready for operation is to start at unpacking and work your way through connecting.

This section contains the following information:

Introduction – introduces the i401 laser, lists important features, and describes i401 nomenclature.

Unpacking – provides important information about unpacking your i401 laser.

Inventory – displays and describes all components shipped with your i401 laser.

Mounting – describes how to attach your i401 laser to a mounting surface.

Connecting – explains how to connect cooling tubing, power, and control cabling.

# Introduction

The Introduction section includes subsections:

- I401 nomenclature
- Model numbers

The i401 laser is a new addition to Novanta i401 series of high-power lasers. This single tube 400 W 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.

## i401 features include:

- Built-in electromechanical shutter
- Built-in gas purge port
- TCP/IP web-based Internet interface
- Color-coded LEDs mirror user output status
- Field-replaceable integrated RF modules
- “Industrial-strength” ±5 V to 24 VDC I/O
- Built-in internal humidity sensor
- Beam output pre-aligned to within ±1.0 mm
- Duty cycles from 1% to 100% (CW)
- Low 6 kW heat load

### i401 nomenclature

i401 lasers are divided into two distinct functional categories: Key switch and OEM models. OEM lasers, like the i401, do not incorporate key switch 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 i401 lasers are available only as OEM lasers, they do include a built-in electromechanical shutter assembly.

### Model numbers

The last three characters in the i401 model number serve to designate the functional category, cooling method, and model version. The functional category is indicated by either a “K” for Key switch or “S” (Switch-less) for OEM models. The next letter indicates the cooling method: “W” for water-cooled units, “F” for fan-cooled units, and “A” for air-cooled lasers (the cooling method, the “W,” is omitted on all i401 lasers since they are all water-cooled lasers). The last letter in the model number indicates the current model version beginning with “B.”

## Unpacking

The Unpacking section includes subsections:

- Incoming inspection
- Packaging guidelines
- Unpacking the i401
- Removing the lifting handles

### 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, Inc.

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

## Packaging guidelines

**Warning: Serious Personal Injury**

Lifting or moving the i401 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 small components, use care when removing packaging materials.
- After unpacking, review the Inventory section and verify that all components are on hand.
- Do not lift or support the laser using the cooling fittings; lift the laser by the lifting handles or base plate only.
- Save all shipping containers and packaging materials, including covers and plugs. Use these specialized packing materials when shipping the laser to another location.
- When packing a laser for shipment, be sure to remove all accessory items not originally attached to the laser including beam delivery components, cooling tubing, etc.
- Refer to packaging instructions drawings in the Technical Reference section for details on packaging i401 lasers using Novanta supplied shipping materials.
- When storing or shipping water-cooled lasers, remember to drain all cooling water from the laser and then cap the open fittings to prevent debris from entering the coolant path.
- i401 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.

## Unpacking the i401 laser

To unpack the i401 laser, refer to Figure 1-1 and perform the following steps. The numbered items in Figure 1-1 correspond to the step numbers in the following procedure.

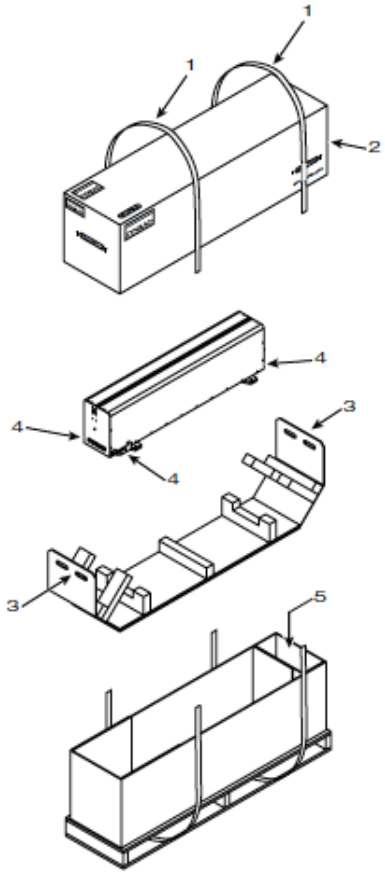



Figure 1-1 Unpacking the laser.

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 i401 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 i401 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 i401 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.

**Important Note**: Do not lift or support the i401 laser using the cooling fittings. Lift the laser by the lifting handles or base plate only

## Removing the lifting handles

Once you have placed the i401 laser in its final mounting location, perform the following steps to remove the lifting attachments.

1 Remove the 1/4–20 × 5/8" cap screws from two locations on each of the three handles as shown in the figure below.

2 Save the lifting handles and cap screws so the handles can be reinstalled if the i401 is moved to another location.

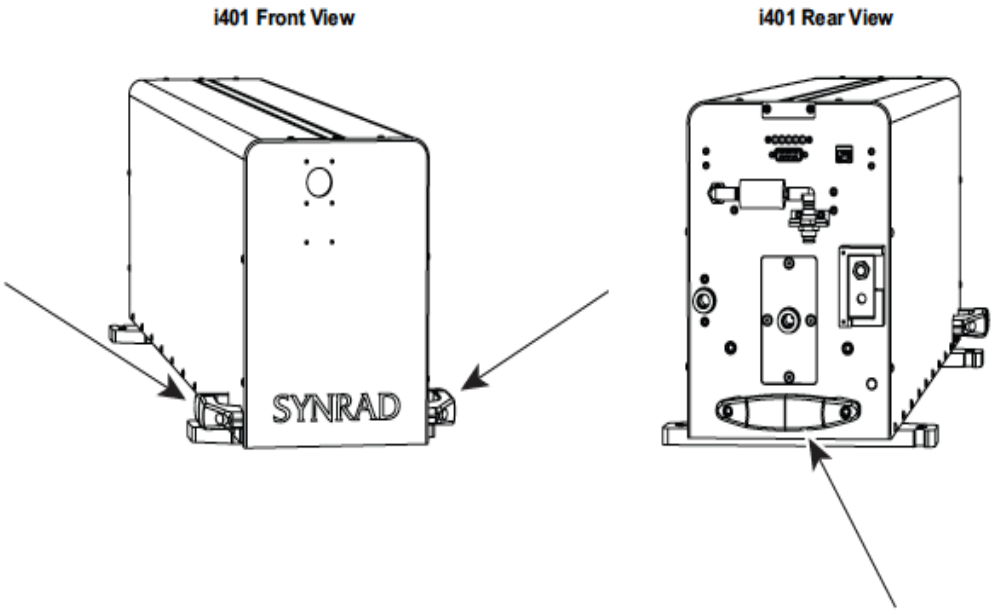



Figure 1-2 Removing the i401 lifting handles.

# Inventory

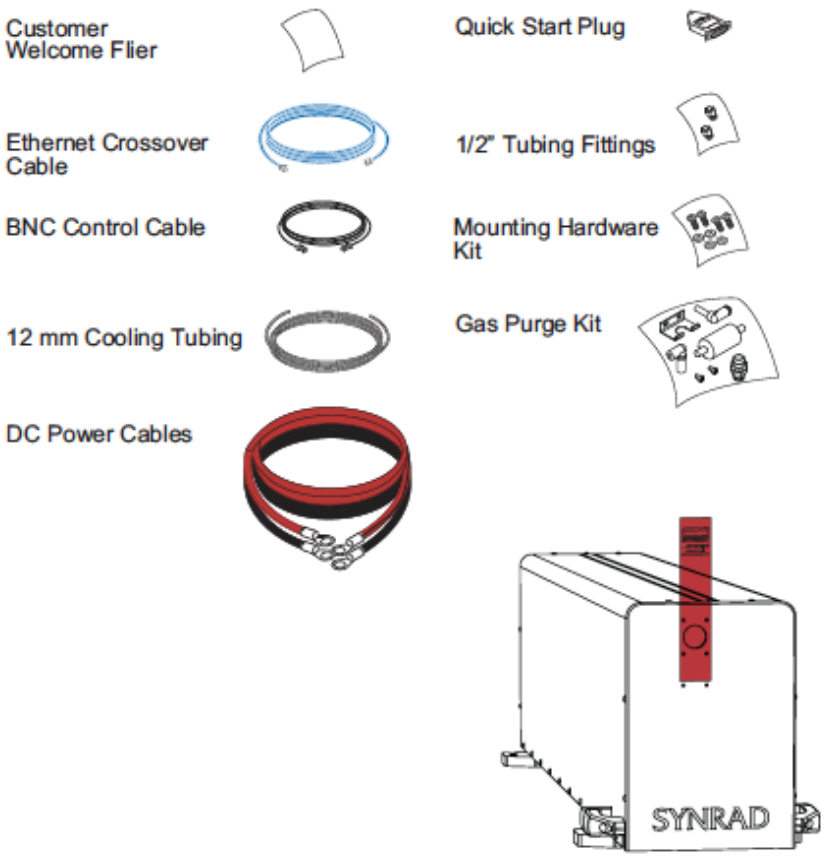



Figure 1-3 i401 shipping box contents.

Table 1-1 i401 ship kit contents.

| Shipping Box Contents | Qty | Shipping Box Contents | Qty |
|---|---|---|---|
| i401 400 W Laser | 1 | Quick Start Plug | 1 |
| Customer Communication Flier | 1 | 1/2" Tubing Fitting Kit | 1 |
| Ethernet Crossover Cable | 1 | Mounting Hardware Kit | 4 |
| BNC Control Cable | 1 | Gas Purge Kit | 1 |
| 12 mm Cooling Tubing | 1 | Spare Fuses (not shown) | 4 |
| DC Power Cables | 1 | Final Test Report (not shown) | 1 |

## i401 contents description

Each item below is also listed in tables that follow:

i401 400 W Laser – i401 laser is a compact, single tube 400 W laser producing near-perfect beam quality with < 100 µs rise/fall times and a PWM duty cycle range from 1% up to 100% (full CW operation).

Customer Communication Flier – contains a i401 website location information that provides setup, operation, and maintenance information for your i401 laser.

Ethernet Crossover Cable – provides the communications link between a host and the laser for accessing operating parameters via a TCP/IP web-based interface.

BNC Control Cable – Coaxial cable carries the PWM Command signal from the UC-2000 Controller to the laser's Quick Start Plug.

12 mm Cooling Tubing – 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.

DC Power Cables – carry DC power from the 48 V power supply to your i401 laser. Standard cable length is 2.0 meters (6.5 feet) while optional 5.0 m (16 ft) power cables are available.

Quick Start Plug – connects to 401's User I/O connector. Jumpers are built into the plug to enable Fire-star's interlock circuits for initial start-up and testing.

1/2" Tubing Fitting Kit – provides a means to replace the i401's 12 mm fittings with fittings that accept 1/2" coolant tubing. See the Connecting section for installation details.

Mounting Hardware Kit – fasten i401 to your mounting surface. Four each M10 × 1.5 × 35 mm cap screws and M10 washers are provided for mounting the i401 laser.

Gas Purge Kit – provides a filtering and connection point to the laser from your facility's purge gas system.

Spare Fuses (not shown) – 40 ampere fast-blow fuses protect i401's internal RF circuitry.

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

# Mounting

The Mounting section includes subsections:

- Four-point mount with feet
- Four-point mount without feet
- Three-point mount without feet

The i401 base plate is designed so that the laser is easily mounted in various configurations as described in the subsections below. Refer to the i401 package outline drawing in the Technical Reference section for mounting locations and dimensions.

**Caution: Possible Equipment Damage**

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

## 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").

To install a i401 (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) cap screws and M10 flat/split washers are included in the ship kit.
2. Refer to the i401 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 following figure.
3. Carefully place the i401 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 cap screw 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 N m (29 ft lb.).

**Important Note:** Each mounting foot also contains a 9.65 mm (0.380") dowel pin guide (labeled "B" in the following) for applications that require precision positioning for alignment purposes.

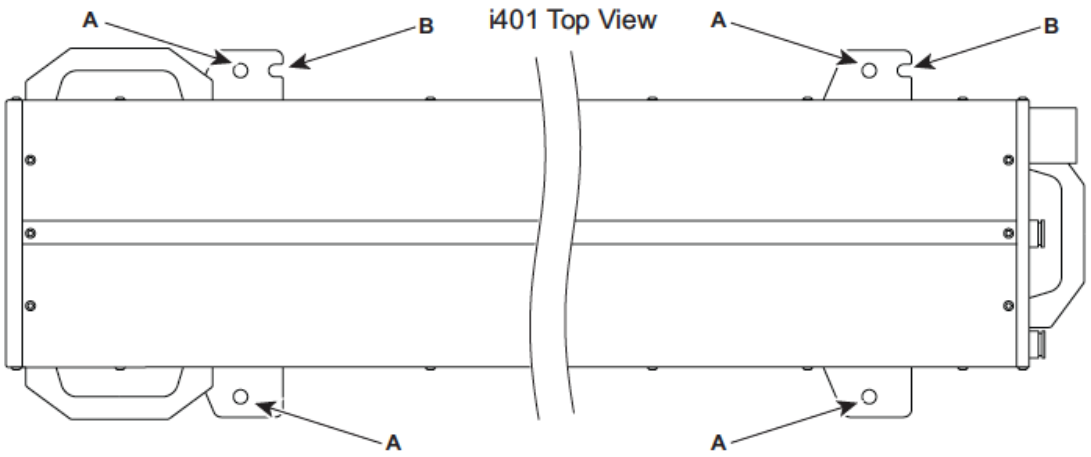



Figure 1-4 Mounting locations for four-point mount with feet.

**Important Note:** After the laser is fastened into position, remove the lifting handles if necessary

## 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 i401 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.

To install a i401 (without feet) using the four-point mounting method, perform the following steps:

1. Raise the i401 laser and place support blocks under the base plate.
2. Unscrew the four M10 cap screws fastening the feet to the bottom of the i401 laser and remove the factory-installed mounting feet.
3. Refer to the i401 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) thru holes in your mounting

surface. These holes should correspond with the fastener locations labeled “C” shown in the figure below.

4 Carefully place the i401 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 cap screw 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 four fasteners to a torque of 40 N m (29 ft lb.).

**Important Note:** The i401 base plate contains two 6.40 mm × 12.70 mm (0.252″ × 0.500″) dowel pin slots and a 6.40 mm (0.252″) dowel pin hole for applications that require precision positioning of the laser.

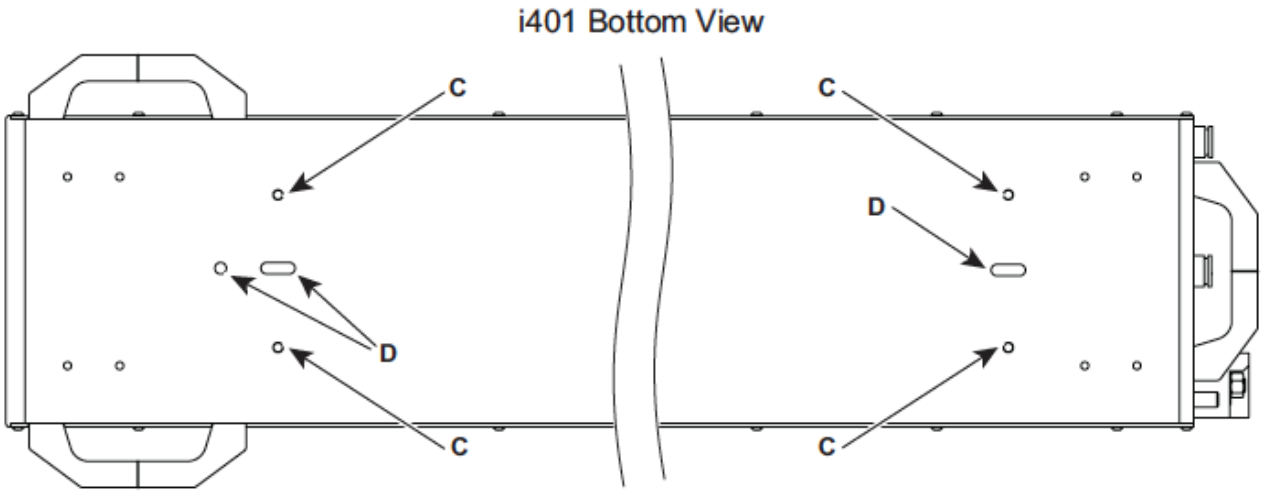



Figure 1-5 Mounting locations for four-point mount without feet.

**Important Note:** Verify the correct fastener length for your mounting application. The M10 × 1.5 × 35 mm cap screws the ship kit are for use with the factory-installed mounting feet. When fastening the i401 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.

## 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 i401 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.

To install an i401 (without feet) using the three-point mounting method, perform the following steps:

1. Raise the i401 laser and place support blocks under the base plate.
2. Unscrew the four M10 cap screws fastening the feet to the bottom of the i401 laser and remove the factory-installed mounting feet.
3. Refer to the i401 outline and mounting drawing (Sheet 2 of 2) for Option 'B' mounting dimensions, then drill three 10.6 mm (close fit) or 11.2 mm (normal fit) thru holes in your mounting surface. These holes should correspond with the fastener locations labeled "E" shown in Figure 1-6.
4. Carefully place the i401 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 cap screw 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 torque of 40 N m (29 ft lb.).

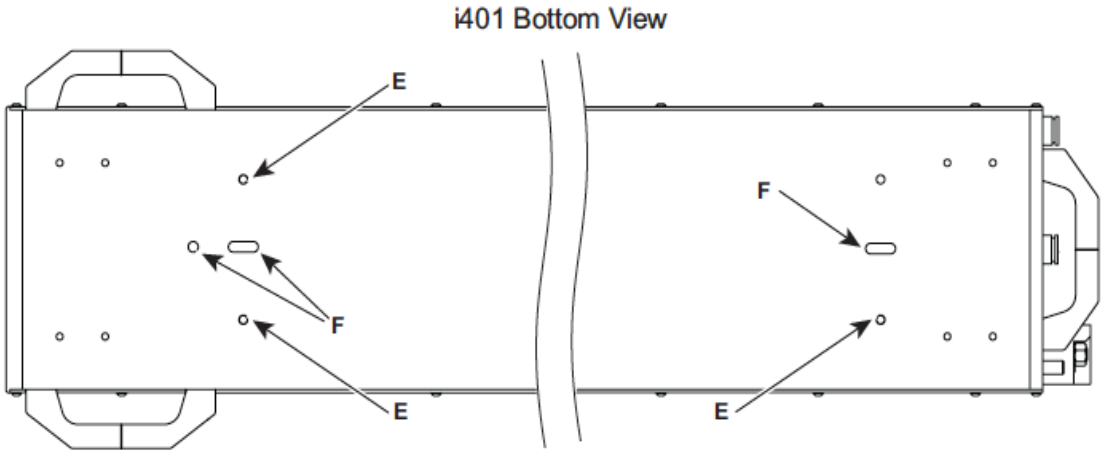



Figure 1-6 Mounting locations for three-point mount without feet.

# Connecting

The Connecting section includes subsections:

- Cooling connections
- 48 V power supply connections
- Control connections
- Other connections

## Cooling connections

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

## Guidelines for cutting and installing tubing

- Cut tubing lengths generously to allow for trimming.
- Cut tubing squarely; diagonal cuts may not seal properly. Trim away burrs if the cut is “ragged.”
- Avoid excessive stress on fittings; create gentle bends when routing tubing close to connectors.
- 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 tubing from a fitting, trim 12.7 mm (0.50″) from its end before reconnecting. Trimming the end of the tubing provides an undisturbed sealing surface inside the fitting.

## Adapting cooling fittings for 1/2" tubing

i401 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. These adaptors are available from suppliers including McMaster-Carr (P/N 51495K416).

The second option is to remove the 12 mm Tri Thread fittings from the laser’s cooling manifold and install 1/2″ Tri Thread fittings—which are included in the i401 ship kit. The Tri Thread fittings used on i401 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 1/4 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 i401 cooling manifold as this may damage the manifold threads and/or cause coolant leakage.

## Chiller preparation guidelines

- You must provide fittings to adapt the laser's 12 mm O.D. polyethylene cooling tubing to the chiller's Inlet and Outlet ports. These fittings can be either "quick disconnect" or compression type fittings.
- Because the i401's factory-installed fittings and tubing are metric (12 mm), do not use 1/2inch 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.

## Coolants

Novanta recommends the laser's cooling fluid contain at least 90% distilled water by volume. In closed-loop systems, use a corrosion inhibitor/algaecide such as Opti shield® Plus or equivalent as required. Avoid glycol-based additives because they reduce the coolant's heat capacity and high concentrations may affect power stability. For Novanta lasers, the minimum coolant setpoint is 18 °C (64 °F) so glycol is not necessary unless the chiller is subjected to freezing temperatures. If tap water is used, chloride levels should not exceed a concentration of 25 parts per million (PPM) and total hardness should be below 100 PPM. Install a filter on the chiller's return line and inspect frequently. i401 lasers incorporate the following wetted materials in the coolant path—brass, copper, Delrin®, PBT, polyethylene, stainless steel, and Viton®.

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

## Setting coolant temperature

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

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

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

- 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.
- Increase coolant flow by an additional 3.8 lpm (1.0 GPM). Do not exceed a coolant pressure of 414 kPa (60 PSI).
- Refer to Table 1-2 and gradually increase coolant temperature until it is above the dew point temperature and condensation disappears. Do not exceed a coolant temperature of 28 °C (82 °F).

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

Table 1-2 Dew point temperature

**Dew Point Temperature Chart °F (°C)**

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

To use Table 1-2, look down the Air Temp column and locate an air temperature in Fahrenheit or Celsius (°C values are shown in parentheses) that corresponds to the air temperature in the area where your laser is operating. Follow this row across until you reach a column matching the relative humidity in your location. The value at the intersection of the Air Temp and Relative Humidity columns is the Dew Point temperature in °F (or °C). The chiller's temperature setpoint must be set above the dew point temperature. For example, if the air temperature is 85 °F (29 °C) and the relative humidity is 60%, then the dew

point temperature is 70 °F (21 °C). Adjust the chiller's temperature setpoint to 72 °F (22 °C) to prevent condensation from forming inside the laser.

**Caution: Possible Equipment Damage**

Inlet cooling water temperature must always be maintained above the dew point to prevent condensation and water damage to your i401 laser

## Cooling tubing connections

To connect cooling tubing to your i401 laser, refer to Figure 1-7 and perform the following steps. The numbered items in Figure 1-7 correspond to the step numbers in the following procedure.

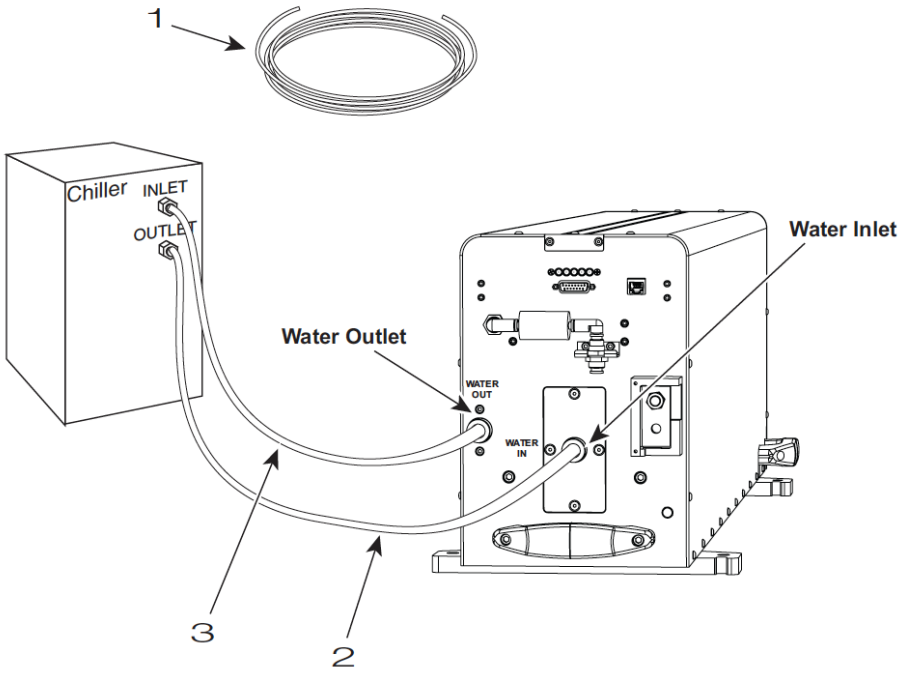



Figure 1-7 i401 cooling connections

1 Locate the 12 mm clear polyethylene cooling tubing in the i401 ship kit.

2 Cut and connect a length of cooling tubing to fit between the chiller's Outlet port and the WATER IN port on the rear of the i401 laser.

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

4 Turn on the chiller and adjust the temperature setpoint to 18 °C to 22 °C. Regulate coolant flow to 15.1 lpm (4.0 GPM) at less than 414 kPa (60 PSI) of pressure.

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

Important Note: The i401 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.

## 48 V power supply connections

Important 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.

i401 lasers require a DC power source capable of supplying a minimum of 135 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. 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.

## PS-401 DC power supply

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.

## Input voltage selection

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 voltage to the supply is physically locked out or disconnected.
2. Refer to Figure 1-8 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 1-8.
6. Securely tighten the thumbscrews fastening the selection assembly to the PS-401 chassis.

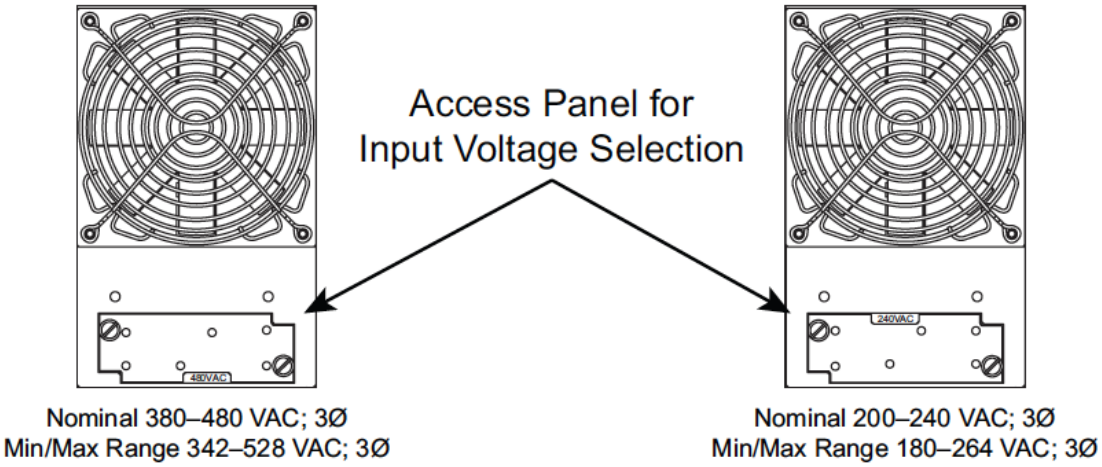



Figure 1-8 PS-401 voltage selection access panel

## AC three-phase connections

**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.

Table 1-3 provides recommendations for three-phase input wiring and fusing.

Table 1-3 AC three-phase electrical recommendations

| Parameter | Recommendation |
|---|---|
| Input voltage range (3Ø) | 342 V–528 VAC; 380 V–480 V nominal<br>180 V–264 VAC; 200 V–240 V nominal |
| Input current, max. | 25 Amperes per phase |
| Wire gauge | 10 AWG |
| Fuse/circuit breaker | 30 Amps |

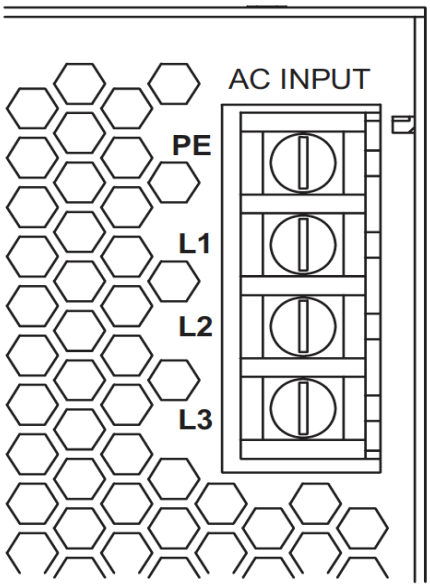



Figure 1-9 PS-401 input section

Important 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.

To connect three-phase AC input power, refer to Figure 1-9 and perform the following steps:

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.

## DC power/DC voltage sense cables

To connect DC power and the DC voltage sense cables between your i401 laser and PS-401 DC power supply, refer to Figure 1-10 and Figure 1-11 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.

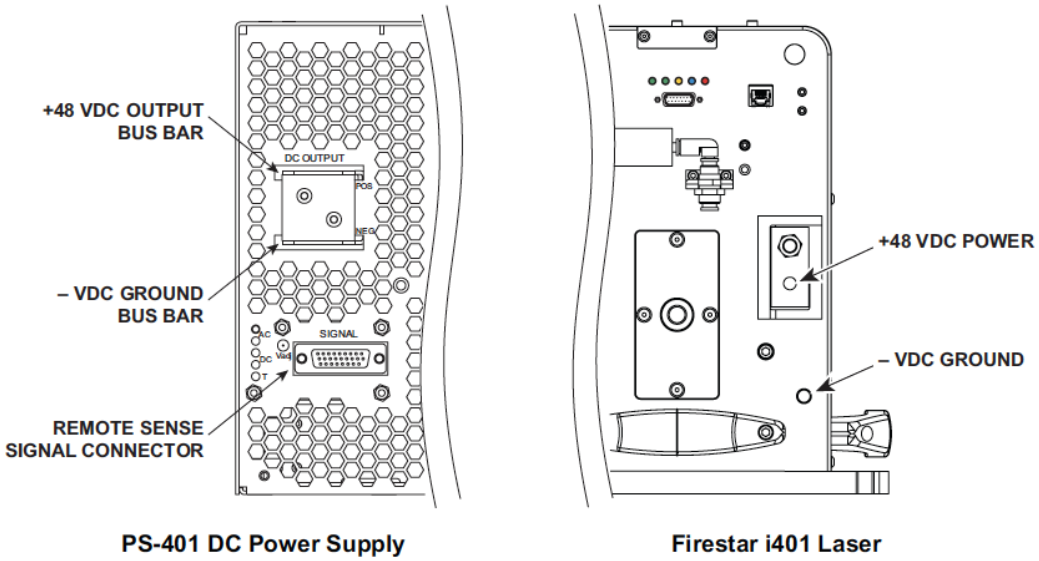



Figure 1-10 DC power connection locations – rear view

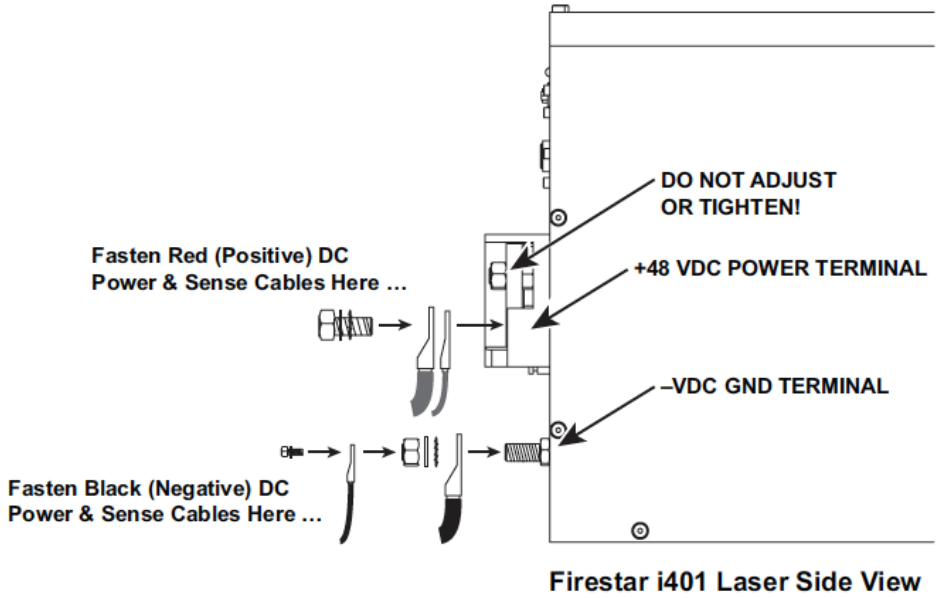



Figure 1-11 DC power connection locations – side view

## Laser connections

Important Note: 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 1 Locate DC Power Cables and DC Voltage Sense Cable in the i401 and PS-401 ship kits.

2 Remove the two 6–32 cap screws 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 1-11).

6 Tighten the M10 hex nut to a torque of 20 N m (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 cap screw and flat washer. Carefully tighten the M4 screw to a torque value of 1.8 N m (16 in 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 1-11. Carefully tighten the M10 bolt to a torque of 7.4 N m (65 in lb.) maximum.

9 Replace the acrylic cover on the +48V POWER terminal block and fasten it in place using two 6–32 cap screws.

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

## DC power supply connections

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

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 1/4 inch) fasteners (Figure 1-10).

3 Attach the red (positive) DC power cable to the +48 VDC Output Bus Bar on the PS- 401 power supply using M6 (or 1/4 inch) 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.

**Important 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.

## Control connections

All control connections to i401 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 serves as the connection point for auxiliary signals between the laser and any parts handling, automation, or monitoring equipment.

### Warning: Serious Personal Injury

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

Because this plug jumpers Remote Interlock and Shutter Open Request signals, the laser will fire immediately on application of a PWM Command signal. Your integrated control system should

provide interlock and shutter signals directly to the DB-15 User I/O connector only after safe operating conditions are established.

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

### Caution: Possible Equipment Damage

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

## Quick Start Plug

For your i401 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 I401 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 i401 laser.

For further information about User I/O connector, see User I/O connections in the Technical Reference section for User I/O pinouts and signal descriptions. See Integrating I401 safety features, also in the Technical Reference section, for detailed instructions on integrating I401's key switch, shutter, and remote interlock functions with automated control systems.

## 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 uncommented lasing.

Novanta recommends the use of a UC-2000 Universal Laser Controller to generate pulse width modulated (PWM) Command signals that control the laser's output power. To connect a UC-2000 Controller (available separately), perform the steps described below:

**Note:** i401 lasers can also be controlled from an alternate user-supplied Command signal source. Refer to Controlling laser power in the Technical Reference section for control signal descriptions and refer to User I/O connections, also in the Technical Reference section, for signal specifications and connection details.

1. Disconnect DC power from the laser.
2. Locate the Quick Start Plug in the ship kit.
3. Connect the Quick Start Plug to the User I/O connector on the rear of the i401 laser.
4. Attach the BNC connector on the end of the UC-2000's Power/Control cable to the BNC connector on the rear of the Quick Start Plug.
5. Connect the miniature DC power plug on the UC-2000's Power/Control cable to the miniature connector on the cable from the UC-2000's wall plug transformer.
6. Connect the mini-DIN connector on the other end of the UC-2000's Power/Control cable to the Laser connector on the UC-2000's rear panel.
7. Plug the UC-2000's compact transformer into any 100–240 VAC, 50–60 Hz outlet.

## Other connections

### 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.

To connect the i401 gas purge port, refer to Figure 1-12 and perform the following steps:

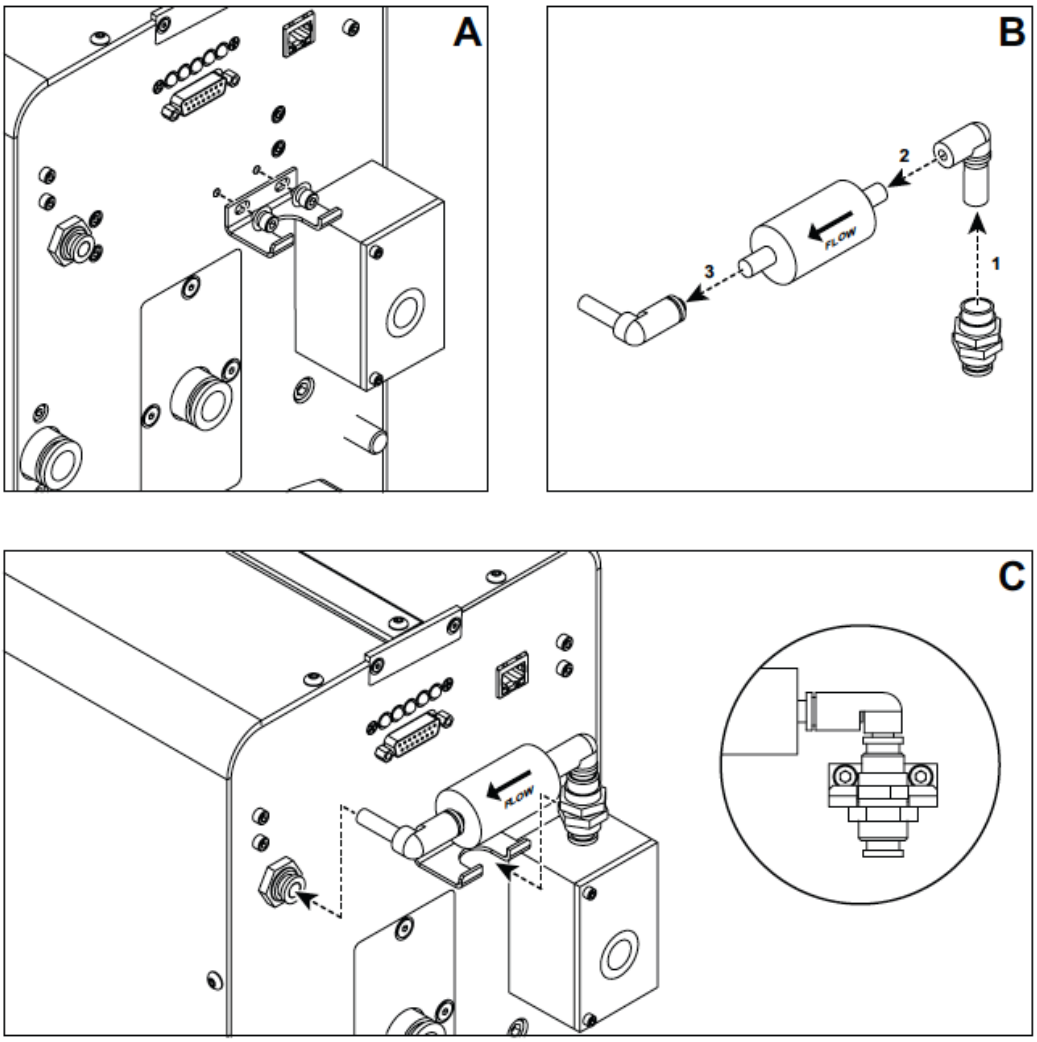



Figure 1-12 Gas purge kit assembly

## Connecting

1 Locate the Gas Purge Kit in the i401 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 1-12A and fasten the filter support bracket to the rear of the i401 laser using the 6–32 Allen cap screws and # 6 flat washers provided in the kit.

3 Assemble the two 90° fittings, straight fitting, and filter as shown in Figure 1-12B. 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 1-12C and plug the filter assembly into the Gas Purge port connector.

6 Adjust the jam nuts on the 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-inch plastic tubing.

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 $m^3$/hr. (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 i401's 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.

**Important 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 com- ponents.

Do not use argon as a purge gas. Use only nitrogen or clean, dry air as described in Table 1-4, Purge gas specifications.

The Gas Purge port on the i401 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 1-4 below.

Table 1-4 Purge gas specifications

| Purge Gas | Specification | |
|---|---|---|
| Nitrogen | High Purity Grade | ≥ 99.9500% purity; filtered to ISO Class 1 particulate level |
| 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 1.0–5.0 µm particles/$m^3$; ≤ –40 °F dew point; ≤ 0.01 mg/$m^3$ oil vapor) |

## Ethernet port

A connection to the i401 Ethernet port is not required for normal operation; however, we strongly recommend that you setup the i401 web page and verify its functionality as part of the initial start-up procedure. This will ensure an i401 web connection is available for troubleshooting purposes if necessary, during preliminary testing of the i401 laser.

## Set-up the i401 web page

i401 lasers are pre-configured with a fixed IP address that allows a simple Ethernet connection between the i401 laser and a host. To connect your host computer to the i401 laser using a peer-to-peer Ethernet connection, perform the steps in the following sections:

Important Note: Connection to a local network is permitted if 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 i401 laser and your Ethernet router or hub.

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 i401 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 computer's 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 From the Start menu, go to Settings, and choose Network Connections.

3 Double-click on the appropriate Local Area Network (LAN).

4 Locate the LAN's Internet Protocol (TCP/IP) properties.

5 Select "Use the following IP address:" and enter the following information:

| | |
|---|---|
| IP Address: | 192.168.50.100 |
| Subnet Mask: | 255.255.255.0 |

6 Click OK to submit the changes.

## Connect to the i401 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 i401's Ethernet port.

4 Follow the initial start-up procedure in the operation section 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 i401 home page should appear as shown in Figure 1-13.

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.

**Important Note:** The i401 web page is not compatible with the Google Chrome browser.

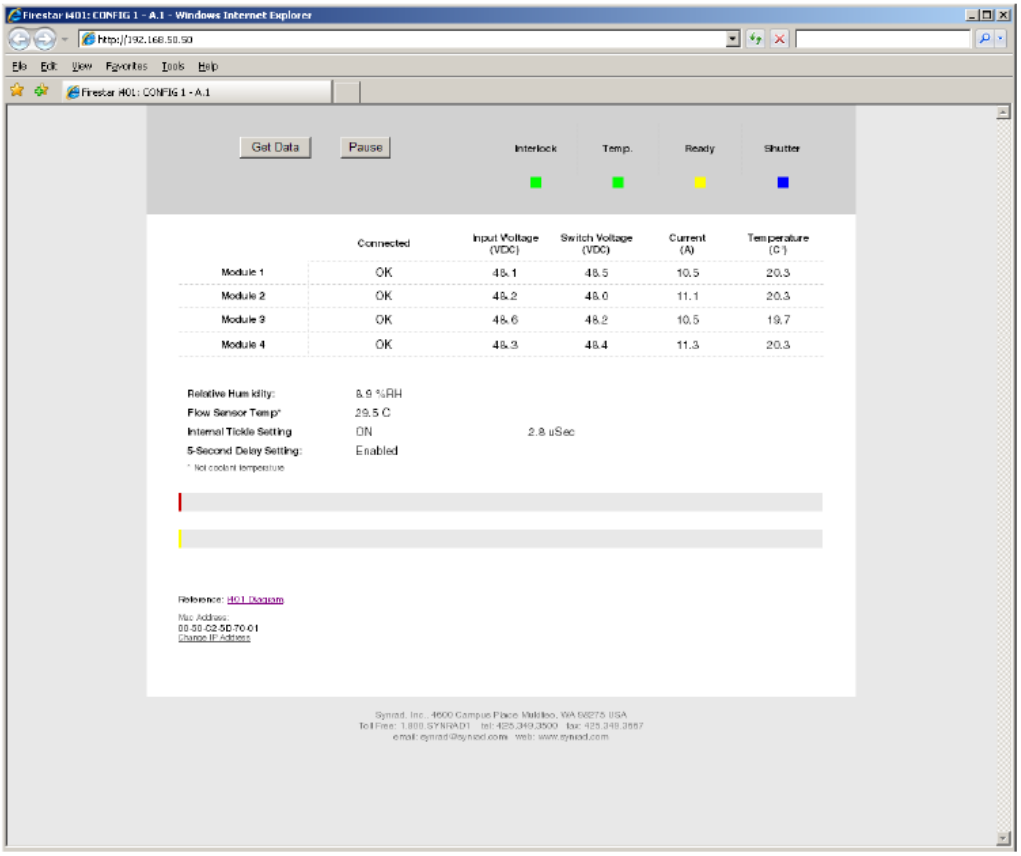



Figure 1-13 I401 home page

To use the i401's web page capability to monitor various operating or service parameters, see the I401 i401 web interface section in the Technical Reference section for additional information. If you have problems connecting to the i401 web page, refer to the Troubleshooting – Web interface section in the Maintenance/Troubleshooting section.

## Laser Safety

This section contains safety information that you will need to know prior to getting started.

- Hazard Information – includes equipment label terms and hazards, please familiarize yourself with all definitions and their significance.
- General & Other Hazards – provides important information about the hazards and unsafe practices that could result in death, severe injury, or product damage.
- Disposal – information on your i401 laser parts and/or components as they pertain to disposal.

- Additional Safety Information – describes how to find additional information about your i401 laser.
- Compliance – explains in the subsections therein applicable and appropriate regulation information.

Important Note: Read the entire safety section. This will ensure you are familiar with the hazards and warnings prior to starting.

**Warning: Serious Personal Injury**

Class 4 CO2 laser product emits invisible infrared laser radiation in the 9.3–10.6 µm wavelength band.

Because direct or diffuse laser radiation can inflict severe corneal injuries, always wear eye protection when in the same area as an exposed laser beam.

Do not allow the laser beam to contact a person!

This product emits an invisible laser beam that is capable of seriously burning human tissue.

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

**Warning: Serious Personal Injury**

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

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

## Hazard Information

Hazard information includes terms, symbols, and instructions used in this manual or on the equipment to alert both operating and service personnel to the recommended precautions in the care, use, and handling of Class 4 laser equipment.

## Terms

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

- Warning: Potential & Imminent hazards which, if not avoided, will result in death or serious injury.
- Danger: Hazards which, if not avoided, could result in minor or moderate injury.
- Caution: Potential hazards or unsafe practices which, if not avoided, may result in product damage.
- Important Note: Content specific information and or recommendations.

## 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.

i401 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 Z136.1-2014, Safe Use of Lasers always when actively lasing.

Due to the specific properties of laser light, a unique set of safety hazards that differ from other light sources must be considered. Just like light, lasers can be reflected, refracted, diffracted, or scattered.


Warning: Serious Personal Injury

Never use organic material or metals as a beam blocker. There are very few exceptions, e.g., black anodized metal such as aluminum because this is non reflective surface.


Warning: Serious Personal Injury

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

A CO2 laser is an intense energy source and will ignite most materials under the proper conditions. Never operate the laser in the presence of flammable or explosive materials, gases, liquids, or vapors.

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.

### Warning: Serious Personal Injury

Do not allow laser radiation to enter the eye by viewing direct or reflected laser energy.

CO2 laser radiation can be reflected from metallic objects even though the surface is darkened. Direct or diffuse laser radiation can inflict severe corneal injuries leading to permanent eye damage or blindness. All personnel must wear eye protection suitable for 9.3–10.6 µm CO2 radiation when in the same area as an exposed laser beam.

Eye wear protects against scattered energy but is not intended to protect against direct viewing of the beam—never look directly into the laser output aperture or view scattered laser reflections from metallic surfaces.

Enclose the beam path whenever possible. Exposure to direct or diffuse CO2 laser radiation can seriously burn human or animal tissue, which may cause permanent damage.

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

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

Review the following references for further information on exposure criteria:

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

U.S. Government's Code of Federal Regulations: 29 CFR 1910, Subpart Z.

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

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

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, possibly damaging acrylic safety shielding. Do not use air dusters containing difluoroethane in any

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

## Other Hazards

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

## Disposal

This product contains components that are considered hazardous industrial waste. If a situation occurs where the laser is rendered non-functional and cannot be repaired, it may be returned to Novanta® who, for a fee, will ensure adequate disassembly, recycling and/or disposal of the product.

## Thorium Safety

- This laser system incorporates a II-VI Infrared optical component.
- This optical component contains a small amount of thorium fluoride, a type of source material (less than 10% by weight).
- It is exempt from USNRC licensing regulations as an "unimportant quantity of source material" per 10 CFR 40.13(c) (7).
- Shaping, grinding, polishing, or alteration of the optical component is prohibited.
- Use of this optical component in contact lenses, spectacles, or in eyepieces in binoculars or other similar optical instruments is prohibited.

Cleaning optical components is permitted so long as care is taken not to damage the coated surface of the component as sold. This II-VI Infrared requirement only applies to lenses and optics manufactured and distributed by II-VI Infrared. Distributing components or devices that contain lenses and optics manufactured by other companies as if it were manufactured by II-VI Infrared is not in compliance with USNRC distribution requirements.

U.S. distribution of components or devices that contain lenses and optics manufactured by other companies which contain uranium and/or thorium requires a USNRC distribution license. Only II-VI Infrared manufactured lenses and optics which contain thorium are covered by the II-VI Infrared distribution license.

### 10 CFR 40.13(c) (7) Unimportant quantities of source material.

(7) Thorium or uranium contained in or on finished optical lenses and mirrors, provided that each lens or mirror does not contain more than 10 percent by weight thorium or uranium or, for lenses manufactured before August 27, 2013, 30 percent by weight of thorium; and that the exemption contained in this paragraph does not authorize either:

(i) The shaping, grinding, or polishing of such lens or mirror or manufacturing processes other than the assembly of such lens or mirror into optical systems and devices without any alteration of the lens or mirror; or

(ii) The receipt, possession, use, or transfer of uranium or thorium contained in contact lenses, or in spectacles, or in eyepieces in binoculars or other optical instruments.

## Additional Laser Safety Information

The Novanta web site (http://www.Novanta.com/LaserFacts/safetyinfo.html) contains an online laser safety handbook that provides information on (1) Laser Safety Standards for OEM's/System Integrators, (2) Laser Safety Standards for End Users, (3) References and Sources, and (4) Assistance with Requirements.

In addition, the Occupational Safety and Health Administration (OSHA) provides an online Technical Manual (located at http://www.osha.gov/dts/osta/otm/otm_iii/otm_iii_6.html). Section III, Section 6 and Appendix III are good resources for laser safety information.

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

# i401 label locations

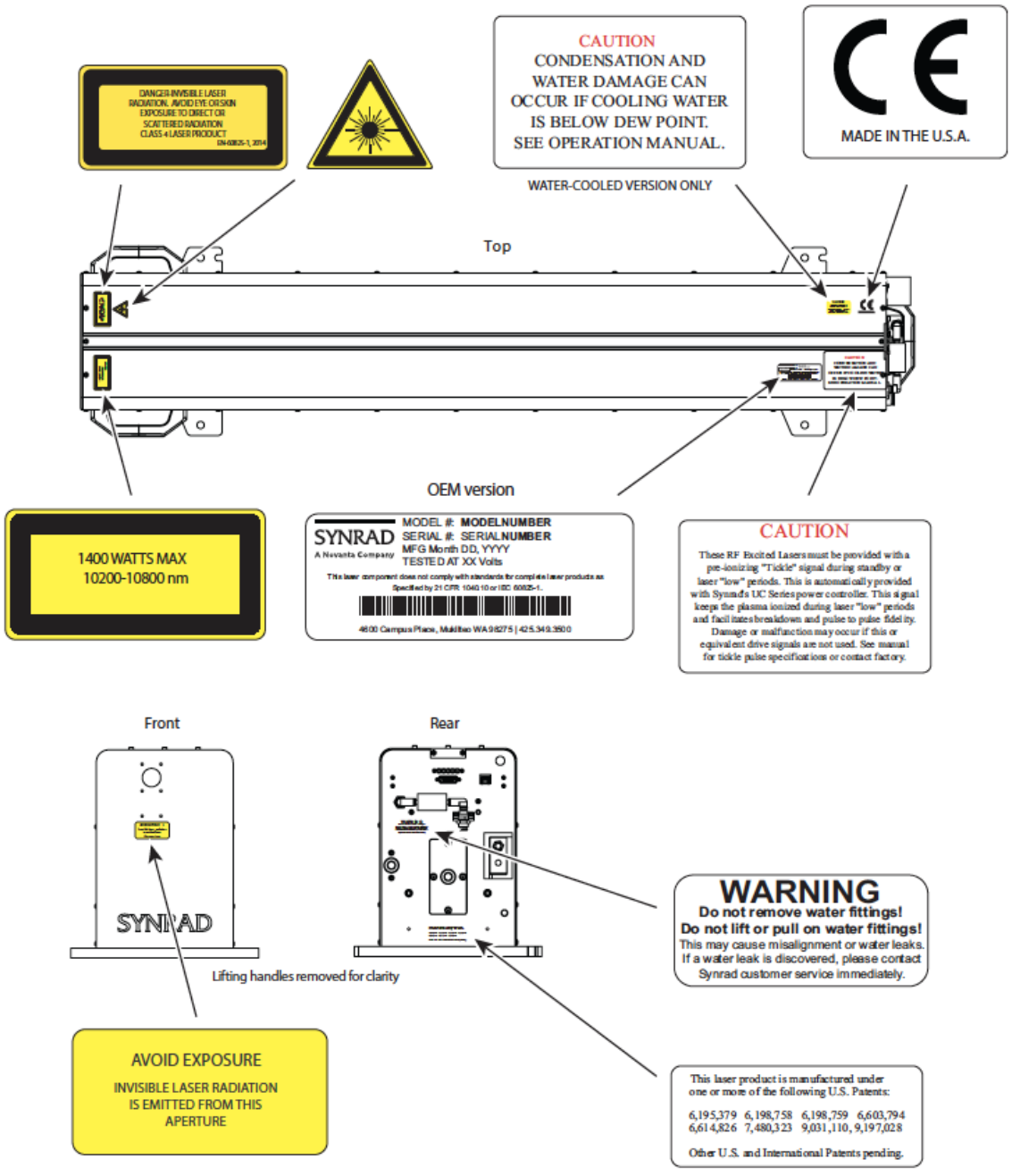



Figure 2-1 Hazard label locations.

# Agency Compliance

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

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 i401 lasers must comply are identified and described in the following paragraphs.

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

In the matter of CE-compliant laser products, 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.

# Center for Devices and Radiological Health (CDRH) requirements

Product features incorporated into the design of our lasers to comply with CDRH requirements are integrated as panel controls or indicators, internal circuit elements, or input/output signal interfaces. Specifically, these features include a 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 (Key switch or OEM). Table 1, Class 4 safety features, indicates which features are available on our lasers, the type and description of the feature, and if the feature is required by CDRH regulations.

## OEM Models

i401 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 21 CFR, Subsection J without additional safeguards. In the U.S., the Buyer of these OEM laser components is solely responsible for the assurance that the laser processing system sold to an end user complies with all laser safety requirements before the actual sale of the system. Under CDRH regulations, the Buyer must submit a report to the CDRH prior to shipping the system. In jurisdictions outside the U.S., it is the sole responsibility of the Buyer of these OEM components to ensure that they meet all applicable local laser safety requirements. In cases where the Buyer is also the end-user of the OEM laser product, the Buyer end-user must integrate the laser so that it complies with all applicable laser safety standards as set forth above.

# Federal Communications Commission (FCC) Requirements

The United States Communication Act of 1934 vested the Federal Communications Commission (FCC) with the authority to regulate equipment that emits electromagnetic radiation in the radio frequency spectrum. The purpose of the Communication Act 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, §18, §§C.

Novanta lasers have been tested and found to comply by demonstrating performance characteristics that have met or exceeded the requirements of 47 CFR, §18, §§C for Radiated and Conducted Emissions.

## FCC Information to the user

The following FCC information to the user is provided to comply with the requirements of 47 CFR, §18, §§ 213 Information to the user.

## Interference Potential

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

## System Maintenance

Ensure that all exterior covers are properly fastened in position.

## Measures to Correct Interference

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

1. Use shielded cables to and from the equipment that is experiencing interference problems.
2. Ensure that the laser is properly grounded to the same electrical potential as the equipment or system it is connected to.

## FCC caution to the user

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

# European Union (EU) requirements

## RoHS compliance

Novanta 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.

## Laser safety standards

Under the Low Voltage Directive, 2014/35/EU, the International Standard specifies the minimum documentation, marking and labeling for all laser products classified in accordance with IEC 60825-1:2014 (hereafter referred to as EN 60825-1) including laser diodes and all laser devices defined in ISO 11145 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 the EN 60825-14:2004 Standard for the safety of laser products 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

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 60825-1:2004, EN 60204-1:2016, Safety of Machinery; the Machinery Directive, 2006/42/EC; and/or any other applicable Standards and in cases where the system is being imported into the U.S., it must also comply with CDRH regulations.

In cases where the Buyer is also the end-user of the OEM laser product, the Buyer/end-user must integrate the laser so that it complies with all applicable laser safety standards as set forth above. Table 1, Class 4 safety features, summarizes product features, indicating the type and description of features and whether those features are required by European Union regulations.

## Electromagnetic interference standards

Novanta lasers have demonstrated performance characteristics that have met or exceeded the requirements of EMC Directive 2014/30/EU. 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 lasers, EN 61000-6-4:2018 defines radiated and conducted RF emission limits while EN 61000-6-2:2016 defines immunity standards for industrial environments.

# Laser Safety

Table 2-1 Class 4 safety features.

| Feature | Location/Description | Required by: CDRH | Required by: EN60825-1 | Available on OEM i401 |
|---|---|---|---|---|
| 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 | **Rear Panel Indicator (Blue)** Illuminates blue to indicate shutter is open. | No | No | Yes |
| Ready Indicator | **Rear Panel Indicator (Yellow)** Indicates that laser has power applied and is capable of lasing. | Yes | Yes | Yes |
| Laser Indicator | **Rear panel indicator (Red)** Indicates that the laser is actively lasing. Lase LED illuminates when the duty cycle of the Command signal is long enough to produce laser output. | No | No | Yes |
| Five second delay | **Circuit Element** Disables RF driver/laser output for five seconds after Key switch is turned to "On" or remote reset/start pulse is applied when Key switch 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 Key switch is in "On" position | Yes | Yes | No |
| Remote Interlock | **Side 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 | **Rear panel indicator (Green/Red)** Illuminates green when Remote Interlock circuitry is closed. Illuminates red when interlock circuitry is open. | No | No | Yes |
| Over Temperature Protection | **Circuit Element** Temperature shutdown occurs if temperature of the laser tube rises above safe operating limits | No | No | Yes |
| Temp Indicator | **Rear panel indicator (Green/Red).** Illuminates green when laser temperature is within operating limits, changing to red when thermal limits are exceeded. | No | No | Yes |
| Warning Labels | **Laser Exterior** Warnings to personnel of potential laser hazards. | Yes | Yes | Yes |

[1] *Not available on OEM lasers*

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

Table 2-2 European Union Directives.

| Applicable Standards/ Norms | |
|---|---|
| 2014/30/EU | Electromagnetic Compatibility Directive |
| 2014/35/EU | Low Voltage Directive |
| 2015/863/EU | RoHS Directive |
| EN 61010-1:2010 | 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 Electromagnetic Field Immunity |
| EN 61000-6-2:2005 | Electrical Fast Transient/Burst Immunity |
| EN 61000-6-2:2005 | Conducted RF Disturbances Immunity |

After a laser or laser processing system has met the requirements of all applicable EU Directives, the product can bear the official compliance mark of the European Union as a Declaration of Conformity.

# 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:**

Tim Freni, Quality Manager of SYNRAD

Dated: 7/22/19

**European Contact:**

Novanta Distribution (USD) GmbH
Parkring 57-59
85748 Garching bei München, Germany

CE

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

Figure 2-2 i401 Declaration of conformity

# Operation

Use information in this section to familiarize yourself with i401 controls and indicators and to begin operating the laser.

This section contains the following information:

- Controls and indicators – display and describes exterior controls and indicators on i401 lasers.
- Initial start-up – explains how to start your i401 laser while verifying proper operation.

## Controls and indicators

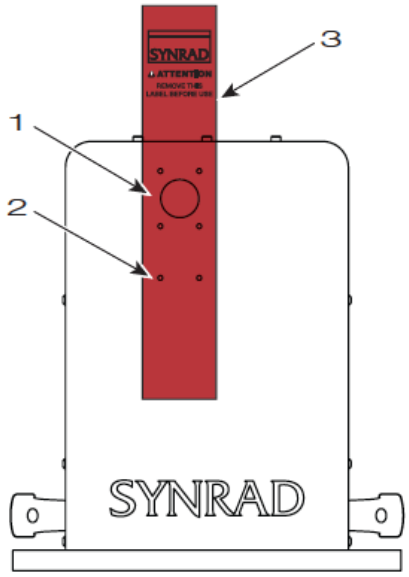



Figure 3-1 i401 front panel controls and indicators

1 Laser Aperture – provides an opening in I401's front panel from which the beam exits. The opening is threaded to accept beam delivery components with M29× 1.0 threads.

2 Optical Accessories Mounting – provides six threaded holes (8–32) for mounting optional beam delivery components available from Novanta. Because excessive weight may damage the laser, consult Novanta before mounting components not specifically designed as i401 options. Refer to I401 package outline drawings in the Technical Reference section for mounting dimensions.

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

4 Status Indicators – LED indicators display i401 laser status. From left to right:

INT (Remote Interlock) LED illuminates green to indicate the remote interlock circuit is closed and lasing may be enabled; the LED is red, and lasing is disabled if the interlock input is open.

TMP (Temperature) LED illuminates green to indicate laser temperature is within limits and lasing may be enabled; the LED is red, and lasing is disabled if coolant temperature or flow rate is outside operating limits.

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

SHT (Shutter) LED illuminates blue to indicate that the electromechanical shutter is Open and lasing is enabled. The SHT LED is off, and lasing is disabled if the shutter is Closed.

LASE LED illuminates red to indicate the I401 is actively lasing.

Important Note: When mounting optical components to i401 lasers, the 8–32 UNC fasteners must extend no further than 6.35 mm (0.25") into the laser's faceplate.

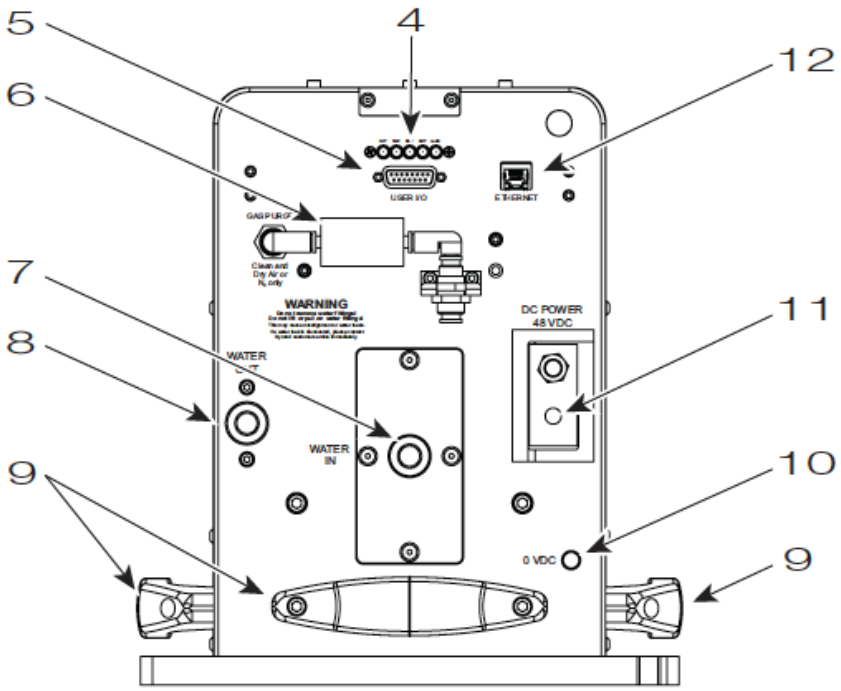



Figure 3-2 i401 rear panel controls and indicators

5 User I/O Connector – provides a connection point for auxiliary output power, as well as input and output signals. Refer to the Technical Reference section 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 – provides a 12 mm inlet connection to i401 cooling system for 12 mm O.D. cooling tubing.

8 WATER OUT Port – provides a 12 mm outlet connection from i401 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 i401 laser.

## Initial start-up

The Initial start-up section includes subsections:

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

**Danger: Serious Personal Injury**

This Class 4 laser product emits invisible infrared laser radiation in the 10.6 µm CO2 wavelength band. Since direct or diffuse laser radiation can inflict severe corneal injuries, always wear eye protection when in the same area as an exposed laser beam. Do not allow the laser beam to contact a person. This product emits an invisible laser beam that is capable of seriously burning human tissue.

**Danger: Serious Personal Injury**

Remote interlock faults are not latched on i401 OEM lasers. 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 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.

**Danger: 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 i401 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.

## With a UC-2000 Controller

Before your i401 laser is put into service for the first time, its functionality should be verified. Follow this procedure to verify the laser system is operating at optimum performance. For this procedure, use the UC-2000 as a stand-alone controller; do not attempt to control the laser or UC-2000 externally.

**Important 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 signals to the User I/O connector. See User I/O connections in the Technical Reference section for pinouts and signal descriptions.

## Starting auxiliary equipment

**Caution: Possible Equipment Damage**

Remove the aperture seal before firing the laser. The self-adhesive seal is installed to prevent dust from entering the laser housing during shipment and installation and must be removed before operation. During laser operation, use a gas purge to keep dust and vapor out of the beam path.

1. Ensure that all personnel in the area are wearing protective eyewear.
2. Remove the red self-adhesive aperture seal from the laser faceplate.
3. Place a beam block 0.5 meters (20 in) 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.

**Caution: Possible Equipment Damage**

Inlet cooling water temperature must always be maintained above the dew point to prevent condensation and water damage to your I401 laser.

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

5 Start purge gas flow at a rate of 0.85–1.7 $m^3$/hr (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 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.

**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 1-4, Purge gas specifications.

## Starting your i401 laser

Unlike other I401 lasers, the SHT LED on i401 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.

Each time an i401 OEM laser is powered up, a five-second delay occurs between the time the RDY indicator illuminates and the i401 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.

**Danger: 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 PWM Adj Knob on the UC-2000 Controller to slowly increase power. The LASE LED turns red when PWM Command 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 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 both turn off.
4. If you are connected to the i401's Ethernet port, access the i401 web page to verify operating conditions and functionality (refer back to Figure 1-13). See the Getting Started or Technical Reference sections for details on accessing the I401 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 i401 laser fails to lase, refer to Troubleshooting in the Maintenance/Troubleshooting section for troubleshooting information.

**Caution: Possible Equipment Damage**

Do not flow coolant through the laser when the laser is shutdown. This causes condensation to form inside the laser which may result in catastrophic damage to internal optics and electronic circuits.

## Without a UC-2000 Controller

If you have chosen not to use a UC-2000 to control the laser, follow the procedure below to verify the laser's functionality. Although a tickle signal is not required, you will need to provide PWM Command signals to I401's User I/O connector. Refer to User I/O connections in the Technical Reference section for connector pinouts and refer to Controlling laser power in the Technical Reference section for Command signal descriptions.

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

## Starting auxiliary equipment

**Caution: Possible Equipment Damage**

Remove the aperture seal before firing the laser. The self-adhesive seal is installed to prevent dust from entering the laser housing during shipment and installation and must be removed before operation. During laser operation, use a gas purge to keep dust and vapor out of the beam path.

1. Ensure that all personnel in the area are wearing protective eyewear.
2. Remove the red self-adhesive aperture seal from the laser faceplate.
3. Place a beam block 0.5 meters (20 in) 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 m3/hr (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.

**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 1-4, Purge gas specifications.

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.

**Caution: Possible Equipment Damage**

Inlet cooling water temperature must always be maintained above the dew point to prevent condensation and water damage to your I401 laser.

## Starting your I401 laser

Unlike other I401 lasers, the SHT LED on i401 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.

Each time an i401 OEM laser is powered up, a five-second delay occurs between the time the RDY indicator illuminates and the i401 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.

**Danger: 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 I401'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 i401's Ethernet port, access the i401 web page to verify operating conditions and functionality (refer back to Figure 1-13). See the Getting Started or Technical Reference sections for details on accessing the I401 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 the Maintenance/Troubleshooting section for troubleshooting information.

**Caution: Possible Equipment Damage**

Do not flow coolant through the laser when the laser is shutdown. This causes condensation to form inside the laser which may result in catastrophic damage to internal optics and electronic circuits.

## Technical reference

Use information in this section as a technical reference for your i401 laser.

This section contains the following information:

**Technical overview** – briefly describes I401's technology and basic optical setup.

**Controlling laser power** – explains various aspects of I401 control signals.

**User I/O connections** – describes input/output signals and specifications for the 15-pin User I/O connector.

**DC power/DC sense cables** – provides information about i401 DC power and voltage sense cables.

**I401 web interface** – explains details about the I401 i401's Ethernet interface.

**I401 firmware upgrade** – describes how to perform an upgrade to the i401's operating firmware.

**Integrating I401 safety features** – describes how to integrate I401 safety features into your automated control system.

**I401 general specifications** – provides specifications for the i401 laser.

**I401 outline and mounting drawings** – illustrates laser package outline and mounting dimensions for i401 lasers.

**I401 packaging instructions** – illustrates how to package the i401 lasers for shipment.

## Technical overview

The Technical overview section includes subsections:

- Laser design
- RF power supply
- Optical setup

# Laser Design

## Optical resonator

i401 lasers were developed using new technology developed by Novanta, Inc. This new technology, based on a hybrid waveguide/unstable resonator design (Figure 3-1), 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. I401's 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.

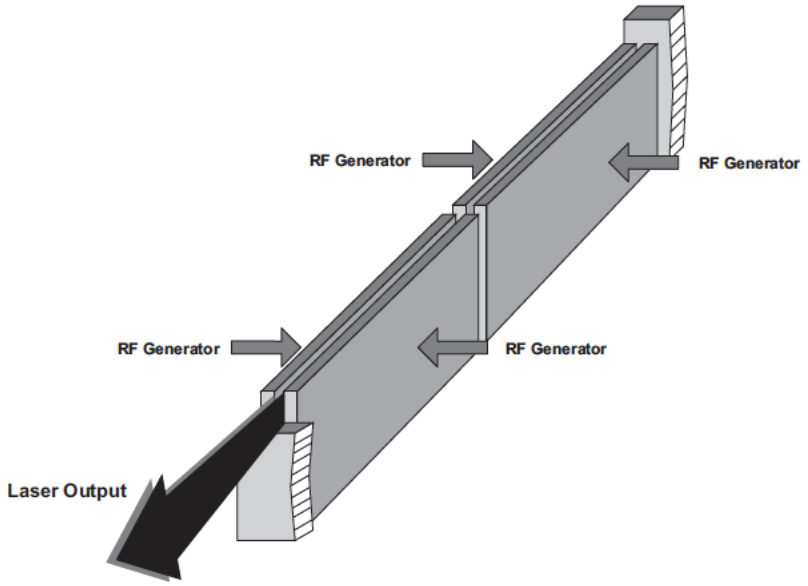



Figure 4-1 Hybrid waveguide/unstable resonator design

The optical resonator, in conjunction with the electrodes and the gas mixture, generates the laser beam. I401 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 ($M_2$ 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) as shown in Figure 3.2.

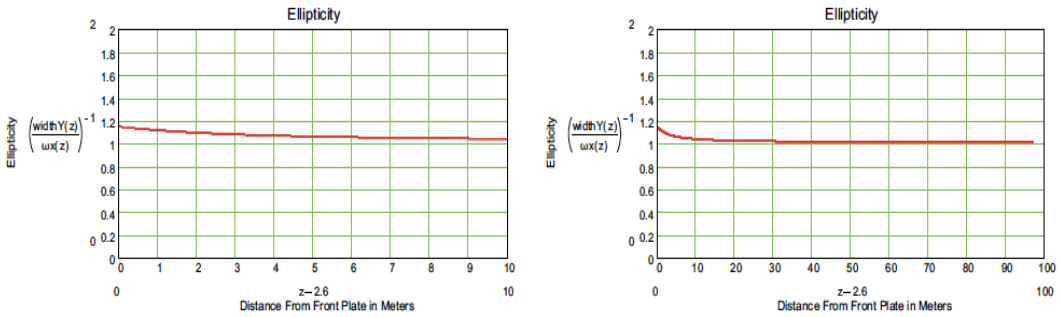



Figure 4-2 i401 beam ellipticity

## 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.

## Beam conditioning

The i401 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 in) 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.

### Technical overview

To reduce the complexity and cost of beam delivery components, the i401 laser was designed with the beam polarized at 45° to the base plate (see Figure 3-19 for details). This de- sign 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 3-3.

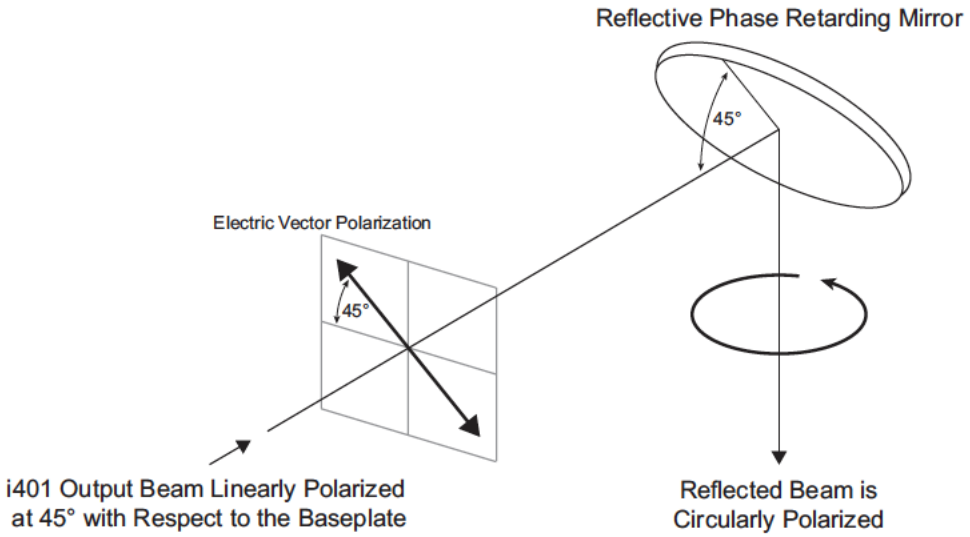



Figure 4-3 Converting 45° linear polarization to circular polarization

## RF power supply

i401 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: (1) the electromechanical shutter is closed; (2) the Shutter Open Request input signal is missing; (3) an over temperature or low coolant flow condition occurs; (4) the Remote Reset/Start Request input signal is enabled; (5) the Remote Interlock input signal is missing; or (6) any fault is present.

**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.

## Optical setup

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

### Beam delivery optics

Divergence, or expansion, of the laser beam is important in materials processing since a larger beam entering the focusing optic produces a smaller focused spot.

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

### 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 to be 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 to the specifications shown in Table 4-1.

Table 4-1 Assist gas purity specifications

| Assist Gas | Typical Purpose | Specification |
|---|---|---|
| Air | Cutting/ Drilling | **Breathing Grade:** ≥ 99.9996% purity; filtered to ISO Class 1 particulate level |
| Air | Cutting/Drilling | **Compressed:** Instrument-grade air filtered and dried to ISO 8573-1:2010 Class 1, 2, 1 (< 10 1.0– 5.0 µm particles/m3; < –40 °F (–40 °C) dew point; < 0.01 mg/m3 oil vapor) |
| Argon | Welding | **High purity grade:** ≥ 99.998% purity; filtered to ISO Class 1 particulate level |
| Helium | Welding | **High purity grade:** ≥ 99.997% purity; filtered to ISO Class 1 particulate level |
| Nitrogen | Cutting/Drilling | **High purity grade:** ≥ 99.9500% purity; filtered to ISO Class 1 particulate level |
| Oxygen | Cutting/Drilling | **Ultra-Pure Grade:** ≥ 99.9998% purity; filtered to ISO Class 1 particulate level |

# Controlling laser power

The Controlling laser power section includes subsections:

- Control signals
- Operating modes

# Control signals

Much of the information provided in this section describes the use of a Novanta UC-2000 Universal Laser Controller to provide PWM Command signals to the i401 laser. If using an alternate method of laser control, thoroughly review this section, controlling laser power, as well as the following section, User I/O connections, for an understanding of the signal requirements necessary to control I401 lasers. For more information about the UC-2000, please consult the UC-2000 Laser Controller Operator's Manual.

## Tickle pulse

Tickle pulses pre-ionize the laser gas to just below the lasing threshold so that a further increase in pulse width adds enough energy to the plasma to cause laser emission. Tickle pulses cause the laser to respond predictably and almost instantaneously to PWM Command signals, even when there is considerable delay (laser off time) between applied Command signals. All I401 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

Danger: 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.

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.

## Pulse Width Modulation (PWM)

Pulse Width Modulation, or PWM, controls laser power by varying the duty cycle of I401'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).

I401 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 the majority of laser applications, the UC-2000's default Command signal frequency of 5 kHz has proven to work well. When considering Command frequencies at 5 kHz or below, please review Marking/engraving operation later in this section. For high-speed motion applications that cannot tolerate any ripple in the optical beam response but still need adjustable power levels, we recommend the use of higher PWM frequencies, up to 100 kHz maximum.

## Command signal

The modulated Command signal applied between Pin 9, PWM Input, and Pin 1, PWM Return, of the User I/O connector on the i401 laser has three parameters: signal amplitude, base frequency, and PWM duty cycle. By changing these parameters, you can command the beam to perform a variety of marking, cutting, welding, or drilling operations.

### Warning: Serious Personal Injury

Always use shielded cable when connecting your PWM signal source to the laser's PWM connections.

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

The first Command signal parameter, signal amplitude, is either logic low—corresponding to laser beam off, or logic high—corresponding to beam on. The laser off voltage, typically 0 V, can range from 0.0 V to +0.8 VDC while the laser on voltage, typically 5 V, can range from +3.5 V to +6.7 VDC.

Base frequency, the second parameter, is the repetition rate of the PWM input signal. The standard base frequency is 5 kHz, which has a period of 200 µs. Maximum PWM frequency is 100 kHz. The third Command signal parameter, PWM duty cycle, is the percentage of the period that the Command signal is high. For example, if the Command signal's amplitude (at 5 kHz) is high for 100 µs and low for 100 µs, it has a 50% duty cycle; if the amplitude is high for 190 µs and low for 10 µs, it has a 95% duty cycle. Figure 3-4 illustrates typical PWM Command signal parameters.

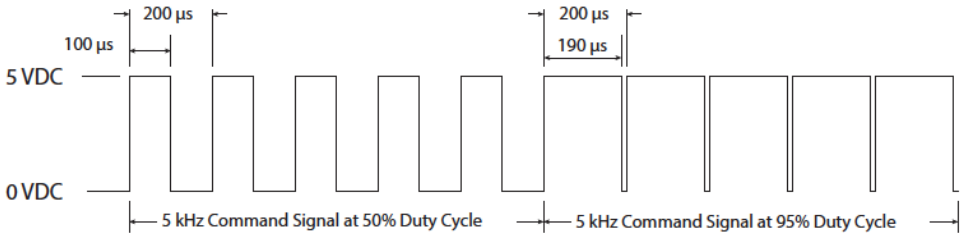



Figure 4-4 PWM Command signal waveform

I401 User I/O PWM input consists of a high-speed opt isolator 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 3-2 on the following page provides minimum, maximum, and nominal PWM signal specifications.

### Controlling laser power

Table 4-2 PWM Command signal specifications

| 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% |

## Operating modes

### External control

In addition to controlling the i401 laser using a UC-2000 Controller, control of the i401 externally, without a UC-2000, is also possible. The two primary elements of laser control are gating, the ability to turn the laser on and off at the appropriate times, and power, the ability to control the laser's output energy. Both gating and power can be handled by a device such as a personal computer, Programmable Logic Controller (PLC), or function generator capable of sending PWM pulses at the proper time (gating) and with the proper duty cycle (power).

### Analog voltage or current control

Although i401 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.

## Continuous wave (CW)

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

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

**Important Note:** Novanta lasers are designed for maximum performance using a 95% duty cycle. Increasing the maximum PWM percentage beyond 95% greatly increases the laser's heat load with little or no corresponding increase in laser output power. Continuous operation at 99% duty cycle may lead to thermal instability and optical degradation.

## Gated operation

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

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

### Warning: Serious Personal Injury

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

In an integrated system, you should configure the UC-2000's gate input logic to internal Pull-Down (normally off) mode. This prevents the beam from being enabled unless a high level (+3.5 V to +5.0 VDC) signal is applied to the Gate input connector. In the Pull- Down (normally off) mode an asserted logic low signal, short circuit to ground, or an open or disconnected Gate input locks the beam off.

Many CO2 lasers operating in applications requiring short gating pulses at repetition rates below 500 Hz will exhibit some leading-edge overshoot regardless of the PWM frequency. This occurs because a cooler lasing medium (the CO2 gas) is more efficient than a hotter one. This overshoot effect is more pronounced at lower gating frequencies since the gas has a longer time to cool down between Command signal pulses.

### Marking/engraving operation

When the delay between the end of one PWM Command signal pulse and the beginning of the next PWM pulse exceeds 200 microseconds (less than or equal to 5 kHz), F201 laser's 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.

## User I/O connections

The User I/O connections section includes subsections:

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

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 i401's rear panel. Figure 3-5 below illustrates the pin arrangement of the User I/O connector.

**Caution: Possible Equipment Damage**

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

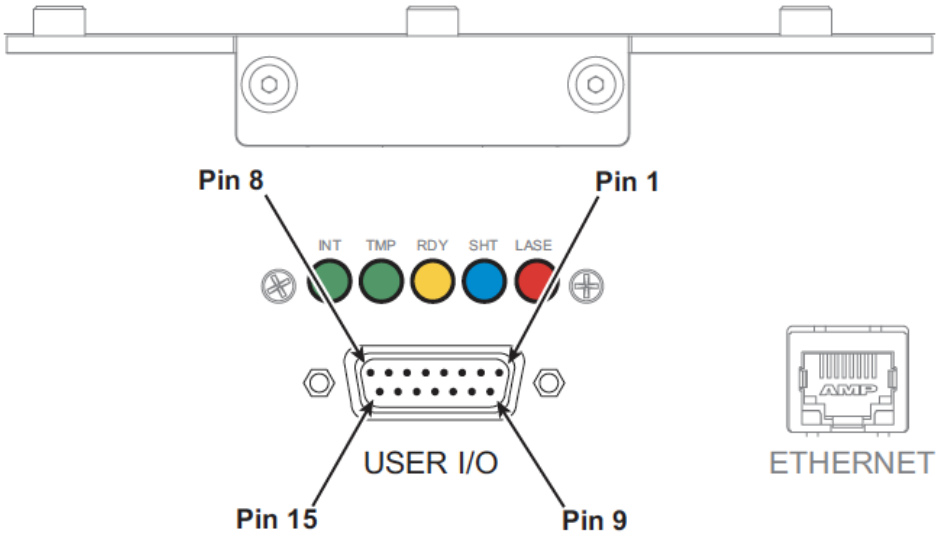



Figure 4-5 User I/O connector pinouts.

## User I/O connection summary

Table below provides a quick reference summary to i401 User I/O connections.

Table 4-3 User I/O pin descriptions

| Pin | Description | Function |
|---|---|---|
| 1 | PWM Return | Use this input pin as the return side of the PWM Command signal. |
| 2 | Remote Reset/Start Request input | Apply a positive or negative voltage (±5–24 VDC) with respect to Pin 11, Input Common, to reset or remote key switch the laser. The laser remains disabled while voltage is applied. Removing voltage from the Remote Reset/Start Request input causes the laser's RDY indicator to illuminate and begins a five-second countdown after which lasing is enabled. |
| 3 | Remote Interlock input | Apply a positive or negative voltage (±5–24 VDC) with respect to Pin 11, Input Common, to enable lasing. If your system does not use a remote interlock, this pin must be connected to a voltage source in the range of ±5–24 VDC. Refer to Figure 3-7 for a diagram showing how the Remote Interlock input is factory-jumpered on the Quick Start Plug. |
| 4 | + 5 VDC Auxiliary Power | This connection provides +5 VDC for driving external inputs or outputs. The +5 VDC Auxiliary Power output can source up to 0.5 A and is protected by a 0.5 A self-resetting fuse. The return (ground) path must be through Pin 12, Auxiliary DC Power Ground. |

| | | |
|---|---|---|
| 5 | + 24 VDC Auxiliary Power | This connection provides +24 VDC for driving external inputs or outputs. The +24 VDC Auxiliary Power output can source up to 0.5 A and is protected by a 0.5 A self-resetting fuse. The return (ground) path must be through Pin 12, Auxiliary DC Power Ground. |
| 6 | Laser Active output | This bi-directional switched output is internally connected to Pin 13, Output Common, when the laser is actively lasing (LASE indicator illuminated red). This output is open (high impedance) 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 (1) laser temperature is above safe operating limits (TMP LED illuminated red) or (2) a No-Strike condition has occurred (blue SHT indicator is flashing). The output is open (high impedance) 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 LED illuminated yellow), indicating that lasing will occur when a PWM Command signal is applied to Pin 9 and Pin 1. When this output is initially switched closed, there is a five-second delay during which lasing is inhibited. This output is open (high impedance) when the laser is disabled (RDY indicator Off). |

| Pin | Description | Function |
|---|---|---|
| 9 | PWM Input | Connect your PWM Command signal (+5 VDC, 5 kHz nominal, 100 kHz max, pulse width modulated) to this input pin to control laser output power. Refer 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 open the internal electromechanical shutter assembly. If your system does not supply a Shutter Open Request signal, this pin must be connected to a voltage source in the range of ±5–24 VDC. Refer to Figure 3-7 for a diagram showing how the Shutter Open Request input is factory-jumpered on the Quick Start Plug. 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 (high impedance) when lasing is enabled (INT indicator green). |

## Input/output signals

The I401 i401's input/output signals are divided into three categories: auxiliary DC power, input signals, and output signals. Signals in each category are fully described in the following sections.

### Auxiliary DC power

i401 User I/O connector provides auxiliary DC power for driving external inputs or outputs connected to the User I/O port. Pin 4, +5 VDC Auxiliary Power, and Pin 5, +24 VDC Auxiliary Power, are protected by self-resetting fuses rated at 0.5 A. Pin 12, Auxiliary DC Power Ground, is connected to chassis ground while all other User I/O pins are floating with respect to chassis ground. Figure 3-6 illustrates I401's internal DC supply wiring.

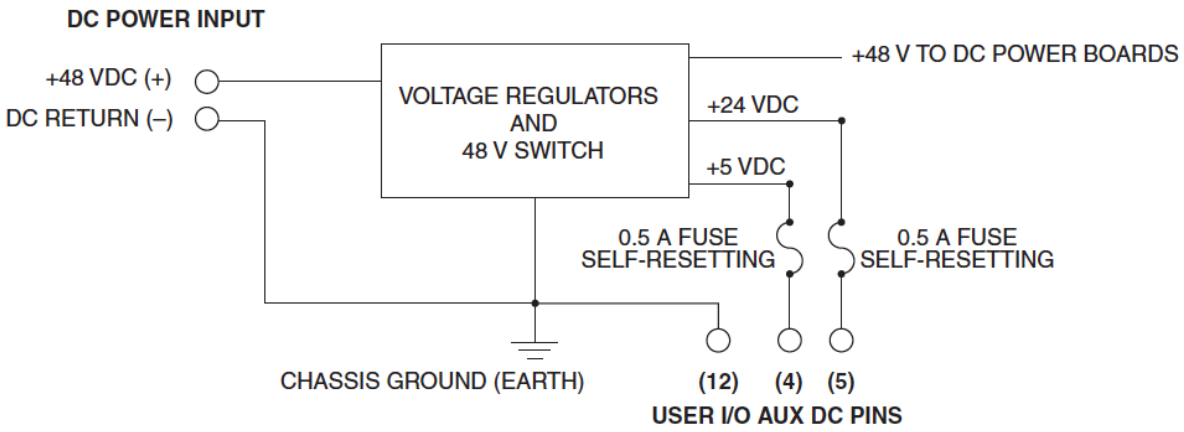


Figure 4-6 Auxiliary DC power diagram

### Pin 4 + 5 VDC Auxiliary Power

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

### Pin 5 + 24 VDC Auxiliary Power

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

### Pin 12 Auxiliary DC Power Ground

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

## Input signals

A total of four user inputs allows control of I401 lasers. Remote Interlock, Shutter Open Request, and Remote Reset/Start Request inputs are optoisolated and bi-directional, allowing for positive or negative polarity signal inputs. These three signals also share a common return connection, Input Common, which is separate from chassis ground to completely isolate control signals for optimal EMI performance. The fourth input, PWM Input, is optoisolated and has a separate return, PWM Return, to fully isolate PWM signals from the other three user inputs. Note that throughout this manual, input voltage levels are specified with respect to their corresponding return line.

### Pin 1 PWM Return

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

### Pin 2 Remote Reset/Start Request

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

### Pin 3 Remote Interlock

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

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.

### Pin 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 section for further information on laser control signals. Connect the PWM signal source return to Pin 1, PWM Return. See Table 3-4 for input circuit specifications.

### Pin 10 Shutter Open Request

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 3-4 for input circuit specifications.

### Pin 11 Input Common

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

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

**Warning: Serious Personal Injury**

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

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

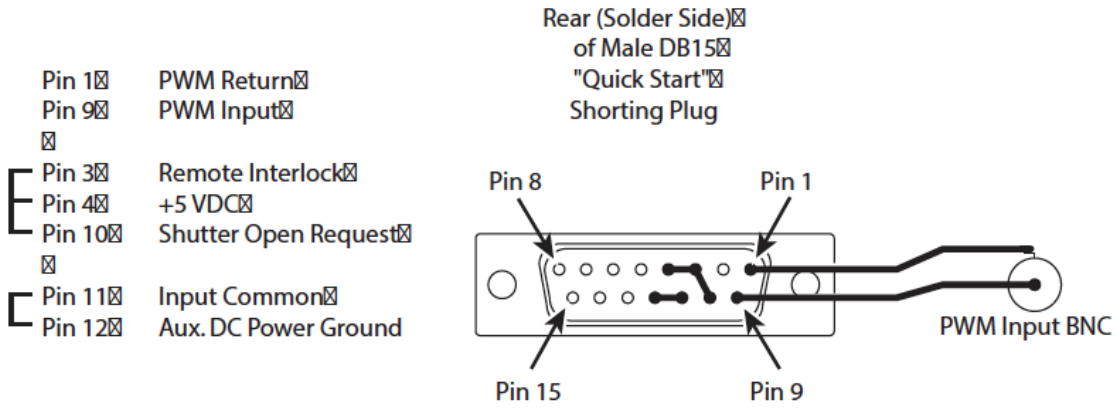
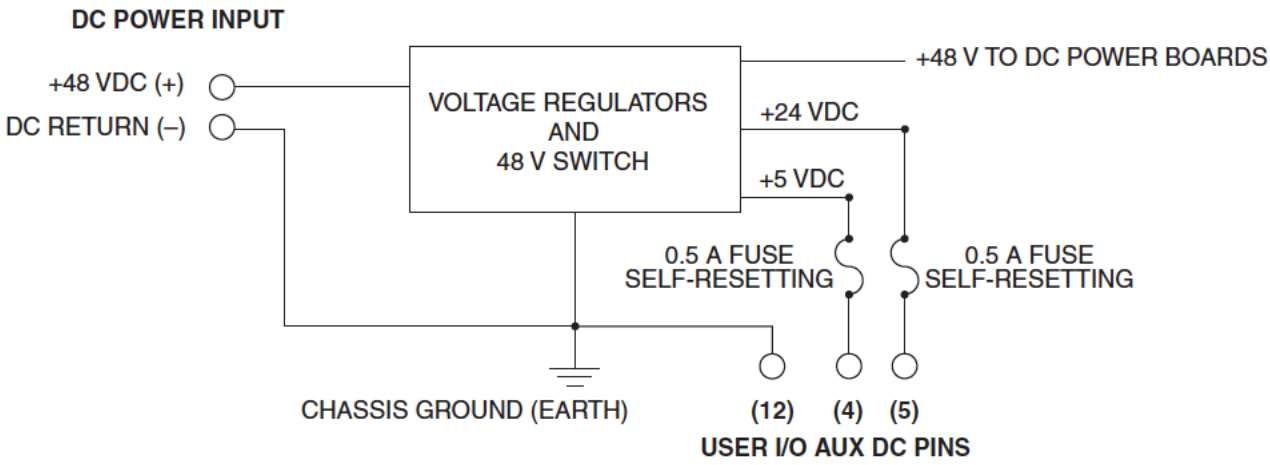



Figure 4-7 Quick Start Plug wiring diagram

Figures below illustrates the input circuit's equivalent internal schematic while the following table provides i401 input circuit specifications.



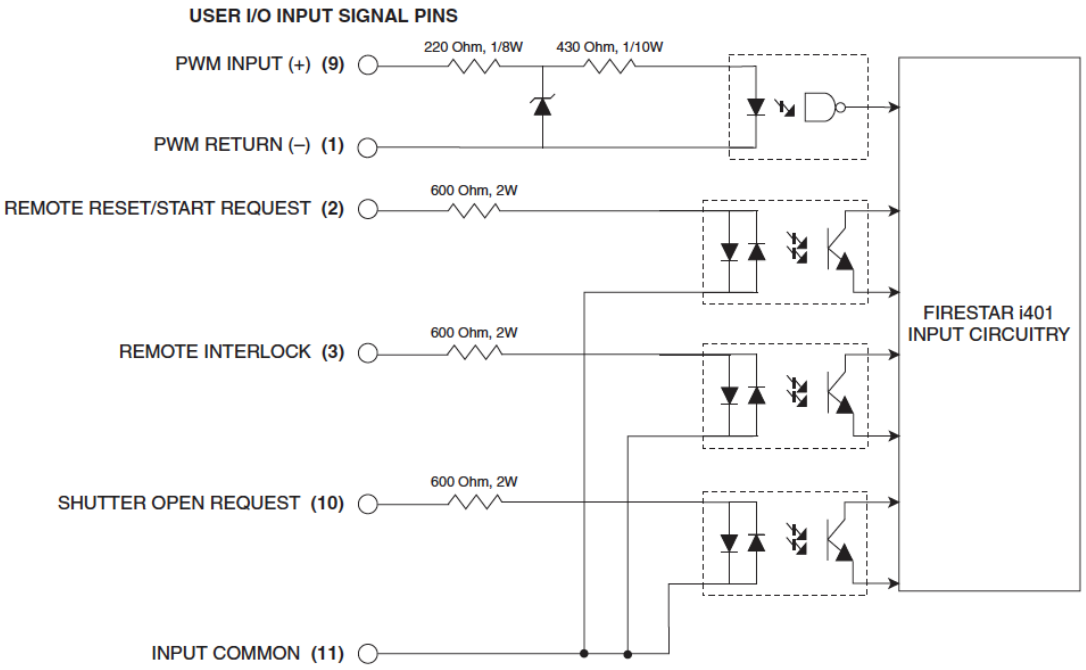



Figure 4-8 Input equivalent schematic

Table 4-4 Input circuit specifications

| Input Signal Name | Input Device Type and Specifications |
|---|---|
| PWM Input | High-speed optoisolator LED, forward voltage drop (Vf) 1.5 VDC<br>Off state Vmax +0.8 VDC<br>On state Vmin +3.5 VDC @ 3 mA<br>On state (continuous) Vmax +6.7 VDC @ 10 mA<br>Frequency, max. 100 kHz |
| Remote Reset/Start Request<br>Remote Interlock<br>Shutter Open Request | Bi-directional optoisolator LED, forward voltage drop (Vf) 1.15 VDC<br>Off state Vmax < 1.0 VDC<br>On state Vmin ±5.0 VDC @ 7 mA<br>On state (continuous) Vmax ±24.0 VDC @ 40 mA |

**Important Note:** The Remote Reset/Start Request input must not be sent until I401's +5 VDC power supply has stabilized (approximately 200 ms after DC power-up).

## Output signals

I401's five user outputs correspond to the status functions described below. These outputs are optoisolated solid-state relays 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.

I401's optically isolated outputs are useful for sending laser status to a Programmable Logic Controller (PLC) or computerized control system. Each of the five outputs can source 50 mA at ±24 VDC maximum for a total load of 250 mA. For controlling larger loads, use these outputs to drive a control relay.

**Important 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).

### Pin 6 Laser Active

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 (high impedance) when no beam is being emitted (LASE indicator Off). Refer to Table 3-5 for output circuit specifications.

### Pin 7 Fault Detected

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 (high impedance) when laser operation is within limits (TMP LED green and SHT LED blue). Refer to Table 3-5 for output circuit specifications.

### Pin 8 Laser Ready

This bi-directional switched output is internally connected to Pin 13, Output Common, when the laser is enabled (RDY indicator On), indicating that lasing will occur when a PWM Command signal is applied to Pin 9 and Pin 1. When this output is initially switched closed, there is a five-second delay during which lasing is inhibited. This output is open (high impedance) when the laser is disabled (RDY LED Off). Refer to Table 3-5 for output circuit specifications.

### Pin 13 Output Common

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

### Pin 14 Shutter Open

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 (high impedance) when the laser is disabled (SHT LED Off). Refer to Table 3-5 for output circuit specifications.

### Pin 15 Interlock Open

This bi-directional switched output is internally connected to Pin 13, Output Common, when remote interlock input circuitry is open (INT indicator red), indicating that lasing is disabled. This output is open (high impedance) when the laser is enabled (INT indicator green). When this output is initially switched open, there is a five-second delay during which lasing is inhibited. See table below for output circuit specifications.

The figure below illustrates the output circuit's equivalent internal schematic and below provides i401 output circuit specifications.

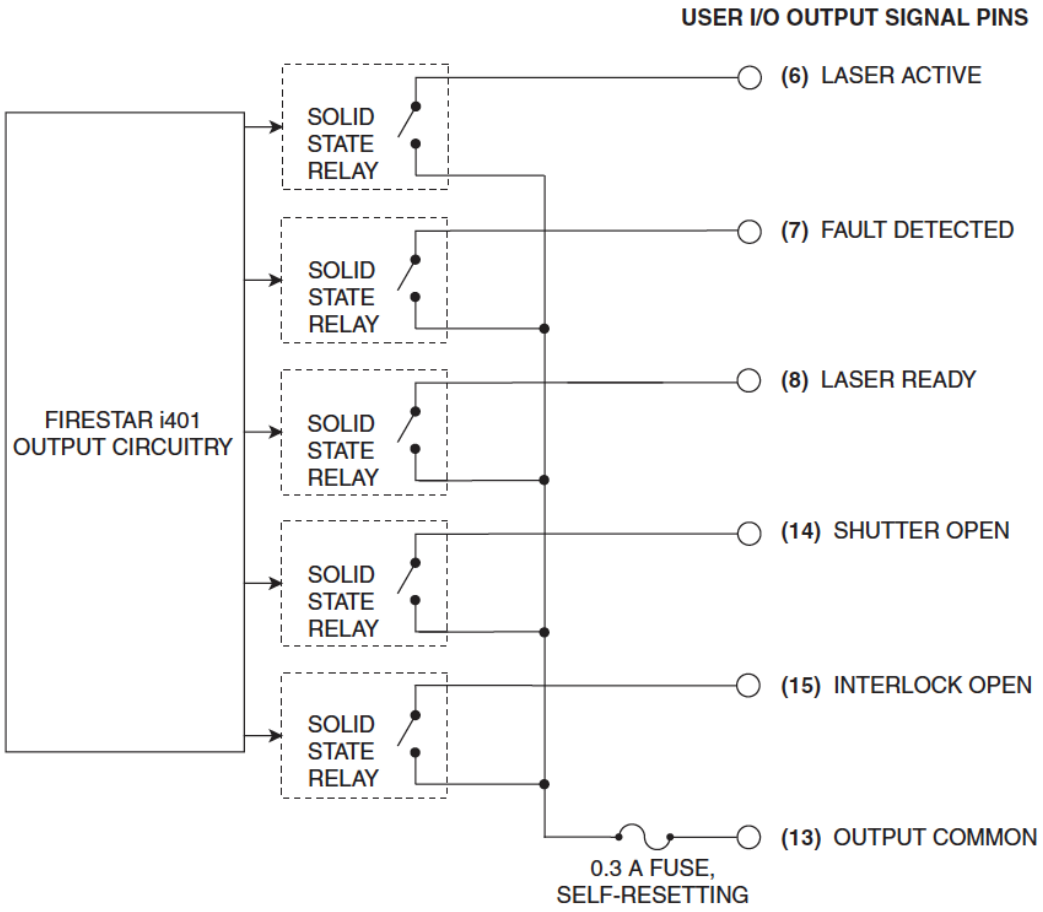



Figure 4-9 Output equivalent schematic

Table 4-5 Output circuit specifications

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

# Sample I/O circuits

## Sample inputs

Figure below illustrates one method of supplying a Remote Interlock signal using a customer-supplied limit switch. I401's +24 VDC Auxiliary Power output powers the circuit. Note that Pin 4, +5 VDC Auxiliary Power, could have been used instead, depending on circuit voltage requirements.

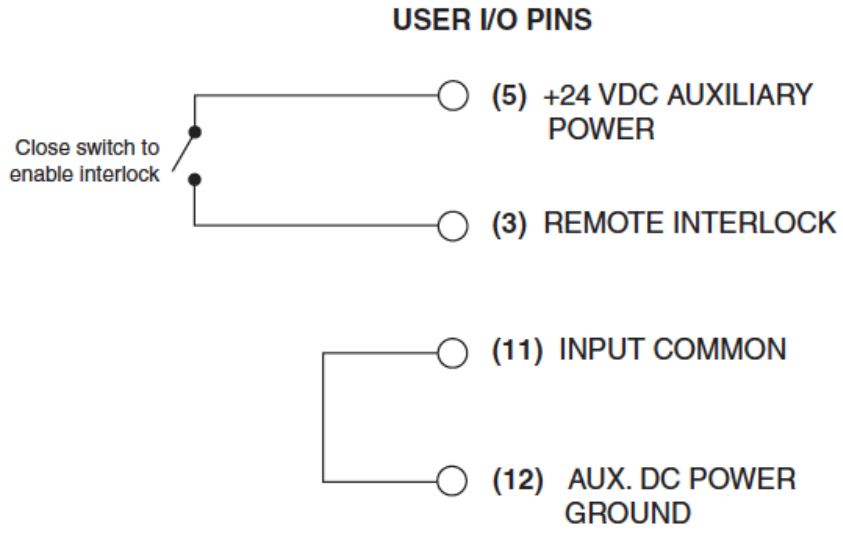



Figure 4-10 Customer supplied interlock

The figure below shows another variation for supplying a Remote Interlock signal to the laser. In this case, the customer is using a limit switch and supplying a negative voltage to drive I401's input circuit.

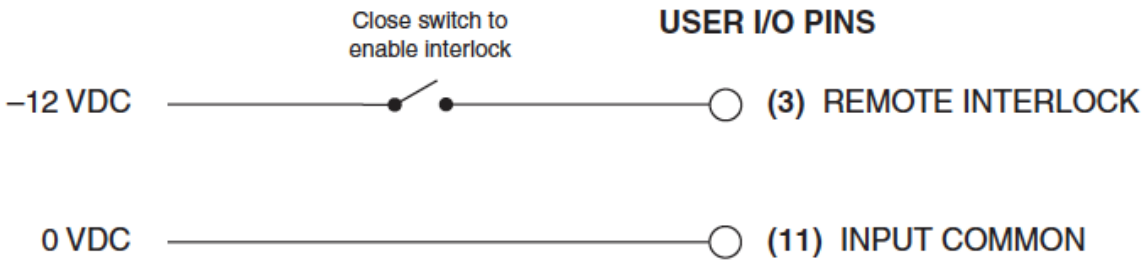



Figure 4-11 Customer-supplied interlock, negative voltage

## User I/O connections

A Programmable Logic Controller (PLC) can also drive I401 inputs. Figure below shows a typical method for connecting to a PLC output module when only one I401 input is used.

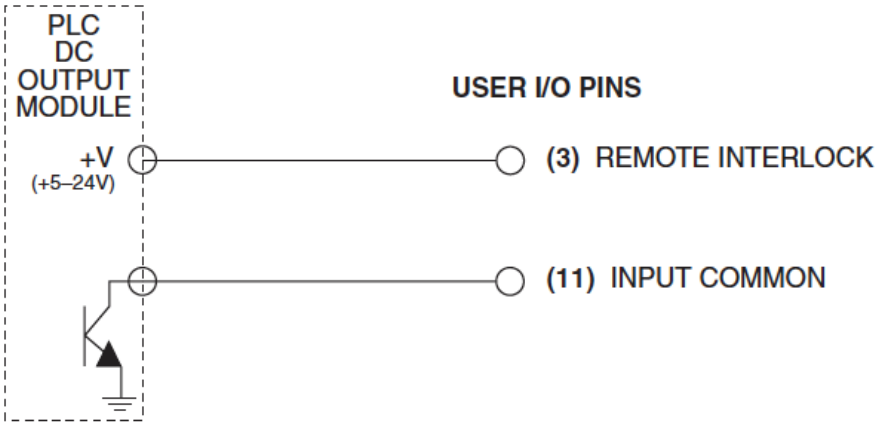



Figure 4-12 PLC driven interlock signal

When multiple PLC outputs are used, connect I401 inputs to the PLC as shown in Figure 3-13. By supplying voltage (+VDC) to Pin 11, Input Common, and pulling individual inputs to ground, each input can be independently activated by the PLC's output module.

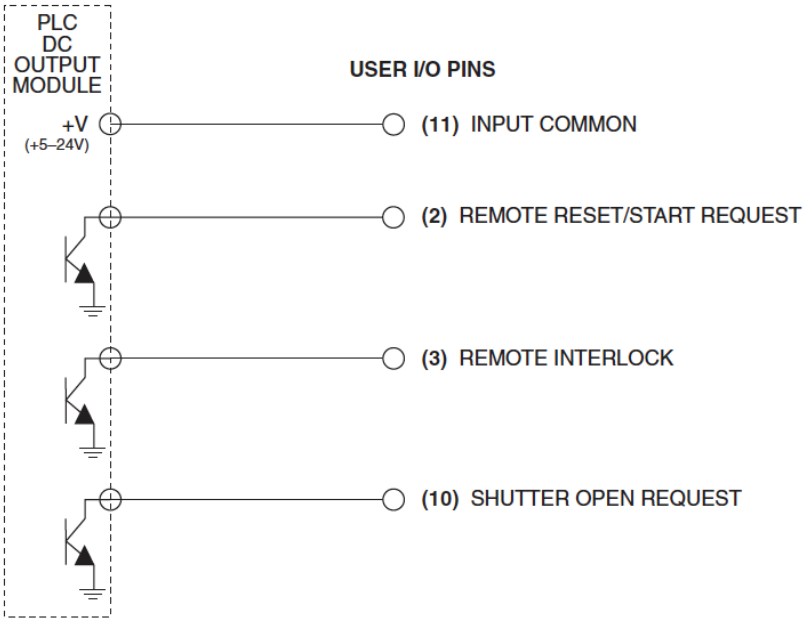



Figure 4-13 Multiple PLC driven inputs

## Sample outputs

I401's optoisolated, bi-directional switched outputs can drive small loads (50 mA max), PLC inputs, or relays that can control higher current loads. Figure below illustrates one method of controlling a remote warning lamp using power supplied by I401's +24 VDC Auxiliary Power output. Remember to size current-limiting resistor, R1, so that the current draw does not exceed 50 mA.

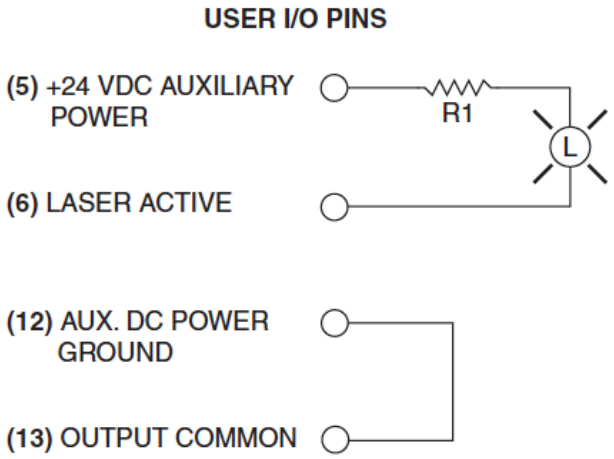



Figure 4-14 I401 output driving warning lamp

Figure below illustrates a method for controlling a higher voltage, higher current load by using a 24V 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 I401 outputs.

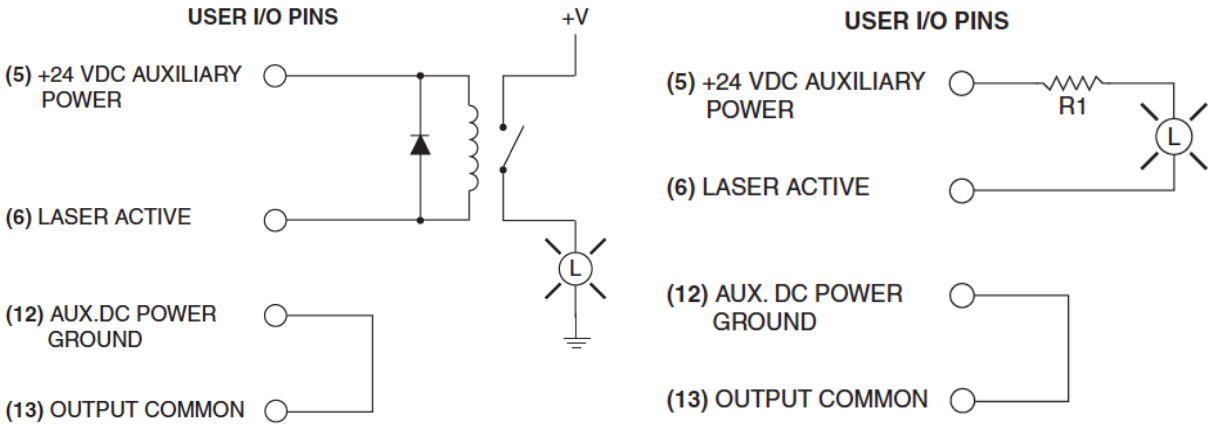



Figure 4-15 I401 output driving relay

Figure below illustrates how I401's outputs can drive the DC Input Module of a Programmable Logic Controller (PLC). By supplying voltage (+VDC) to Pin 13, Output Common, each I401 output is independently switched to activate individual PLC inputs.

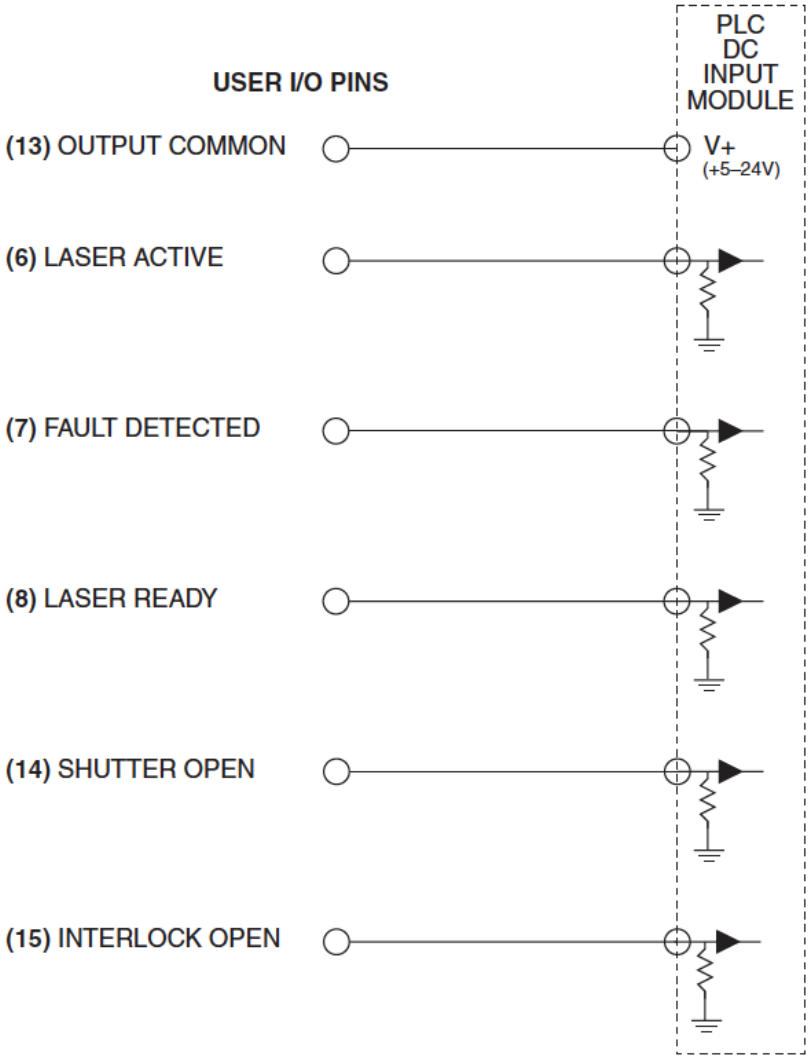



Figure 4-16 I401 output driving PLC input module

# DC power/DC sense cables

The DC power/DC sense cables section includes subsections:

- DC power cables
- DC voltage sense cable

## DC power cables

The DC power cables shipped with I401 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 i401 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.

## DC voltage sense cable

The DC voltage sense cable shipped with the i401 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.

# i401 web interface

The i401 web interface section includes subsections:

- Accessing the i401 web page
- Home page layout
- Event log page layout
- Changing the i401's IP address
- Alternate Ethernet connection

## Accessing the i401 web page

i401 lasers are pre-configured with a fixed IP address that allows a simple Ethernet connection between the i401 laser and a host. To connect your host computer to the i401 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. The i401 web interface is not compatible with the Google Chrome browser.

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 i401 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 computer's static IP address

The exact steps may vary depending on your operating system.

1. Disconnect the computer from your local network by removing any networking cables.
2. From the Start menu, go to Settings, and choose Network Connections.
3. Double-click on the appropriate Local Area Network (LAN).
4. Locate the LAN's Internet Protocol (TCP/IP) properties.
5. Select "Use the following IP address:" and enter the following information. When done, click OK to submit the changes:

IP Address: 192.168.50.100

Subnet Mask: 255.255.255.0

## Connect to the i401 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 i401's Ethernet port.
4. Apply 48 VDC power to the laser.
5. Launch your web browser, type "http://192.168.50.50" (without the quotes,) and then press Enter.

**Important Note:** When connecting to a local network, use a straight-thru Ethernet cable between the i401 laser and your Ethernet router or hub.

# Home page layout

i401 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 below.

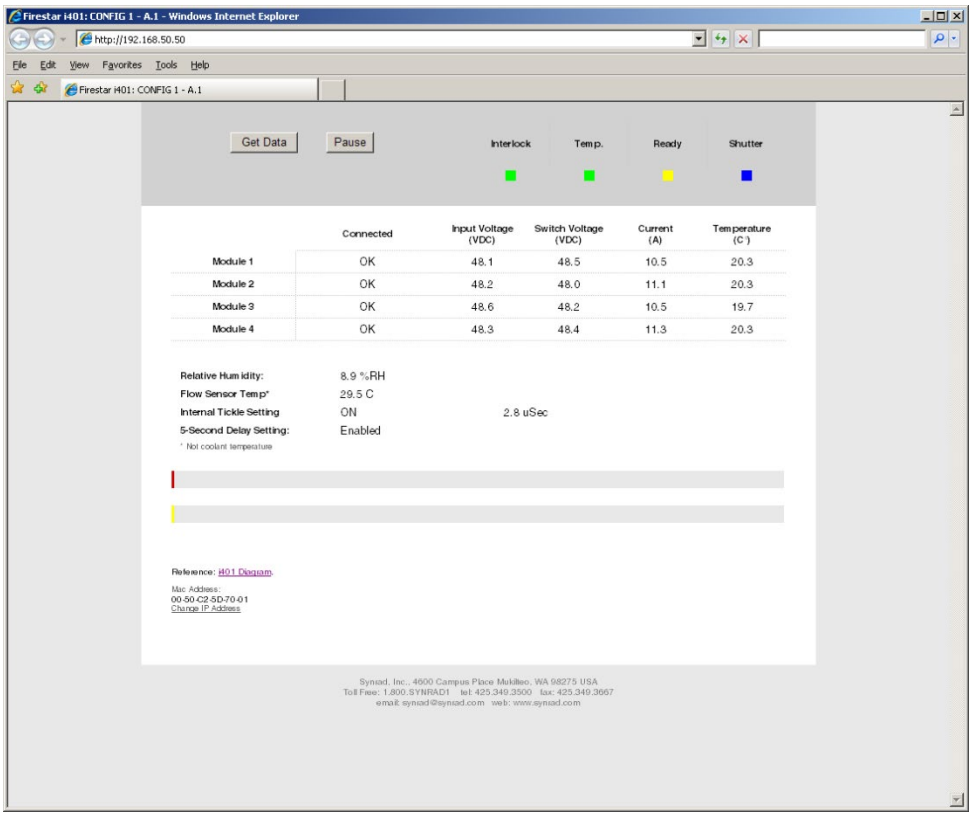



Figure 4-17 I401 home page

**Important 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 I401 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.

## I401 web interface

### Get Data button

Click to begin refreshing web page data once a second.

### Pause button

Click to halt web page updates.

### Status LEDs

Interlock, Temp, Ready, and Shutter icons display the current state of the laser's Status LEDs.

**Important Note:** Because the i401 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.

### RF module data

This section displays operating conditions for each of the i401's 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 (°C)

Displays the heat sink temperature of each RF module.

### Relative Humidity:

Displays the measured relative humidity (RH) within the i401 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.

**Important Note:** The low 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 Seconds 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.

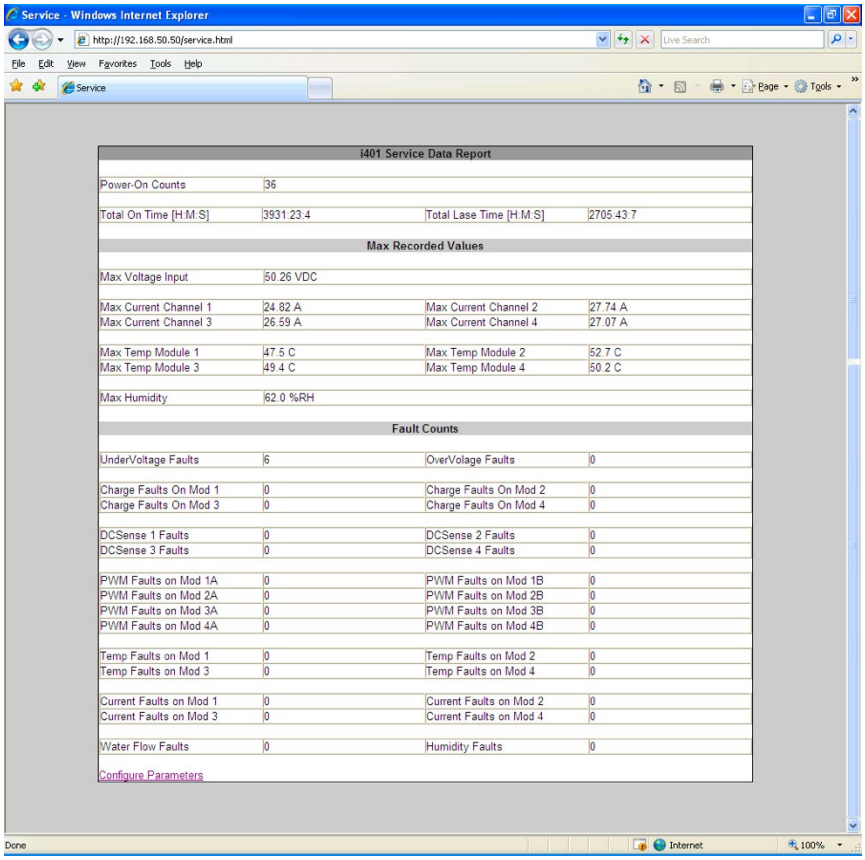
### Reference: i401 Diagram:

Hyperlink to an illustration showing various i401 modules and their location inside the laser housing.

### Configure IP Address link:

Click this link to change the laser's factory-default IP address (192.168.50.50). See the Changing the i401's IP address section for details.

# Event log page layout




**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

Figure 4-18 I401 event log page

## i401 web interface

To access the i401's event log page (prior figure), 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.

## Changing the i401's IP address

To change the i401's 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 I401 web page, click the Configure IP Address link.
2. The Change IP Address page loads (Figure 3-19), displaying the factory default IP Address, Subnet Mask and Gateway addresses.
3. Change 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 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 i401 home page will appear as shown back in Figure 3-17. 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.

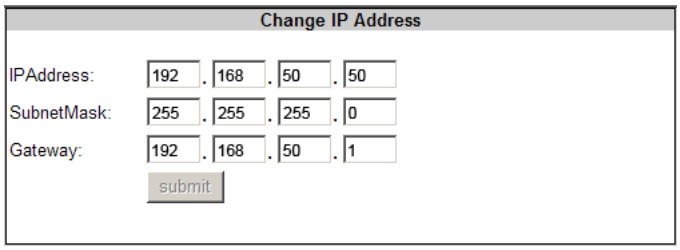



Figure 4-19 I401 Change IP Address page

## Alternate Ethernet connection

In situations where it is necessary to isolate the i401 laser from your internal IT network, but still access the i401 web page from a networked control computer, you can connect the i401 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 I401 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 i401 laser and the USB to Ethernet adapter.

## i401 firmware upgrade

i401 firmware upgrade section includes subsections:

- Required materials/equipment
- Firmware upgrade procedure

### Required materials/equipment

The following materials and equipment are required to upgrade the firmware in an i401 laser:

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

## Firmware upgrade procedure

**Important Note:** The firmware upgrade must be performed using a peer-to-peer connection between the i401 laser and host computer as described below. The i401 web interface is not compatible with Google Chrome browsers.

### Disable your computer's firewall

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

By default, the TFTP Client is disabled on Windows® 7 and Vista operating systems. Follow the steps in this subsection to enable the TFTP Client feature.

1 In the Windows Control Panel (Figure below), double-click Programs and Features.

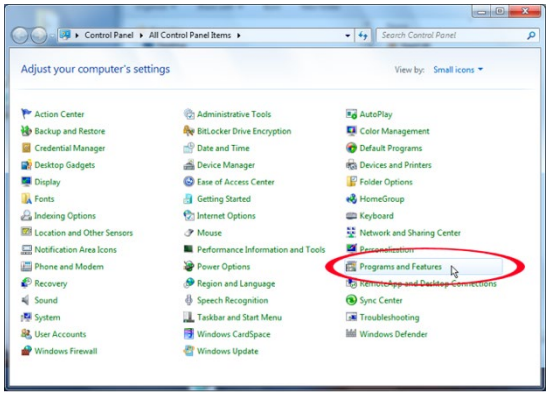



Figure 4-20 Windows Control Panel

2 In the Programs and Features dialog, click the Turn Windows Features On or Off option as shown in figure below.

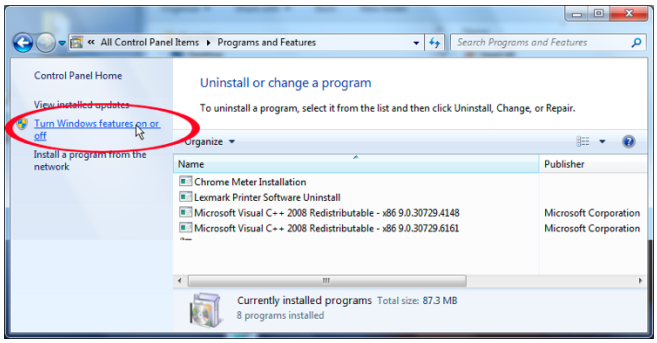



Figure 4-21 Programs and Features dialog

3 In the Windows Features dialog (Figure below), check “TFTP Client” and then click OK.

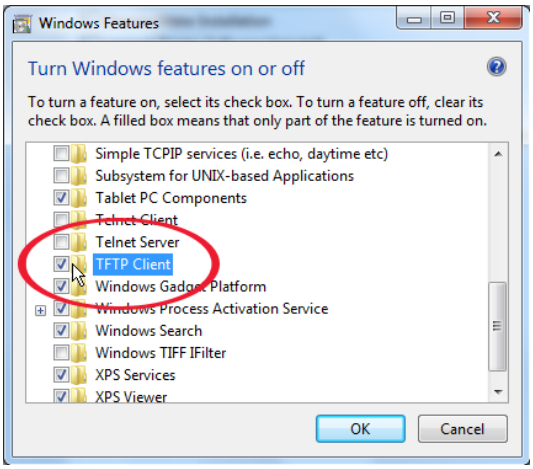



Figure 4-22 Windows Features dialog

4 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 computer’s static IP address

1 Disconnect the computer from your local network by removing any networking cables.

2 In the Windows Control Panel, double-click Network and Sharing Center.

3 In the Network and Sharing Center dialog, click the Local Area Connection option.

4 In the Local Area Connection Status dialog, click the Properties button.

5 In the Local Area Connection Properties dialog (Figure 3-23), select Internet Protocol Version 4 (TCP/IPv4) and click the Properties button.

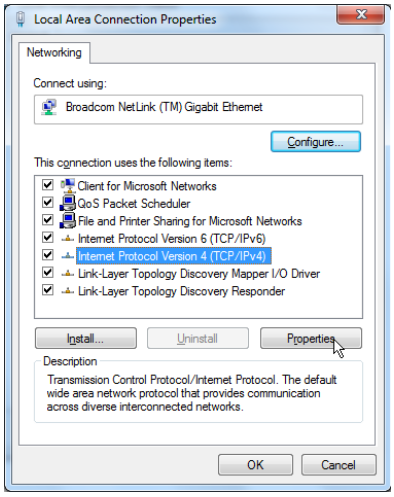



Figure 4-23 Local Area Connection Properties dialog

6 In the Internet Protocol Version 4 (TCP/IPv4) Properties dialog (Figure below), select "Use the following IP address:" and enter the following information:

IP Address: 192.168.50.100

Subnet Mask: 255.255.255.0

The Default Gateway field can be left blank.

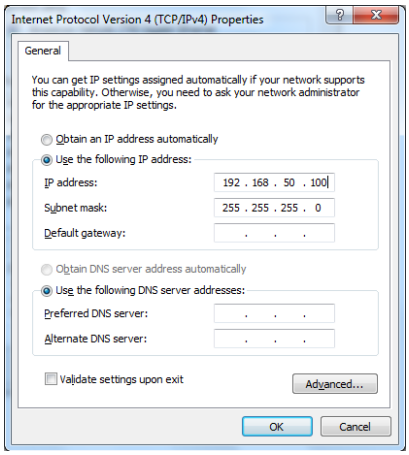



Figure 4-24 Internet Protocol (TCP/IP) Properties dialog

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 i401 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 i401's Ethernet port.

3 Remove the Quick Start Plug from the i401'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 i401'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 below, click the Configure IP Address link at the bottom of the page.

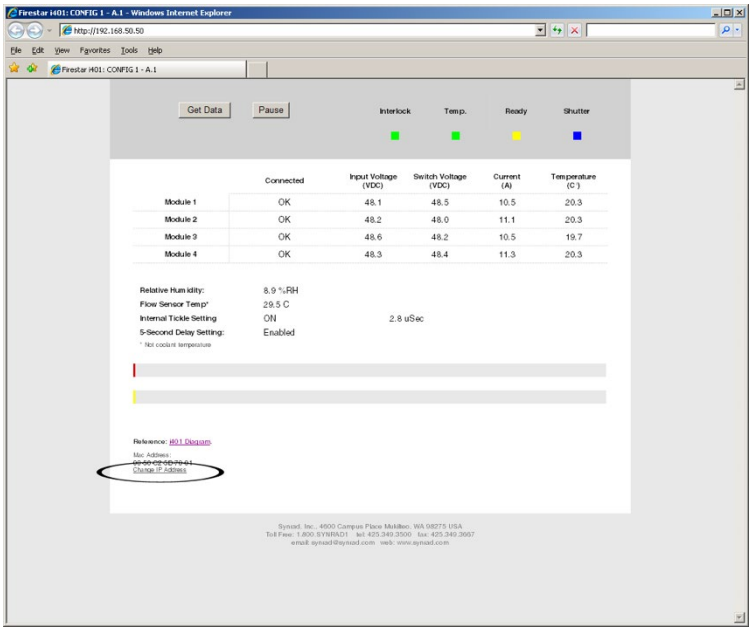



Figure 4-25 Configure IP Address link on I401 home page

C When the Change IP Address page loads showing the default IP address (following figure), click the Submit button. This resets the laser's IP address to 192.168.50.50.

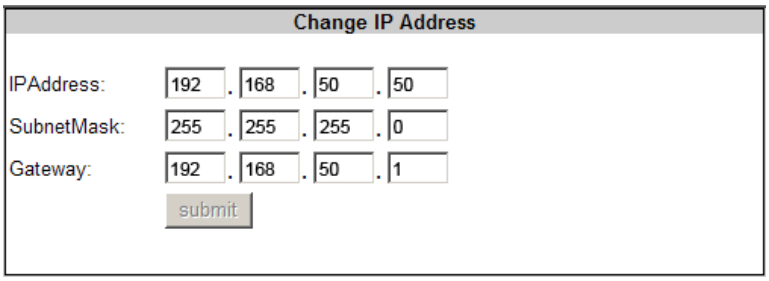



Figure 4-26 i401 Change IP Address page

### 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 i401 Home page appears (Figure below), check the label on the web browser’s tab. It should read: I401: CONFIG 2 – Rx.x to indicate the laser is running upgraded firmware.

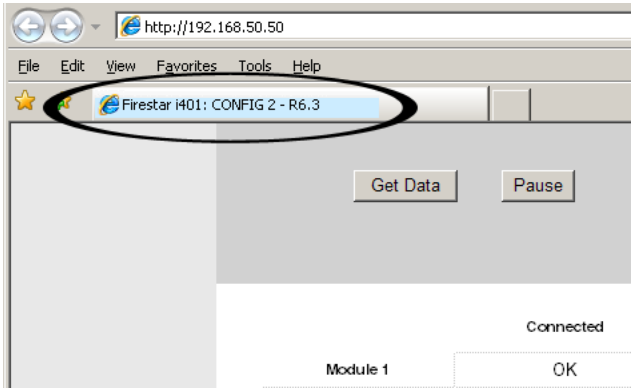



Figure 4-27 I401 web browser display

7. If necessary, click the Configure IP Address link at the bottom of the i401 web page and reset the default IP address to the specific address required for your application.

### Re-enable your computer’s firewall

If your computer’s firewall was disabled for this procedure, notify your IT Administrator and re-enable the firewall.

## Integrating i401 safety features

The Integrating I401 safety features section includes subsections:

- Key switch functions
- Shutter functions
- Remote interlock functions

i401's DB-15 User I/O connector allows system integrators or end-users to integrate I401 safety features into their control system. I401's key switch, shutter, and remote interlock functions serve to enable or disable DC power to I401's RF drive. Without DC power, the RF driver cannot supply RF energy to the resonator, causing the CO2 gas to remain in a zero-energy state. I401 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).

## Key switch functions

### 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.

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 4-16).

The Laser Ready output closes when the laser is enabled (RDY LED illuminated yellow), indicating that lasing is possible. The output is open (RDY LED off) when lasing is disabled. After the Laser Ready output closes, a five-second delay occurs before lasing is enabled.

## Shutter functions

An internal electromechanical shutter is installed on all i401 lasers. Lasing is enabled when the shutter is open (SHT LED illuminated blue) and disabled when the shutter is Closed (SHT LED off).

For i401 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 to Pin 14, Shutter Open, and Pin 13, Output Common (see Figure 4-16). The Shutter Open output closes when a 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).

## Remote interlock functions

Interlock circuits are often used to disable machinery when a shield, panel, or door is opened. I401's remote interlock function allows you to connect into an external remote interlock circuit and prevent lasing by removing DC power from the laser's RF driver boards 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 Re-mote Interlock signal via Pin 3 on the User I/O connector.

To use I401's remote interlock feature to initiate lasing, apply a voltage in the range of ±5–24 VDC to Pin 3, Remote Interlock. Applying a Remote Interlock signal causes the INT LED to turn green, the RDY indicator to turn yellow, and sends DC power to the laser's RF 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 to Pin 15, Interlock Open, and Pin 13, Output Common (see Figure 3-16). This output is closed when remote interlock circuitry is open (INT LED illuminated red). The output is open (INT LED green) when interlock circuitry is closed.

## i401 general specifications

Table 4-6 i401 general specifications

| Parameter | Firestar i401 |
|---|---|
| **Output Specifications** | |
| Wavelength† | 10.2; 10.6 microns |
| Power output, continuous[1,2] | 400 Watts |
| Power Stability[3] | ± 7% |
| Power Stability[4] | ± 5% |
| Mode Quality[5] | $M^2 \leq 1.2$ |
| Beam Waist Diameter (at $1/e^2$)[6] | 6.0 ± 0.6 mm |
| At faceplate ($1/e^2$), typical | 6.7 ± 0.7 mm |
| Beam Divergence, full angle, | 2.5 ± 0.3 mrad |
| Ellipticity | < 1.2 |
| Polarization | linear, rotated 45° |
| Extinction Ratio | > 100:1 |
| Rise Time[7] | < 100 µs |
| **Input Specifications** | |
| Power Supply | |
| Voltage | 48 V ±0.5 VDC |
| Maximum Current[8] | 125 A |
| Inrush Current (max.) | 170 A for < 10 ms |
| **Command Input Signal** | |
| Voltage | +3.5 to +6.7 VDC |
| Current (max., continuous) | 10 mA @ +6.7 VDC |
| Frequency | DC–100 kHz |
| Duty Cycle | 1%–100% (CW) |
| Logic Low State (Vmin–Vmax.) | 0.0 to +0.8 VDC |
| Logic High State (Vmin–Vmax.) | +3.5 to +6.7 VDC |

* Specifications subject to change without notice.

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

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

2 48 VDC input voltage to obtain guaranteed output power.

3 From cold start (tube at 20 °C for 30 minutes before start) at 99% duty cycle with 4 GPM flow and 20 °C coolant temperature.

4 After two minutes (typical) at 99% duty cycle, 4 GPM flow, and 20 °C coolant temperature.

5 Measured at 99% duty cycle, 5 kHz, and 20 °C coolant temperature after 30-minute warm-up.

6 Measured at beam waist. See the laser's Final Test Report for beam waist location.

7 Measured at 100 Hz, 10% duty cycle.

8 Measured at 48 VDC input, 100% duty cycle

9 i401 lasers can be operated at coolant temperatures up to 28 °C (82 °F) in order to reduce problems associated with condensation; however, this may result in decreased laser performance and/or reduced laser lifetime.

10 Published specifications guaranteed at a cooling temperature of 20 °C.

## i401 general specifications

Table 4-7 Cooling specifications

| Parameter | Firestar i401 |
|---|---|
| **Cooling Specifications** | |
| Maximum Heat Load | 6000 Watts (20.5 kBtu/hr) |
| Flow Rate (minimum) | 4 GPM at < 60 PSI (15.1 lpm at < 414 kPa) |
| Pressure Drop | 10 PSI at 4 GPM (69.0 kPa at 15.1 lpm) |
| Coolant Temperature[9] | 18 °C to 22 °C |
| Coolant Temperature Stability | ± 1.0 °C |
| **Environmental Specifications** | |
| Operating Temperature[10] | 15 °C – 40 °C |
| Humidity | 0–95%, non-condensing |
| **Physical Specifications** | |
| Length | 48.3 in (122.7 cm) |
| Width | 8.2 in (20.8 cm) |
| Height | 11.8 in (30.0 cm) |
| Weight | 130 lbs (59.0 kg) |

* Specifications subject to change without notice.

# i401 outline & mounting drawings

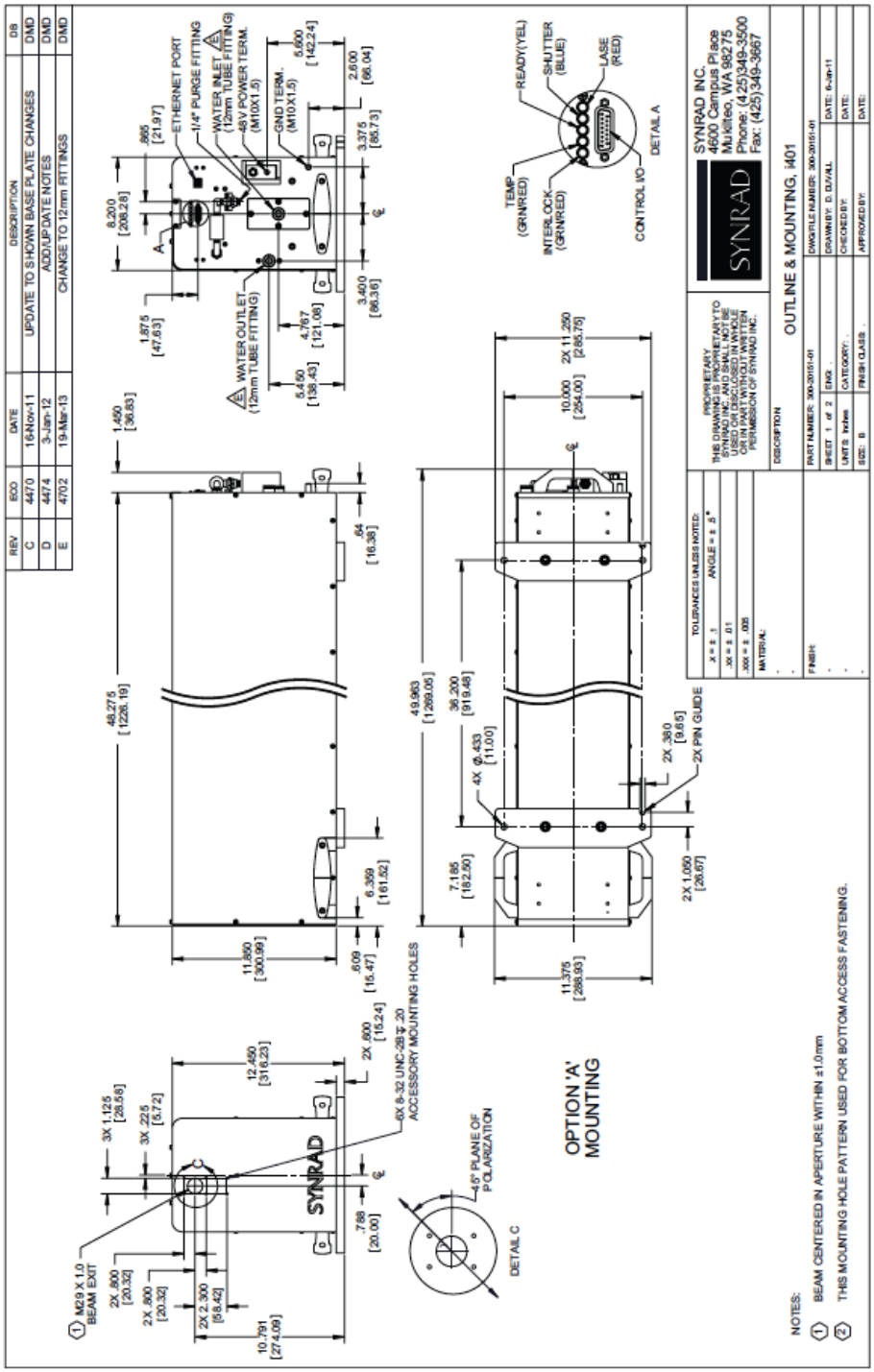



Figure 4-28 i401 outline & mounting dimensions

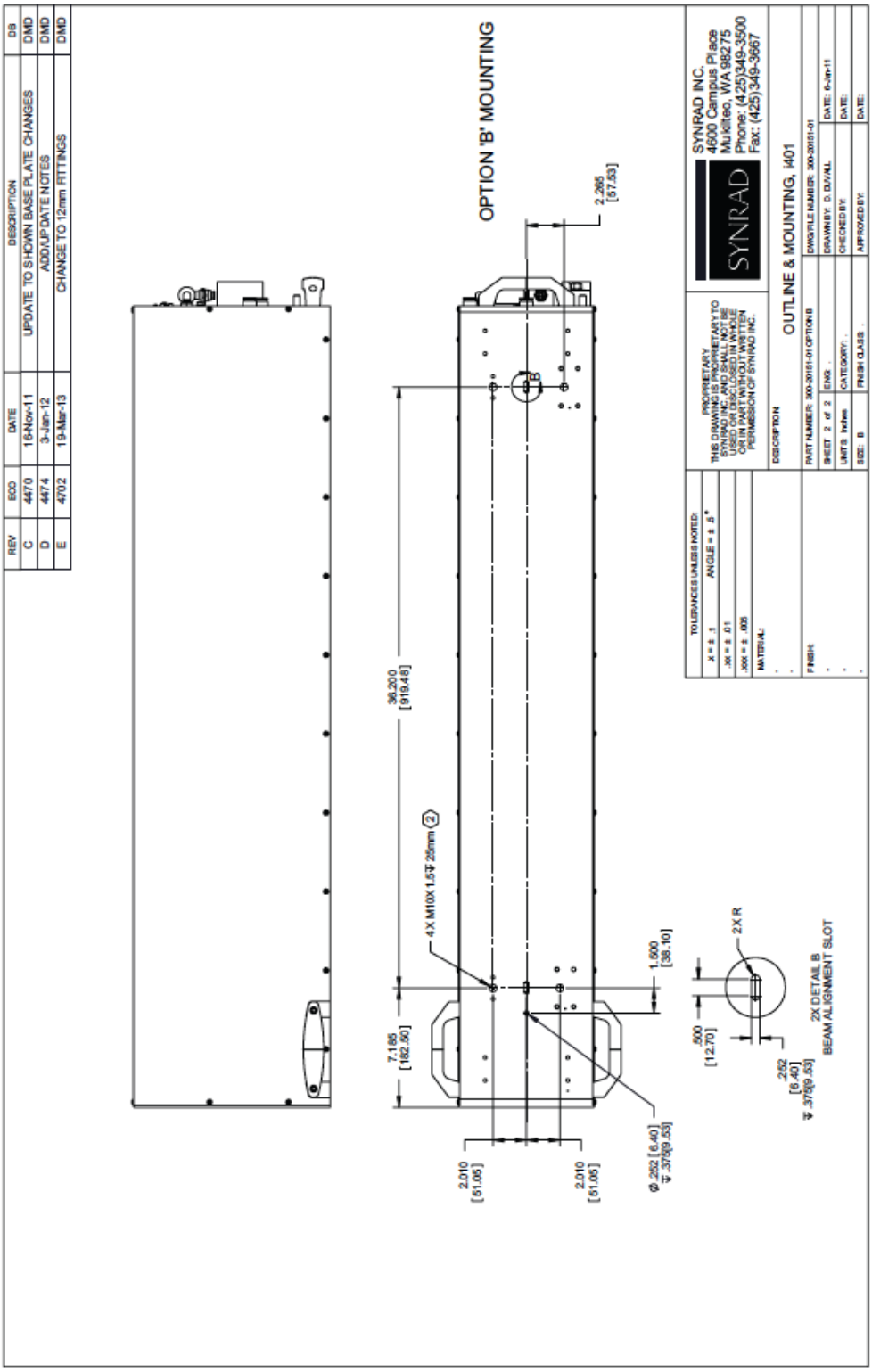



Figure 4-29 I401 outline & mounting dimensions (mounting feet removed.

# i401 packaging instructions

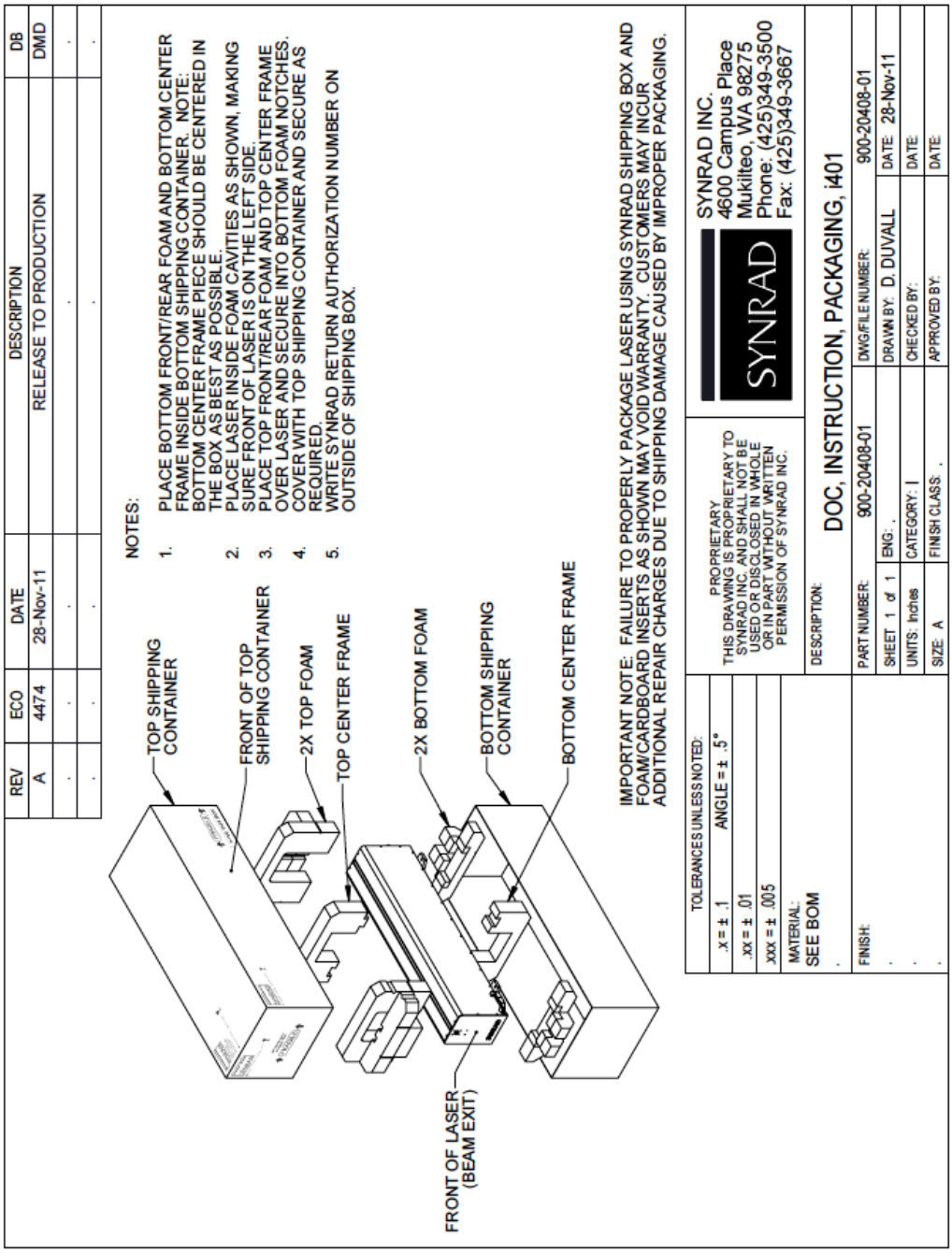



Figure 4-30 i401 packaging instructions

# Maintenance/Troubleshooting

Use information in this section to perform maintenance or troubleshoot your i401 laser.

This section contains the following information:

- Maintenance – describes typical i401 maintenance procedures.
- Troubleshooting – explains how to troubleshoot common i401 problems

## Maintenance

The Maintenance section includes subsections:

- Disabling the i401 laser
- Daily inspections
- Storage/shipping
- Cleaning optical components

## Disabling the i401 laser

Before performing any maintenance on your i401 laser, be sure to completely disable the laser by disconnecting the DC Power Cables from the DC power supply.

## Daily inspections

Perform the following steps daily to keep your i401 laser in optimum operating condition. Except for the procedures described below, no other service is required or should be attempted.

**Caution: Possible Equipment Damage**

If you operate your laser or marking head in a dirty or dusty environment, contact Novanta about the risks of doing so and precautions you can take to increase the longevity of your laser, marking head,

**Warning: Serious Personal Injury**

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

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 Setting coolant temperature in the Getting Started section for details on preventing condensation.

2 When using compressed air as a purge gas on your i401 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 purge gas specifications shown in Table 1-4 in the Getting Started section.

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 section for i401 label types and locations.

## 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)—while wearing safety glasses! —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 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 may void the warranty. Customers may incur additional repair charges for shipping damage caused by improper packaging.

## 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.

### 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 – i401 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.

### Warning: Serious Personal Injury

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

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

## Cleaning guidelines

- Wear latex gloves or finger cots (powder-free) to prevent contamination of optical surfaces by dirt and skin oils.
- Never handle optics with tools; always use gloved hands or fingers.
- Hold optics by the outer edge; never touch the coated surface.
- Always place optics lens tissue 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 (MSDS) and observe all necessary safety precautions.

## Required cleaning materials

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

Table 5-1 Required cleaning materials

| Cleaning Material | Requirements |
|---|---|
| Latex gloves or finger cots | Powder-free |
| Air bulb | Clean air bulb |
| Ethyl or isopropyl alcohol | Spectroscopic or reagent grade |
| Acetone | Spectroscopic or reagent grade |
| Lens wipe (preferred) | Optical (cleanroom) quality |
| Cotton balls or cotton swabs | High-quality surgical cotton/high-quality paper-bodied |

## 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.
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.

### Warning: Serious Personal Injury

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.

**Important Note:** If acetone is used as a cleaning solvent, a second follow-up cleaning of the optical surface using alcohol is required. Use a clean lens wipe on each pass. The wipe will pick up and carry surface contaminants that may scratch optical surfaces or coatings.

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.

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

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

## Troubleshooting

The Troubleshooting section includes subsections:

- Operational flowchart
- Functional block diagram
- Status LEDs
- Laser fault indications
- Web page fault annunciation
- Resetting faults
- General laser fault conditions
- Web interface
- Beam delivery optics

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 i401 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 and the functional block diagram.

### Caution: Possible Equipment Damage

Attempting repair of a Novanta i401 laser without the express authorization of Novanta, Inc. will void the product warranty. If troubleshooting or service assistance is required, please contact Novanta Customer Service.

protection when in the same area as an exposed laser beam. Do not allow the laser beam to contact a person. This product emits an invisible laser beam that is capable of seriously burning human tissue.

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

# Operational flowchart

The flowchart in the figure below illustrates i401 start-up sequence.

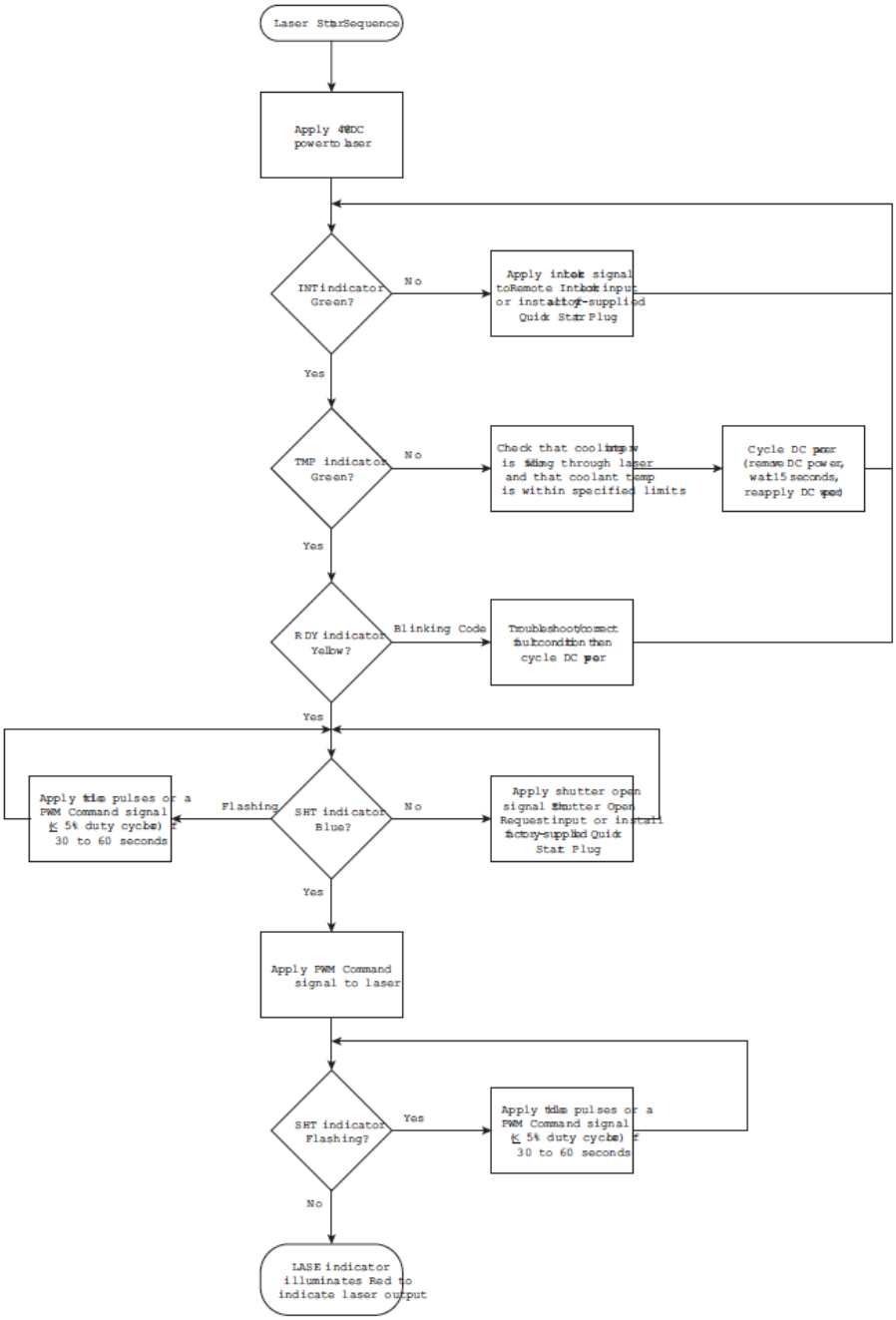



Figure 5-1 I401 operational flowchart

## Functional block diagram

Figure below is a functional block diagram illustrating the i401's control architecture.

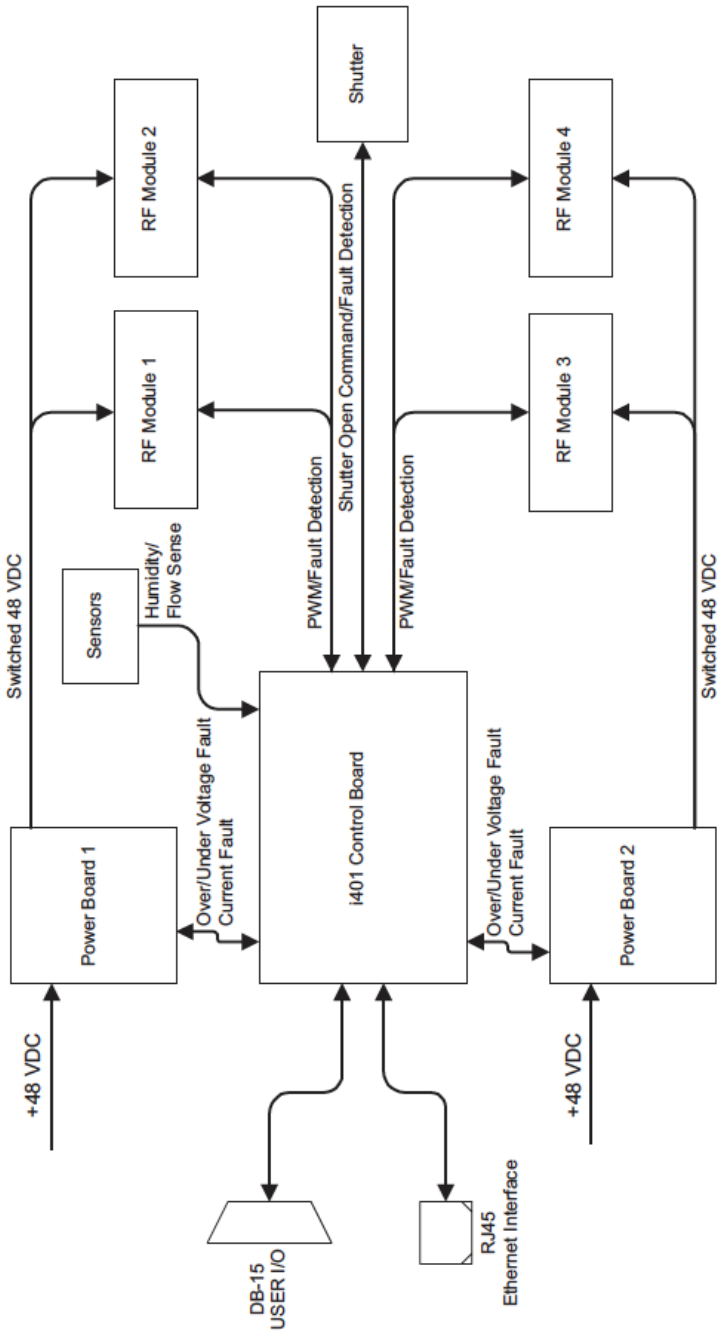



Figure 5-2 I401 functional block diagram

## Status LEDs

i401 LED indicators, also mirrored as output signals on the User I/O connector, provide status information to the user. Table below shows I401 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 logically True.

Table 5-2 Status signals

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

On DC power-up of an i401 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 i401 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).

Following table (on the following page) 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.

Table 5-3 Effect of Remote Interlock input on operating parameters

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

Tables 5-4 through 5-9 show how the I401 i401's LED and output signal status changes as various operating and fault conditions occur. Fault conditions are shown in bold.

Table 5-4 Normal operating condition

| LED Indicator | LED Status | Signal Name | User I/O Signal Status |
|---|---|---|---|
| INT | Green | Interlock Open | Open |
| TMP | Green | Fault Detected | Open |
| RDY | Yellow | Laser Ready | Closed |
| SHT | Blue | Shutter Open | Closed |
| LASE (tickle active) | Off | Laser Active | Open |
| LASE (if PWM applied) | Red | Laser Active | Closed |

Table 5-5 Quick Start Plug or interlock/shutter inputs not connected

| LED Indicator | LED Status | Signal Name | User I/O Signal Status |
|---|---|---|---|
| INT | Red | Interlock Open | Closed |
| TMP | Green | Fault Detected | Open |
| RDY | Off | Laser Ready | Open |
| SHT | Off | Shutter Open | Open |
| LASE (tickle inactive) | Off | Laser Active | Open |
| LASE (if PWM applied) | Off | Laser Active | Open |

Table 5-6 Interlock Open condition

| LED Indicator | LED Status | Signal Name | User I/O Signal Status |
|---|---|---|---|
| INT | Red | Interlock Open | Closed |
| TMP | Green | Fault Detected | Open |
| RDY | Off | Laser Ready | Open |
| SHT | Off | Shutter Open | Open |
| LASE (tickle inactive) | Off | Laser Active | Open |
| LASE (if PWM applied) | Off | Laser Active | Open |

Table 5-7 Over Temperature fault

| LED Indicator | LED Status | Signal Name | User I/O Signal Status |
|---|---|---|---|
| INT | Green | Interlock Open | Open |
| TMP | Red | Fault Detected | Closed |
| RDY | Off | Laser Ready | Open |
| SHT | Off | Shutter Open | Open |
| LASE (tickle inactive) | Off | Laser Active | Open |
| LASE (if PWM applied) | Off | Laser Active | Open |

Table 5-8 Shutter Closed condition

| Signal Name | LED Indicator | LED Status | User I/O Signal Status |
|---|---|---|---|
| INT | Green | Interlock Open | Open |
| TMP | Green | Fault Detected | Open |
| RDY | Yellow | Laser Ready | Closed |
| SHT | Off | Shutter Open | Open |
| LASE (tickle active) | Off | Laser Active | Open |
| LASE (if PWM applied) | Off | Laser Active | Open |

Table 5-9 No-Strike condition

| Signal Name | LED Indicator | LED Status | User I/O Signal Status |
|---|---|---|---|
| INT | Green | Interlock Open | Open |
| TMP | Green | Fault Detected | Closed |
| RDY | Yellow | Laser Ready | Closed |
| SHT | Blue (Flashing) | Shutter Open | Closed |
| LASE (tickle active) | Off | Laser Active | Open |
| LASE (if PWM applied) | Red | Laser Active | Closed |

## Laser fault indications

i401 lasers can 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.

The table on the following page lists error codes, the corresponding fault, and describes basic corrective action. See the Resetting faults section for detailed corrective actions.

Table 5-10 Laser fault codes

| LED | # of Blinks | Fault Condition | Corrective Action in Field |
|---|---|---|---|
| RDY | 1 blink | Under Voltage fault[1] | Verify 48.0 VDC (measured at laser under load) |
| RDY | 2 blinks | Over Voltage fault[1] | Verify 48.0 VDC (measured at laser under load) |
| RDY | 3 blinks | RF Drive Switch fault[1] | Contact SYNRAD Customer Service |
| RDY | 4 blinks | PWM Drive fault[1] | Contact SYNRAD Customer Service |
| RDY | 5 blinks | DC Pre-Charge fault[1] | Contact SYNRAD Customer Service |
| SHT | Continuous | No-Strike condition[2] | Apply tickle or PWM signal (≤5% duty cycle) for 30 to 60 seconds |

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

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

## Web page fault annunciation

The i401 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 i401 web interface section in the Technical Reference section for web page access details.

## Resetting faults

**Warning: Serious Personal Injury**

i401 OEM lasers, remote interlock 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 10.6 µm CO2 laser radiation can inflict severe corneal injuries and seriously burn human tissue, the OEM or System Integrator must ensure that appropriate safeguards are in place to prevent unintended lasing.

## Remote interlock condition

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

## Troubleshooting

On i401 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 TMP LED changes from green to red and the Fault Detected output Closes).

To reset an over-temperature fault, lower coolant temperature below 28 °C to cool the laser 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.

Important Note: Because of the over-temperature latch circuit, the TMP indicator remains red (and the Fault Detected output remains Closed) prior to cycling power even after the laser has cooled sufficiently to begin operation. If the TMP indicator remains red after cycling power, the laser is not sufficiently cooled, or the flow rate is too low—cool the laser for several more minutes and/or verify the flow rate and then cycle power.

## 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.

## DC Pre-Charge fault

A DC Pre-Charge fault indicates that 48 VDC is not available on the input of one or more RF modules and causes the RDY LED to flash 5 blinks. If a DC Pre-Charge 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 i401's 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.

## 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**

i401 OEM lasers, remote interlock 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 10.6 µm CO2 laser radiation can inflict severe corneal injuries and seriously burn human tissue, the OEM or System Integrator must ensure that appropriate safeguards are in place to prevent unintended lasing.

### Symptom:

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

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

Possible Causes:

- No voltage is 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 in the range of ±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 section for details).

## Troubleshooting

For systems not using interlocks, 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 3 (Remote Interlock) is jumpered to Pin 4 (+5 VDC Auxiliary Power).

Symptom:

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

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

Possible Causes:

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

Check that your chiller is maintaining a water 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 i401 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 LEDs and I/O states:

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

Possible Causes:

- A No-Strike condition has occurred, possibly due to cold environmental conditions that may prevent the gas from breaking down into a plasma state. 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 at the commanded duty cycle without cycling DC power.

Symptom:

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

| | | | |
|---|---|---|---|
| INT LED | – Green | Interlock Open | – Open |
| TMP LED | – Green | Fault Detected | – Open |
| RDY LED | – Yellow | Laser Ready | – Closed |
| SHT LED | – Off | Shutter Open | – Open |
| LASE LED | – Off | Laser Active | – 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 section 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 electromechanical 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 electromechanical shutter takes approximately 120 ms to fully close.

### Symptom:

Your OEM i401 laser has quit lasing or lasing halted and then restarted. The LASE LED may be Off or On depending on whether PWM Command signals are being applied, but no fault is indicated.

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

## Troubleshooting

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. Refer to Novanta Technical Bulletin #021 for detailed methods to prevent noise-induced voltage transients from activating the Remote Reset/Start Request input.

### Symptom:

Your OEM i401 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 | – Open |
| TMP LED | – Green | Fault Detected | – Open |
| RDY LED | – Off | Laser Ready | – Open |
| SHT LED | – Off | Shutter Open | – Open |
| LASE LED | – Off | Laser Active | – 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 i401's Ethernet port, access the i401 web page to verify the fault condition. If you are not connected to the i401's web page, refer to the Getting Started or Technical Reference sections for details on accessing the I401 i401 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 section.

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

During laser operation, monitor information on the i401's 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.

## Web interface

Symptom:

DC power is applied, but the I401 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 i401 laser and the computer. Use a straight-thru cable when connecting to a network using a network router, switch, or hub.

- The factory-default IP address was changed.

i401 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 I401 is connected to a network; however, the i401 web interface does not open or locks up while receiving data from the laser.

Possible Causes:

- The i401 laser was connected to the network using a crossover cable.

A straight-thru cable is required if connecting an i401 to a network via a network router, switch, or hub.

- Java script is not enabled in the web browser.

Locate your browser's Internet Options menu and configure it to enable Java script. As shown in Figure 4-3, the Java feature is located on the Internet Options dialog's Advanced tab (under Tools/Internet Options). The dialog boxes in your browser may appear differently.

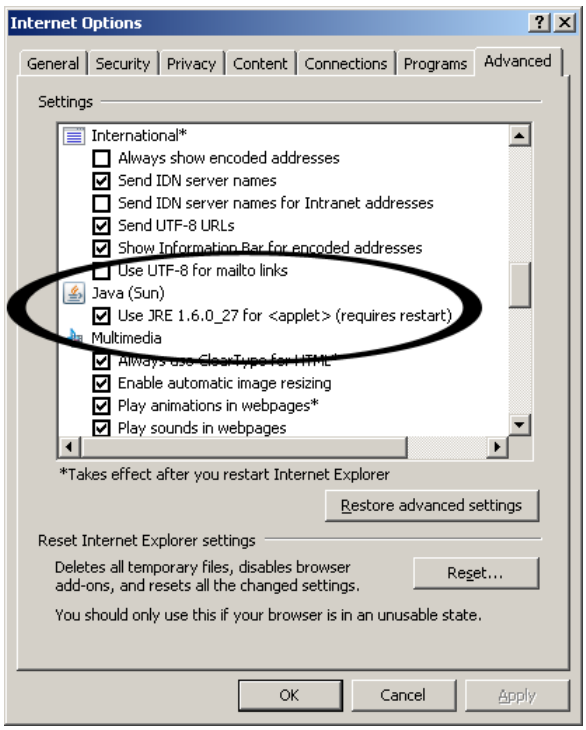



Figure 5-3 Enable Java script in browser

## Troubleshooting

- Multiple i401's are connected to the same network with identical IP addresses.

Make sure only one i401 laser is connected to the network at a time or, if multiple i401's are connected, be sure they have distinct IP addresses to prevent IP addressing conflicts.

- 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 Inter-net Options dialog's Security tab. The dialog boxes in your browser may appear differently.

To authorize the i401 web page on a local intranet (Figure 4.4), 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 i401 web page as a trusted web site (Figure 5.4), 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.

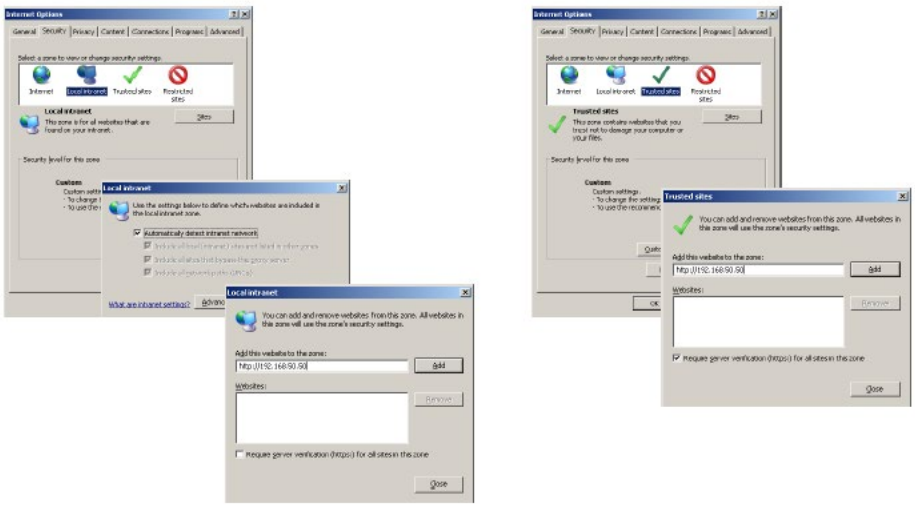


Figure 5-4 Add IP address to list of authorized/trusted websites

## Symptom:

It is necessary to isolate the i401 laser from the IT network, but still important to access the i401 web page from a networked control computer.

## Possible Causes:

- Use a USB to Ethernet adapter to isolate the I401 laser from the network.

In situations where it is necessary to isolate the I401 laser from your internal IT network, but still access the i401 web page from a networked control computer, you can connect the i401 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 I401 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 i401 laser and the USB to Ethernet adapter.

# Beam delivery optics

**Warning: Serious Personal Injury**

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

**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, possibly damaging acrylic safety shielding. Do not use air dusters containing difluoroethane in any area adjacent to $CO_2$ laser systems because difluoroethane persists for long time periods over wide areas.

**Caution: Possible Equipment Damage**

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

## Troubleshooting

### Symptom:

The laser loses power over time; laser output power must be increased to maintain performance.

### Possible Causes:

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

Shut down the laser and carefully inspect each optic in the beam delivery path. If the optic requires cleaning, refer to Maintenance for cleaning instructions. Use only recommended cleaning materials (see Table 4-1) to prevent scratching delicate optical surfaces. If the focusing optic is pitted, it must be replaced immediately. Because of the extremely high-power density of I401 lasers, pits or debris on the lens surface may absorb enough energy from the focused beam to crack the lens. If this happens, other optics in the beam path may be contaminated or damaged as well.

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 welding supply company. Because compressed shop air contains minute particles of oil and other contaminants that will damage optical surfaces, it must be

**Warning: Serious Personal Injury**

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

carefully filtered and dried before use as a purge or assist gas. Refer to the Purge gas specifications, in the Getting Started section for filtering and drying specifications.

# Index

## Symbols

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###### Revision X

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