COHERENT®

# *Operator's Manual DIAMOND™ E-400 Series OEM Lasers*

COHERENT®

*Operator's Manual*
*DIAMOND™ E-400 Series*
*OEM Lasers*

COHERENT
5100 Patrick Henry Drive
Santa Clara, CA 95054

Patents referenced in this manual are active when the manual is printed (see last page for date). You are advised to check to see if the patents are still active **http://portal.uspto.gov/external/portal/pair**.

Every effort has been made to ensure that the data given in this document is accurate. The information, figures, tables, specifications, part numbers, and schematics contained herein are subject to change without notice. Coherent makes no warranty or representation, either expressed or implied, with respect to this document. In no event will Coherent be liable for any direct, indirect, special, incidental, or consequential damages resulting from any defects in its documentation.

## Technical Support

### In the U.S.:

Should you experience any difficulties with your laser or need any technical information, please visit our Web site **www.Coherent.com**. Should you need further assistance, please contact Coherent Technical Support via e-mail **Product.Support@Coherent.com** or telephone, 1-800-367-7890 (1-408-764-4557 outside the U.S.). Please be ready to provide model and laser head serial number of your laser system as well as the description of the problem and any corrective steps attempted to the support engineer responding to your request.

Telephone coverage is available Monday through Friday (except U.S. holidays and company shutdowns). Inquiries received outside normal office hours will be documented by our automatic answering system and will be promptly returned the next business day.

### Outside the U.S.:

If you are located outside the U.S., please visit **www.Coherent.com** for technical assistance, or phone your local Service Representative. Service Representative phone numbers and addresses can be found on the Coherent web site.

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## *Signal Words and Symbols in this Manual*

This documentation may contain sections in which particular hazards are defined or special attention is drawn to particular conditions. These sections are indicated with signal words in accordance with ANSI Z-535.6 and safety symbols (pictorial hazard alerts) in accordance with ANSI Z-535.3 and ISO 7010.

## Signal Words

Four signal words are used in this documentation: **DANGER**, **WARNING**, **CAUTION** and ***NOTICE***.

The signal words **DANGER**, **WARNING** and **CAUTION** designate the degree or level of hazard when there is the risk of injury:

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**DANGER!**
**Indicates a hazardous situation that, if not avoided, <u>will</u> result in <u>death or serious injury</u>. This signal word is to be limited to the most extreme situations.**

---

**WARNING!**
**Indicates a hazardous situation that, if not avoided, <u>could</u> result in <u>death or serious injury</u>.**

---

**CAUTION!**
**Indicates a hazardous situation that, if not avoided, could result in <u>minor or moderate injury</u>.**

---

The signal word "***NOTICE***" is used when there is the risk of property damage:

---

***NOTICE!***
**Indicates information considered important, but not hazard-related.**

---

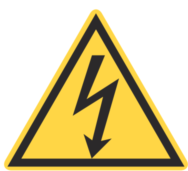
Messages relating to hazards that could result in both personal injury and property damage are considered safety messages and not property damage messages.

## Symbols

The signal words **DANGER**, **WARNING**, and **CAUTION** are always emphasized with a safety symbol that indicates a special hazard, regardless of the hazard level:

**This symbol is intended to alert the operator to the presence of important operating and maintenance instructions.**

**This symbol is intended to alert the operator to the danger of exposure to hazardous visible and invisible laser radiation.**



**This symbol is intended to alert the operator to the presence of dangerous voltages within the product enclosure that may be of sufficient magnitude to constitute a risk of electric shock.**

**This symbol is intended to alert the operator to the danger of Electro-Static Discharge (ESD) susceptibility.**

**This symbol is intended to alert the operator to the danger of crushing injury.**

**This symbol is intended to alert the operator to the danger of a lifting hazard.**

**This symbol is intended to alert the operator to the danger of a fire hazard.**

## Preface

This manual provides installation, operating, and maintenance instructions for DIAMOND™ E-400 Series lasers – OEM version. The laser safety section must be reviewed thoroughly prior to operating the DIAMOND E-400 Series laser system.

*NOTICE!*
**Read this Operator's Manual carefully before operating the laser for the first time. Special attention must be given to the material in Section Two: Laser Safety.**

**WARNING!**
**Use of controls or adjustments or performance of procedures other than those specified in this manual may result in hazardous radiation exposure.**

*NOTICE*!
**Use of the system in a manner other than that described within this manual may impair the protection provided by the system.**

## Export Control Laws Compliance

It is the policy of Coherent to comply strictly with the U.S. export control laws.

Export and re-export of lasers manufactured by Coherent are subject to U.S. Export Administration Regulations, which are administered by the Commerce Department. In addition, shipments of certain components are regulated by the State Department under the International Traffic in Arms Regulations.

The applicable restrictions vary depending on the specific product involved and its destination. In some cases, U.S. law requires that U.S. government approval be obtained prior to resale, export, or re-export of certain articles. When there is uncertainty about the obligations imposed by U.S. law, clarification should be obtained from Coherent or an appropriate U.S. government agency.

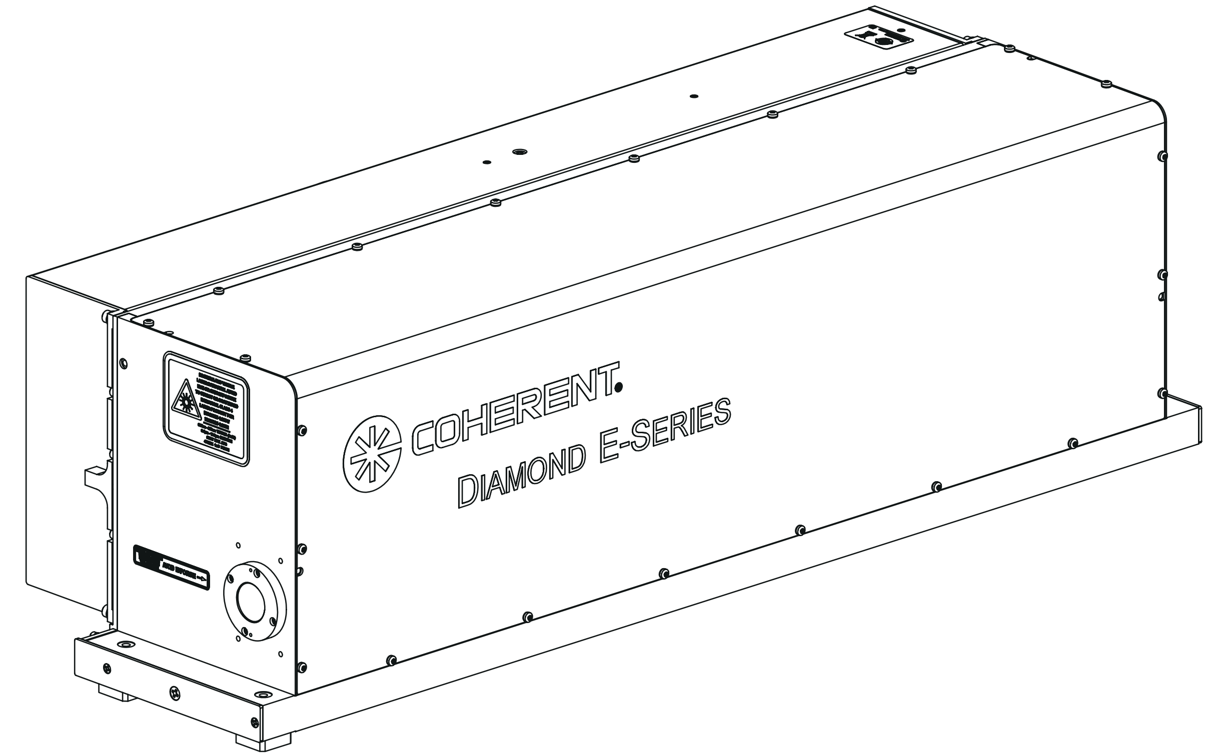
Products manufactured in the European Union, Singapore, Malaysia, Thailand: These commodities, technology, or software are subject to local export regulations and local laws. Diversion contrary to local law is prohibited. The use, sale, re-export, or re-transfer directly or indirectly in any prohibited activities are strictly prohibited.

# SECTION ONE: SYSTEM DESCRIPTION

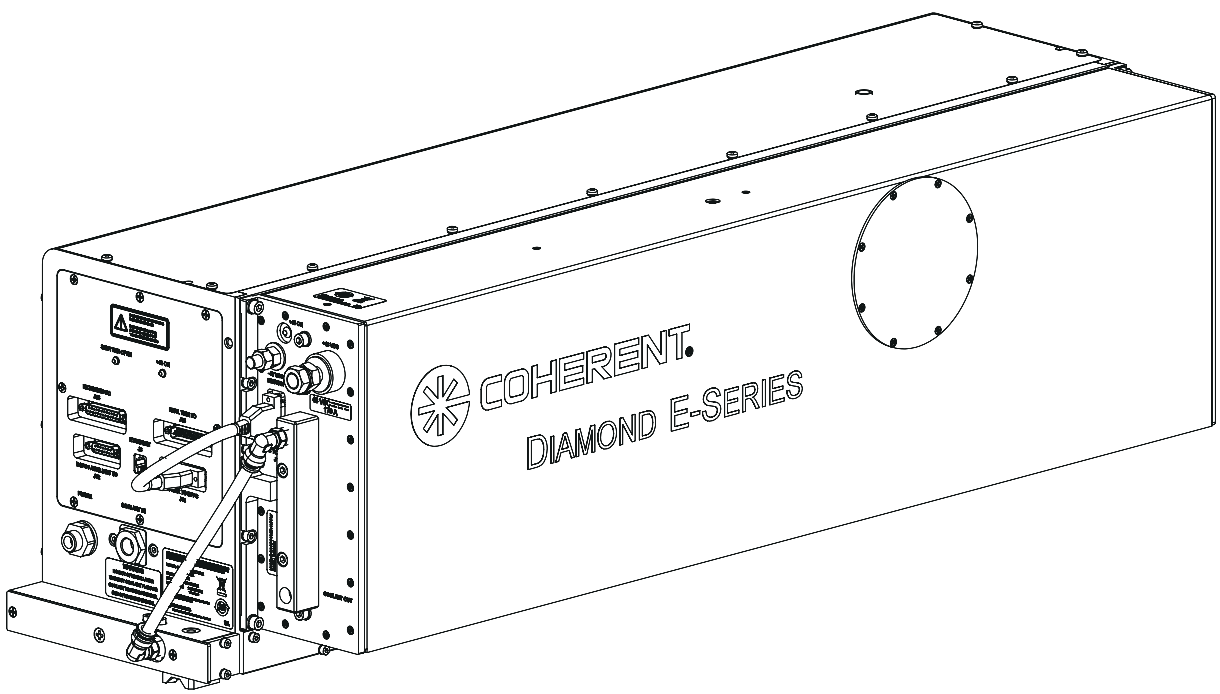
## Introduction

The DIAMOND™ E-400 Series laser systems (Figure 1-1 and Figure 1-2) are integrated, RF excited, liquid-cooled, sealed-tube, pulsed industrial $CO_2$ lasers and consist of an integrated laser head and RF power module. These integrated systems operate on 48 VDC at high currents; therefore a DC power supply is required. To remove heat from the laser system (and from the liquid-cooled DC power supply, if used), external liquid cooling is essential. A continuous supply of purge gas to the laser system is needed to prevent condensation and reduce contamination on optical surfaces. Internal control electronics act on external signals to vary pulse frequency and duty cycle while monitoring laser performance and safety circuits. A simplified laser system block diagram is shown in Figure 1-3 on page 1-3.


*Figure 1-1. DIAMOND E-400 Series Laser Systems*




a. Output End Isometric View




b. Interface End Isometric View

***Figure 1-2. DIAMOND E-400 Series Laser***

## Purpose of This Manual

This manual is designed to assist the Original Equipment Manufacturer (OEM) during the integration of any DIAMOND E-400 Series laser. It contains information on the performance and operation of the laser as well as installation and control methods. This OEM manual is intended to be used by trained staff during the process of integration into a laser tool.

## E-400 Series Lasers

DIAMOND E-400 Series lasers operate in either a pulsed or quasi-continuous wave modes, and can be operated via several control and communication methods to generate many pulse formats. This allows the user complete control of the output beam and power output.

All E-400 Series lasers are equipped with a powerful embedded control system that is useful in providing onboard diagnostics (setup and troubleshooting) as well as fault isolation. Laser data are accessible using a standard LAN connection via HTML protocol. A detailed description of the embedded control is available in Appendix A: Embedded Control and Diagnostics. A simplified laser system block diagram is shown in Figure 1-3.

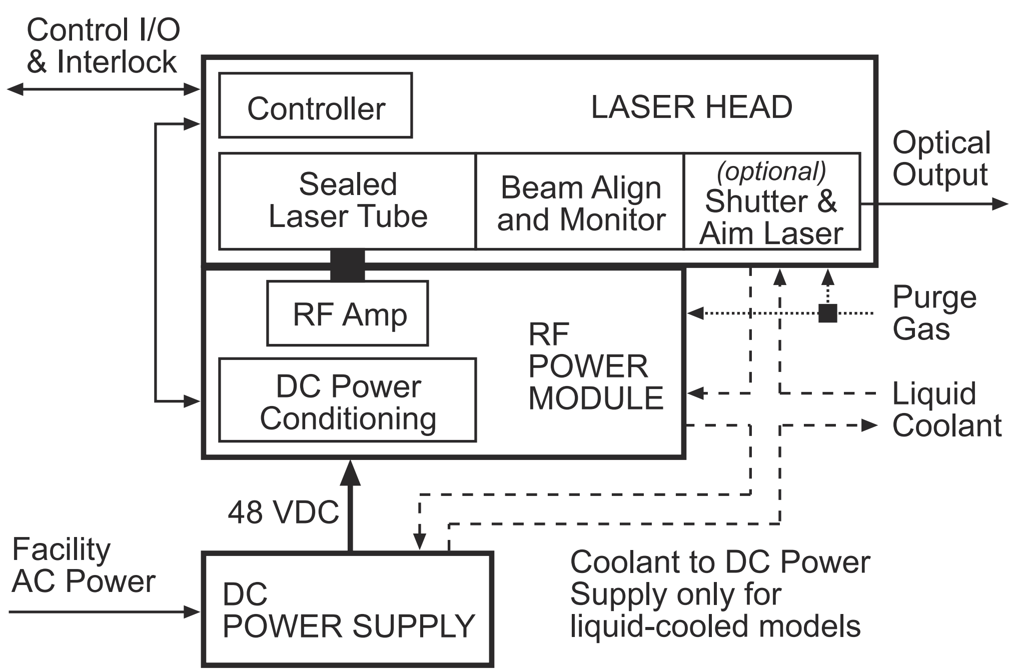



*Figure 1-3. Simplified System Block Diagram*

## Laser System Components

DIAMOND E-400 Series lasers contain the laser head (tube) with beam conditioning optics, (optional) shutter and RF matching network, simmer circuit, control electronics, coolant temperature and internal monitors, and the RF power module (Figure 1-4).

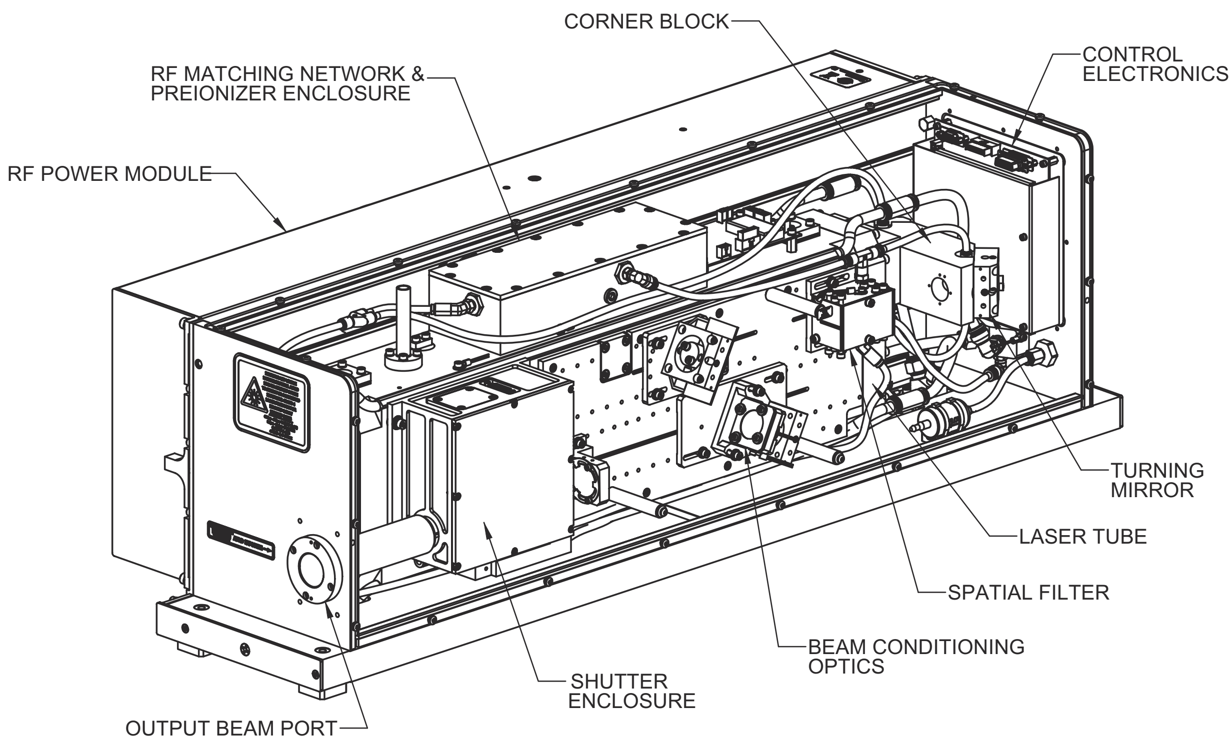



*Figure 1-4. E-400 Series Laser - Component Placement Diagram*

*NOTICE!*
**The laser system incorporates a sealed laser tube, which by design requires no laser gas exchange or periodic refill for operation.**

The all metal construction of the laser head provides high thermal stability and resistance to damage due to shock and/or vibration.

## Tube

The laser tube consists of a two mirror optical cavity with fluid-cooled rectangular shaped (slab design) electrodes extending the length of the tube. An RF matching network is mounted on top of the tube and coils within the tube are positioned to create a uniform distribution of RF energy across the electrodes (see Figure 1-5).

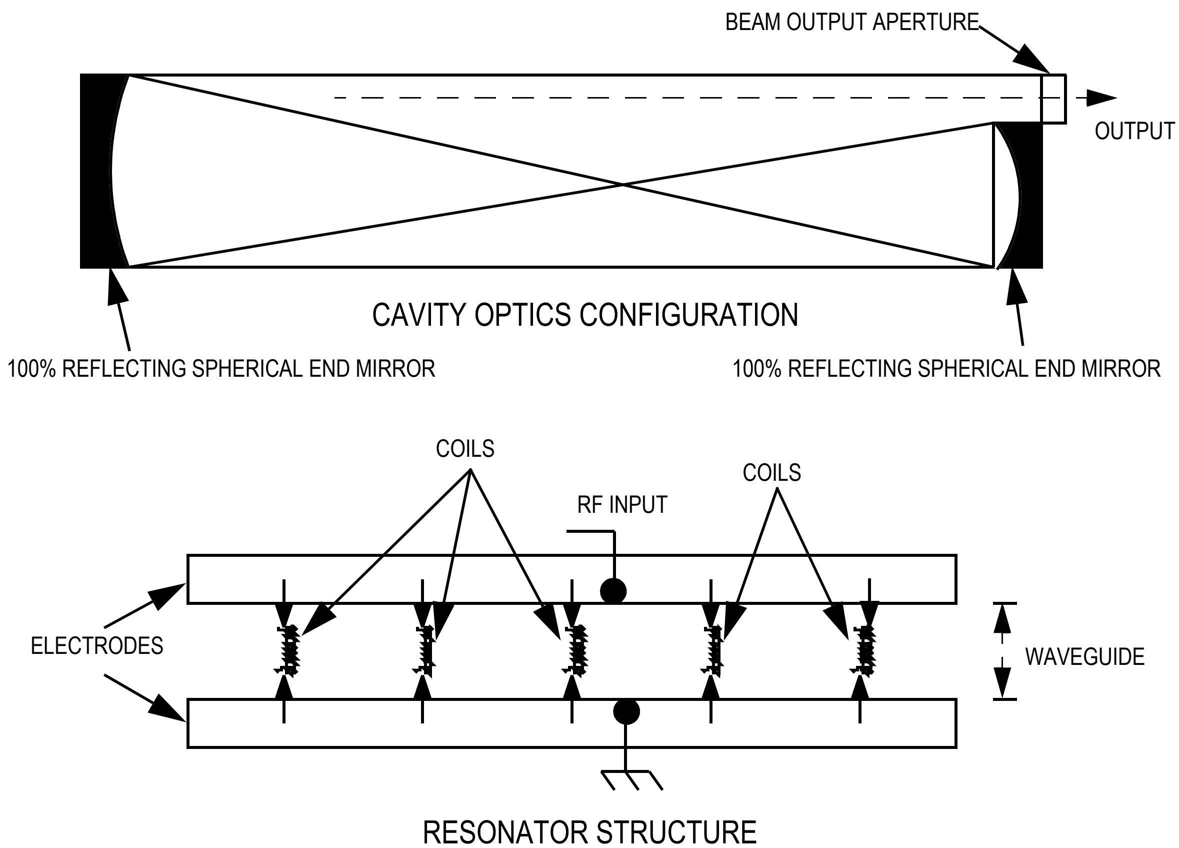



***Figure 1-5. Laser Tube***

One of the 100% reflecting end mirrors partially covers the electrode area. The gap at the end of the mirror forms the output path for the laser beam. The beam exiting in this gap passes through a zinc selenide sealing window at the output end of the tube.

## Optics

The resonator optics are within the sealed head and require no maintenance or alignment. Upon exiting the laser cavity, the asymmetrical laser beam (wide in one transverse beam axis and narrow in the orthogonal beam axis) propagates through an output window and on through a series of precision aligned optical components. These components serve to create a circular symmetrical propagating optical beam. As the beam is corrected for symmetry, it is also focused through a narrow set of knife edges. These knife edges are set wide enough to allow the main lobe of radiation to pass, but also strip off unwanted side-lobe energy. Finally, the beam passes through a final spherical lens which nominally collimates the beam for minimum divergence, then to an (optional) internal shutter assembly before it exits the laser head aperture.

## Simmer Circuit

The simmer circuit generates short duration RF pulses at 1,000 µs intervals (1 kHz rate) to the tube gas in order to promote rapid starting after periods of being turned off. The simmer pulse is automatic to ensure instant-on operation, but is not powerful enough to cause laser action. When commanded to modulate, the simmer circuit is disabled.

## Control Electronics

The E-400 Series control electronics provide control, diagnostics, and fault management for the system. Primary control and diagnostics are provided through dedicated signal connections on the interface panel. The hardware interface circuitry is highly similar to the other DIAMOND OEM products. See Section Four: Control Interfaces for a detailed interface description.

A secondary ethernet interface is provided for remote control, diagnostics, and troubleshooting. See Appendix A: Embedded Control and Diagnostics for more information.

All E-400 Series lasers are equipped with a main controller as well as distributed microcontrollers located throughout the system. Fault management is accomplished by the main controller using data from the distributed microcontrollers. The main controller also polls the distributed microcontrollers for status information and system warnings.

## Coolant Temperature Monitor

All E-400 Series lasers require water with a corrosion inhibitor additive as the cooling medium to remove heat from the laser head and RF power module. Temperature probes and circuits within the laser head and RF power module continuously monitor the coolant temperature whenever the laser is on. If the internal coolant temperature falls outside pre-set limits, the laser will not operate and will indicate a temperature fault condition. To prevent temperature faults, the customer must maintain proper coolant temperature and flow as specified in the utility requirements.

---

***NOTICE!***
**Failure to provide proper coolant temperature and flow to this laser will result in intermittent or halted operation of this laser.**

---

## Coolant Flow Switch (Legacy)

Some early models of the E-400 Series lasers incorporate a flow switch. If incorporated, the flow switch only verifies that cooling fluid is flowing. The customer should maintain proper flow as specified in the utility requirements (with an external flow meter). Failure to provide proper fluid flow will affect the performance of the laser and will void the warranty of this laser.

---

***NOTICE!***
**Failure to provide the proper fluid flow could cause damage to this laser and will void the warranty of this laser.**

---

## RF Power Module

The RF power module provides pulsed RF power to the laser head to energize the laser gas mixture in the tube. The laser output pulse (width and frequency) is based on an input modulation signal to the RF power module.

The RF power module should always be physically and electrically connected to the laser head (load). Although protection is built into the unit, operating the RF power module with no load could cause damage.

The RF power module control circuitry also has the following features:

- Provides protection from duty cycles exceeding mode specific values (see product data sheet located on the Coherent website (www.coherent.com).
- Limits the pulse width to less than 1 msec.
- Monitors forward and reflected RF power to and from the laser head.
- Contains a factory set VSWR limit (a ratio between two monitored voltages, representing efficient coupling of RF Energy) that limits duty cycle in case the laser fails to start.
- Provides a low power RF simmer pulse to ensure that the laser will start after long periods of being off.
- The RF power module contains embedded control sensors which supports fault isolation. Further description of this capability is found in Appendix A: Embedded Control and Diagnostics.

## Internal Power Monitor

Some E-400 Series lasers are equipped with an internal power monitor. If installed, a beam sampling optic is used to provide approximately one percent of the output beam to a thermal detector. This detector generates a voltage that is proportional to the laser output power. This signal is available at the extended interface signal connector. To determine if a power meter is installed in a specific E-400 Series laser, refer to the model-specific data sheet located on the Coherent web site (www.coherent.com).

## DC Power Supply

A high current 48 VDC power supply is the required power source for the all E-400 Series laser systems.

Note that the laser presents a pulsed dynamic load to the DC power supply. Using an oscilloscope, laser modulation induced variation across the RF power module DC input terminals will be observed.

Coherent has qualified a range of air-cooled DC power supplies for use with the E-400 Series laser system (see Appendix E: Accessories and Options). Whichever model is used, refer to the installation instructions provided by the DC power supply manufacturer to determine the correct mounting, AC input power cord/wiring specifications, cooling requirements, connections, and controls.

It is the responsibility of the system integrator to provide AC input power wiring (electrical disconnect, circuit breaker/fusing, power cord, receptacles, and mating plugs). Consult a qualified electrician to select and install the appropriate components that meet local electric codes.

The DC power supply output cables are a critical part of the overall system. Coherent can provide the DC output cables required to handle the high current requirement. Refer to Table 1-1 through Table 1-2.

## Laser System Specifications

The E-400 Series laser system's physical characteristics and utility requirements common to all E-400 Series models are given in Table 1-1 and Table 1-2. Laser performance specifications for a specific E-400 Series laser model are provided in its datasheet available on-line at [www.coherent.com](www.coherent.com) and in the test report provided with each laser system.

***Table 1-1. Physical Characteristics***

| PARAMETER | VALUE |
|---|---|
| **LASER PHYSICAL CHARACTERISTICS** | |
| Weight | 75 kg (165 lbs.) |
| Dimensions (L x W x H) | 948.8 x 336.4 x 320.4 mm<br>(37.35 x 13.25 x 12.62 in.) |

***Table 1-2. Utility Requirements***

| PARAMETER | VALUE |
|---|---|
| **ENVIRONMENT (OPERATING)** | |
| Altitude | <2,000 m (<6,500 ft.) |
| Relative Humidity[(1)] | <95% non-condensing for inlet fluid temperature |
| Ambient Temperature | 5 to 45°C (41 to 113°F) |
| Shock & Vibration | 1G static acceleration<br>0.2G RMS vibration |
| **ELECTRICAL** | |
| DC Input Voltage | 48 VDC ± 1.0% |
| Ripple Voltage | <±1% of peak |
| Maximum Voltage Sag During Peak Current | ≤2.4V from Starting Voltage |
| Line Regulation | ≤±1% |
| Load Regulation | ≤±1% |
| DC Continuous Current[(2)] | ≤170A |
| Dynamic Peak Current | <240A peak for 1 ms |
| **RECOMMENDED DC POWER CABLES (2, 1 RED AND 1 BLACK)** | |
| DC Cable Length (each) | 3 m (10 ft.) |
| DC Cable Wire Gauge (each, 1+ and 1– are used) | 85 $mm^2$ (3/0) |

***Table 1-2. Utility Requirements (Continued)***

| PARAMETER | VALUE |
|---|---|
| **LIQUID COOLING** | |
| Composition | Distilled or de-ionized water plus corrosion inhibitor |
| Flow Rate | 9.5 lpm (2.5 gpm) |
| Heat Load (3) | <8.5 kW (<30 kBtu/hr) |
| Maximum Static Pressure | 827 kPa (120 psi) |
| Pressure Differential (4) | 344 kPa (50 psi) @ 9.5 lpm (2.5 gpm) |
| Set Temperature Range (at laser head coolant inlet) | 21 to 25°C (69.8 to 77°F) |
| Temperature Variation about Set Temperature | <±1°C (±1.8°F) |
| Particulate Size | ≤30 microns in diameter |
| **LASER PURGE GAS** | |
| Composition | $N_2$ or Clean, Dry Air |
| Flow Rate | 2.0 lpm (4.25 scth) |

The above specifications subject to change without notice.

(1) Do not operate at or below dew point.

(2) Current rating may vary with specific model.

(3) If a closed-loop system is used, it must have sufficient capacity to handle this heat load in addition to meeting the other fluid requirements listed in this table. If the liquid-cooled DC power supply option is chosen, the cooling system must also account for the additional heat load.

(4) Measured from system inlet to outlet ports and does not include the pressure drop from chiller fittings or the supply and return hose.

## Laser Dimensional Drawings

The laser dimensions and required clearance are shown in Figure 1-6.

Note that the clearance dimensions given for interface connections and service access are minimums. Increasing the clearance dimensions will provide ease of installation, troubleshooting, and service.

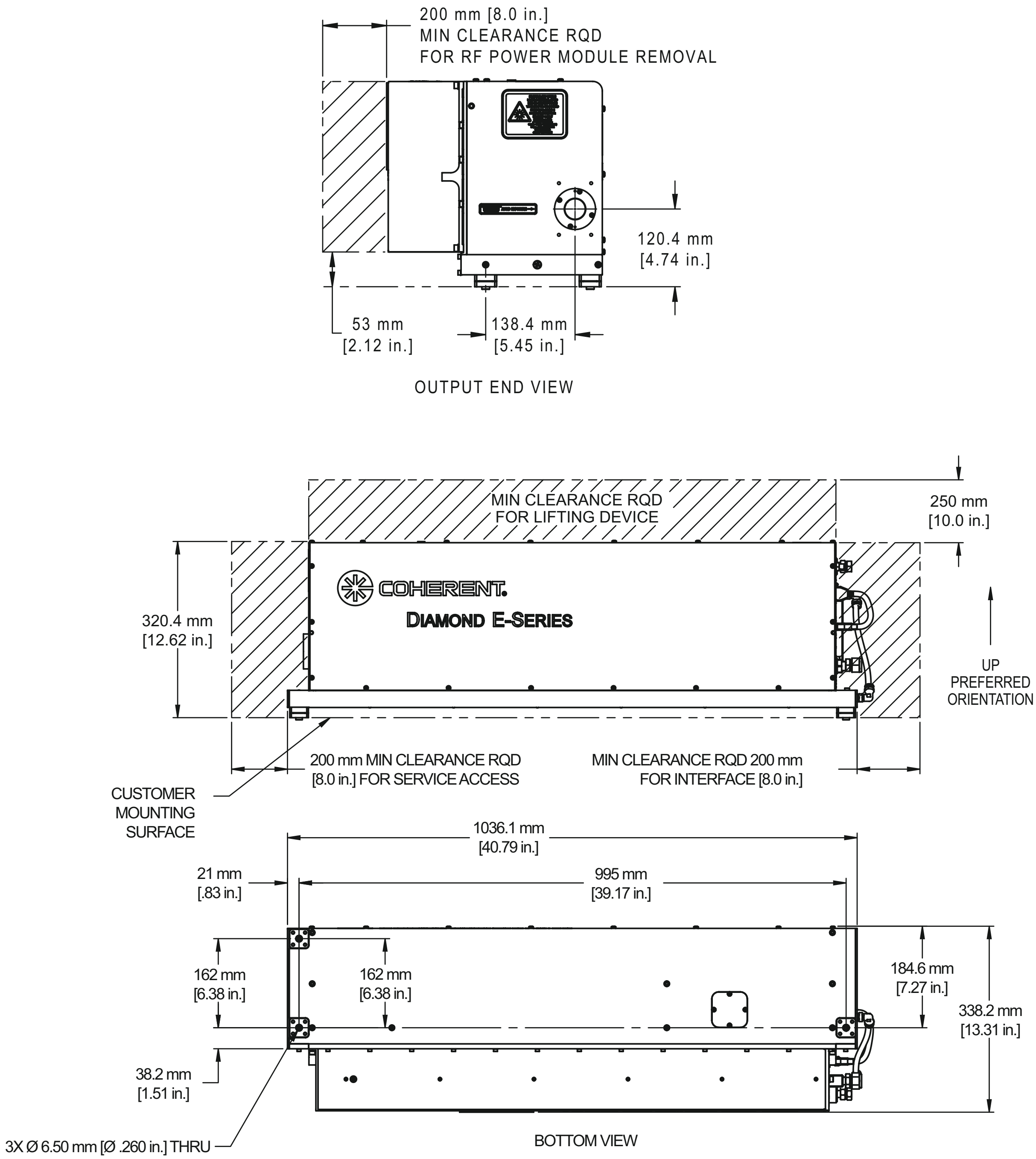



***Figure 1-6. E-400 Series Dimensions (including clearance)***

# SECTION TWO: LASER SAFETY

## *Optical Safety*

DIAMOND E-400 Series lasers have undergone extensive testing to ensure that, with proper usage, it is a safe and reliable device.

Laser light, because of its special properties, poses safety hazards not associated with light from other sources. The safe use of lasers requires that all laser users and everyone near a laser be aware of the dangers involved in laser operation.

**DANGER!**
**Class 4 laser product. Avoid eye or skin exposure to direct or scattered radiation.**

## *Viewing Distance*

The E-400 Series lasers produce optical power levels that are dangerous to the eyes and skin if exposed directly or indirectly. These products must be operated only with proper eye and skin protection at all times. Never view directly emitted or scattered radiation with unprotected eyes. When viewing the laser during operation, the operator must maintain the Nominal Ocular Hazard Distance (NOHD) between the laser or scatter radiation and the operator's eyes. Figure 2-1 summarizes the NOHD for the power range of the E-400 Series for direct viewing of the collimated beam along with two other common configurations. The NOHD in this figure is based on the Maximum Permissible Exposure (MPE = 0.1 W/cm$^2$) level for each power condition as specified in ANSI Z136.1-2007 and IEC 60825-1-2007 (Rule 2 applies over nearly all of the operating range of this laser).

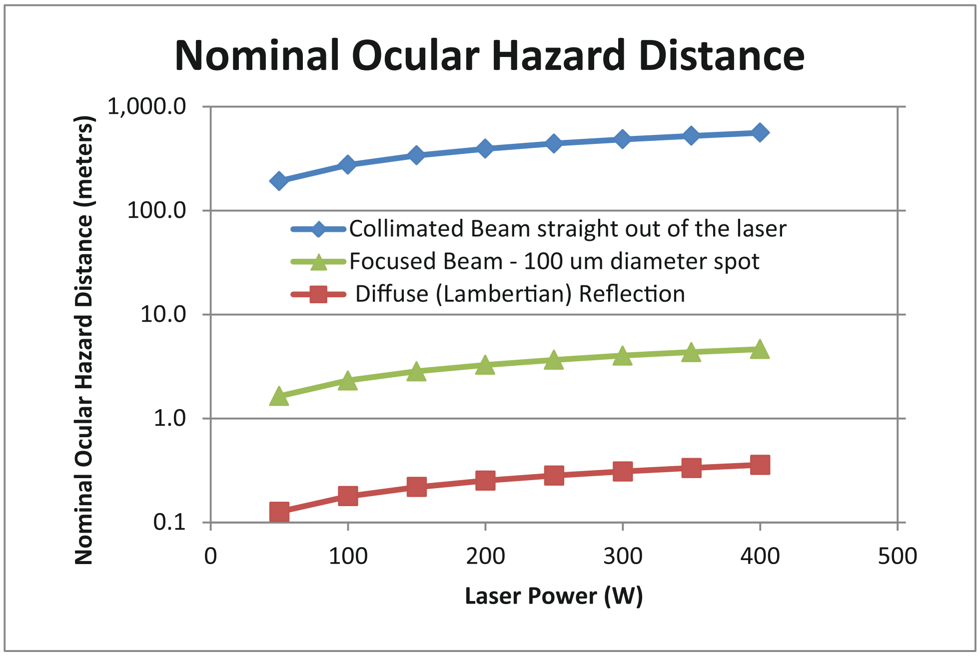



***Figure 2-1. Nominal Ocular Hazard Distance (NOHD) for indicated conditions calculated per ANSI Z136.1-2007***

**WARNING!**
**Direct eye contact with the output beam from the laser will cause serious eye damage and may cause blindness.**

All personnel in the same room as the laser or anyone who may be exposed to the laser beam should be informed that a laser is in operation. All personnel must wear laser safety glasses which protect against the wavelengths in use.

**CAUTION!**
**Exercise caution to protect against specular reflections since all reflections at the E-400 Series wavelength are invisible. These reflections, while weaker than the main beam, may be sufficiently intense to cause eye damage.**

Eye safety is a great concern when using a high-power laser such as the E-400 laser. The long NOHD for the collimated beam highlights the need to avoid stray specular reflections from polished or shiny surfaces. These reflections, while weaker than the main beam, may still be sufficiently intense to cause eye damage.

Laser beams are also powerful enough to burn skin, clothing, or paint. They can ignite volatile substances such as alcohol, gasoline, ether, and other solvents and can damage the light-sensitive elements in video cameras, photomultipliers, and photodiodes.

Coherent provides the following recommendations to promote the safe use of all E-400 Series lasers. Operators are advised to adhere to these recommendations and employ sound laser safety practices at all times.

- Use protective eyewear when operating the laser and guard against inadvertent exposure to skin or clothing. Select eyewear which is suitable for use with the wavelengths and radiation intensity that the laser emits. Refer to the *Guide for Selection of Laser Eye Protection*, Laser Institute of America ($6^{th}$ Edition), 2007.
- Do not remove the protective covering over the beam path. During normal operation, internal reflections are confined within the laser head and pose no safety hazard.
- Never look directly into the laser output port when the power is on.
- Set up the laser and all optical components used with the laser away from eye level. Provide enclosures for the laser beam.
- Use the laser in a room with access controlled by door interlocks. Post warning signs. When operating the laser, limit access to the area to individuals who are trained in laser safety.
- Do not use the laser in the presence of flammables, explosives, or volatile solvents such as alcohol, gasoline, or ether.

For additional information on laser safety, refer to the following publications:

- *American National Standard for the Safe Use of Lasers*, Z136.1-2007, American National Standards Institute, 2007.
- *Performance Standards for Laser Products*, United States Code of Federal Regulations, 21 CFR 1040 10 (d).
- *Laser Safety Guide,* Laser Institute of America. ($11^{th}$ Edition). Orlando, FL 2007.
- D. Sliney and M. Wolbarsht. *Safety with Lasers and Other Optical Sources,*. Plenum Publishing Company, New York, NY, 1980.

Many of these documents on laser safety are available through the Laser Institute of America, 13501 Ingenuity Drive, Suite 128, Orlando, FL 32826. Call them at 800-345-2737, or visit their web site: www.lia.org.

## *Electrical Safety*

All E-400 Series laser systems, which consist of the laser head and the RF power module, require high current +48 VDC to operate. This voltage is supplied by commercial power supplies available from various manufacturers (see Appendix E: Accessories and Options). The typical input voltage to these power supplies is 208 or 380 VAC. These voltages can be lethal. Every portion of the electrical system should be treated as if it is at a dangerous voltage level.

### Laser Head

High RF power levels are present in the RF power module and laser head when the power is on. Please read the appropriate manual sections carefully before attempting any maintenance of components housed within the laser head.

## *Laser Safety Requirements*

This laser does not conform to the United States Government requirements for laser safety. In the United States, it is the responsibility of the buyer that the product sold to the end user complies with all laser safety requirements prior to resale. These laser safety requirements are contained in 21 CFR, Sub Chapter J and are administered by the Center for Devices and Radiological Health (CDRH).

Integrators who incorporate an E-400 Series laser into other products that they introduce into United States commerce are defined in the law as manufacturers who are thus required to manufacture their products to conform to the Federal standard, certify them, and submit product reports to the CDRH.

The text of this federal standard is available from the U.S. Government Printing Office Bookstore located in most major cities in the U.S. as well as Washington, D.C. A report detailing how the laser product complies with the Federal standard is required before the product is shipped. The form of this report is covered in a pamphlet entitled: *Compliance Guide for Lasers*, HHS Publication FDA 86-8260. This pamphlet is available at no cost from:

U.S. Food and Drug Association
Center for Devices and Radiological Health
Document Mail Center – WO66-G609
Sliver Spring, MD 20993-0002
www.fda.gov

For jurisdictions outside of the United States, it is the responsibility of the buyer of this laser device to ensure that it meets the local laser safety requirements.

## Safety Interlocks

The laser head and RF power module covers are not interlocked and should only be removed by trained service technicians.

---

**WARNING!**
**Use of controls or adjustments, or performance of procedures other than those specified herein, may result in hazardous radiation exposure.**

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## *Radiated Emission Compliance*

E-400 Series lasers have been tested and verified that they are in compliance with the radiated emission limits of FCC Part 18 Subpart C Radiated Emissions as required for industrial, scientific, and medical equipment. Test plan / procedure per ANSI C63.4.

## *Compliance to Standards Relevant to CE Mark*

The E-400 Series of lasers are OEM products, and are sold as components for integration into complete laser systems by a system integrator. These products are tested and CE Marked as independent products. For specific details regarding what applicable compliance directives and standards the products have been tested to, please refer to the Declaration of Conformity which is available upon request from Coherent, per contact information on page ii of this manual.

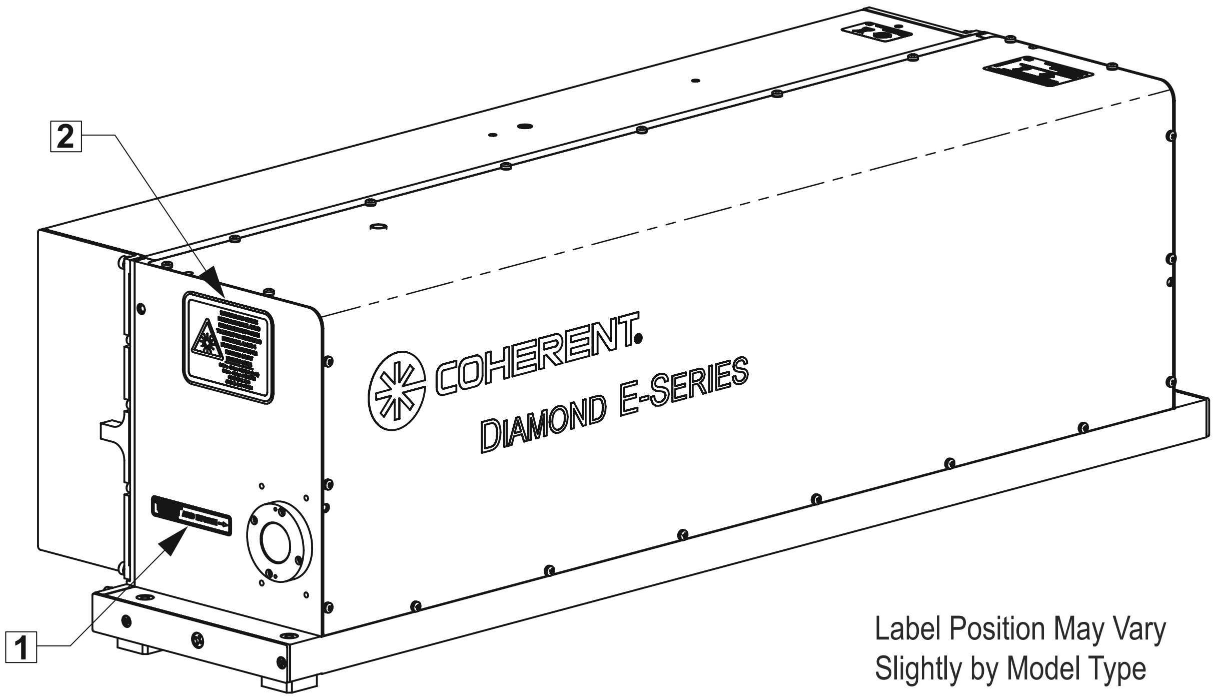
Compliance to applicable standards for a particular laser tool incorporating E-400 lasers must be demonstrated by the manufacturer of the complete system. The primary issue for the system integrator is to design covers, shielding, grounding, routing of electrical cable assemblies, and control elements with the proper safety features so that during subsequent testing the system meets the appropriate standards.

Coherent recommends the following guidelines to control the amount of radiated interference:

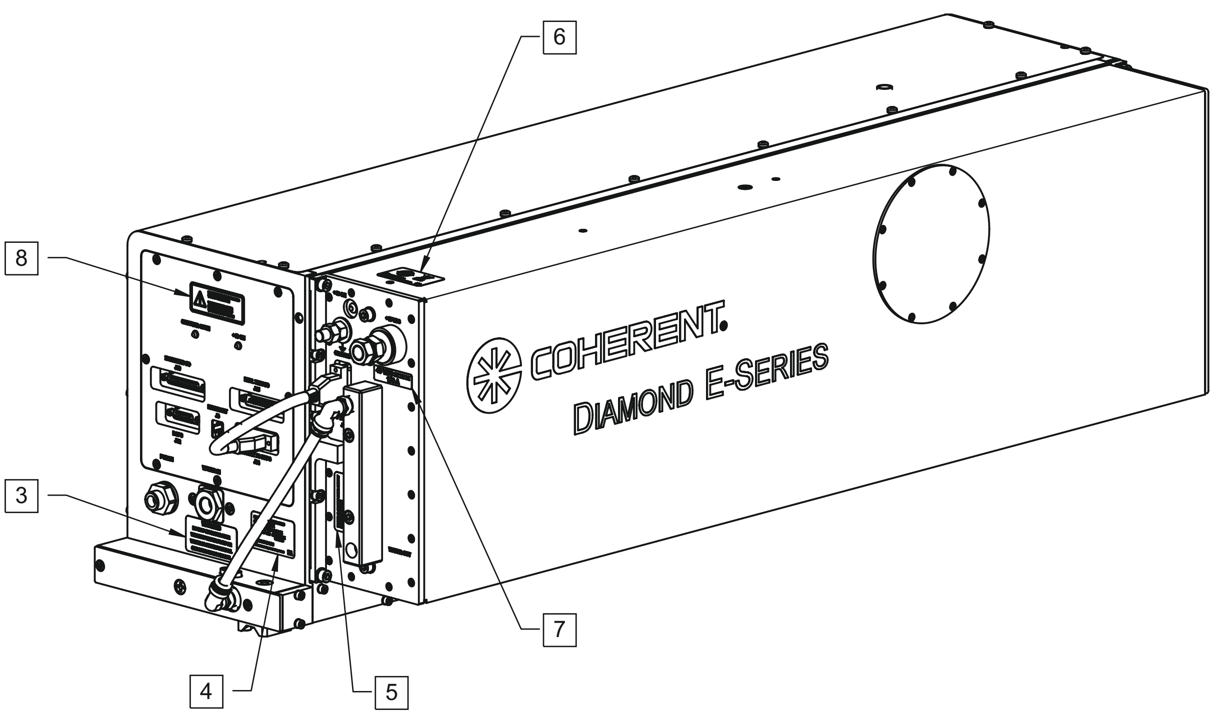
- Use high quality cables an connectors for all electrical connections
- Verify grounding of cable shields, generally at both ends of the cable

## Labeling

Figure 2-2 shows the positions of all the labels located on the DIAMOND E-400 Series laser heads.



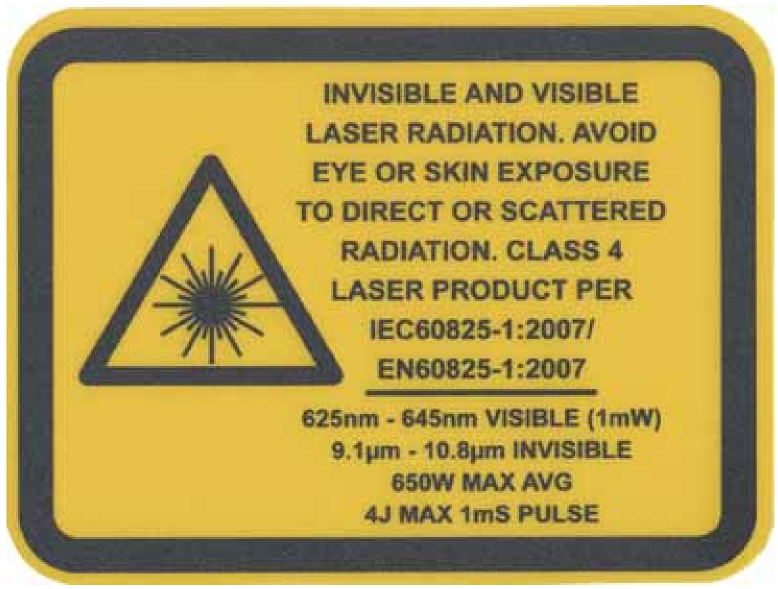

a. Output End




b. Interface End

***Figure 2-2. Label Placement***


1 – Laser Aperture Label




2 – Laser Classification Label


3 – Coolant Requirement Warning Label


E-400i Model
Label Shown

4 - Laser Head Product Nameplate Label (Example)

***Figure 2-3. Labels***


E-400 Model
Label Shown

5 – RF Power Module Product Nameplate Label (Example)


Made in USA


Made in Thailand

6 – Compliance Label on RF Power Module


Current Rating May
Vary by Model Type

7 – Power Input Requirement Label


8 – Cable Disconnect Cautionary Label

***Figure 2-3. Labels (Continued)***

## Waste Electrical and Electronic Equipment (WEEE, 2002)

The European Waste Electrical and Electronic Equipment (WEEE) Directive (2002/96/EC) is represented by a crossed-out garbage container label, as shown in Figure 2-4. The purpose of this directive is to minimize the disposal of WEEE as unsorted municipal waste and to facilitate its separate collection.

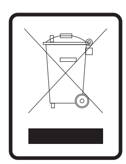
***Figure 2-4. Waste Electrical and Electronic Equipment Label***

## Battery Directive

The battery used in this product are in compliance with the EU Directive 2006/66/EC ("EU Battery Directive").

***Table 2-1. Battery Contained in this Product***

| DESCRIPTION | TYPE |
|---|---|
| 3v memory backup coin cell | Lithium |



Dispose of batteries according to local regulations. Do not dispose as normal waste. Consult your local waste authorities for guidance.

# SECTION THREE: UTILITY REQUIREMENTS AND SYSTEM INSTALLATION

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***NOTICE!***
**Before installation, it is essential that the customer read this manual thoroughly. It is important that the user become familiar with all aspects of the installation and operation of the E-400 Series laser system, including and specifically the information contained in Section Two: Laser Safety.**

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## *Preinstallation Checklist*

In order to perform a smooth integration of the laser system into a tool or installation at a customer site, it is necessary to prepare in advance. A preinstallation checklist outlining the general requirements is provided in Table 3-1.

***Table 3-1. Preinstallation Checklist***

| ACTIVITY | GENERAL REQUIREMENTS | REFERENCE(S) |
|---|---|---|
| Confirm Laser Environment | [ ] Temperature and Humidity in specification<br>[ ] Cleanliness<br>[ ] Vibration<br>[ ] Ventilated space | “Confirm Laser Environment” on page 3-3<br><br>“Operation in Humid Environments” on page 3-4 |
| Receive and Inspect | [ ] Area is clean and sufficiently large enough to uncrate laser<br>[ ] Forklift or pallet jack capable of moving the fully loaded crate (143 kg/315 lbs.)<br>[ ] Forklift or hoist capable of lifting the 75 kg (165 lbs.) laser off shipping pallet<br>[ ] Cart capable of moving 75 kg (165 lbs.) laser to installation area | “Receive and Inspect” on page 3-5<br><br>“Unpacking and Inspection” on page 3-22 |
| Laser Installation Area | [ ] Clear path to the installation site<br>[ ] Forklift or hoist capable of lifting the 75 kg (165 lbs.) laser plus lifting hardware into tool<br>[ ] Laser head mounting area prepared: lift access, mounting feet installed, able to support 75 kg (165 lbs.) laser system plus weight of cables, hoses, output aperture accessories, etc.<br>[ ] Service access provided<br>[ ] All connections reach the laser head | “Laser Installation Area” on page 3-6<br><br>“Mounting Laser System Components” on page 3-34 |
| Laser System Cooling | [ ] Chiller installed and operational (loop test OK)<br>[ ] Coolant is a mixture of water and corrosion inhibitor<br>[ ] 30 µm particle filter installed at laser head inlet<br>[ ] Shut-off valves installed (optional, recommended)<br>[ ] 1/2” ID or greater hose between the laser system and chiller<br>[ ] Required flow rate, temperature set point and temperature stability capability verified | “Laser System Cooling” on page 3-7<br><br>“Coolant Composition” on page 3-8<br><br>Table 1-2 on page 1-10 |
| Laser System Purge Gas | [ ] $N_2$ or filters installed to provide clean, dry air<br>[ ] Shut-off valve installed (optional, recommended)<br>[ ] Output fitting installed to accept 1/4” OD tubing<br>[ ] Clean, flexible 1/4” OD tubing to connect purge gas supply to the laser head | “Laser System Purge Gas” on page 3-12<br><br>“Air Filter Dryer Unit” on page E-2 |
| DC Power Supply | [ ] Rack w/shelf, bench or frame (mounting) prepared<br>[ ] Electrical circuit with circuit breaker/fuse and electrical disconnect ready<br>[ ] Mains input (electrical disconnect to power supply) power cable ready<br>[ ] Cooling water system, supply and return lines and fittings ready (for liquid-cooled DC power supplies only) | OEM Product Literature (external document(s))<br><br>“DC Power Supply” on page 3-15 |

***Table 3-1. Preinstallation Checklist (Continued)***

| ACTIVITY | GENERAL REQUIREMENTS | REFERENCE(S) |
|---|---|---|
| Beam Delivery System | [ ] Beam delivery system purge gas ready<br>[ ] Optical Isolator installed (if cutting/marking reflective material)<br>[ ] External optical beam delivery system meets optical specifications | “Beam Delivery System” on page 3-16 |
| Laser Control, Measurement and Diagnostic | [ ] If using a Coherent E/G/K Remote Controller, controller is available<br>[ ] If monitoring laser diagnostics with a personal computer via network cable, a computer Ethernet cross-over cable is required<br>[ ] For 3rd party controller, see OEM documentation<br>[ ] Interlocks installed<br>[ ] Suitable Power Meter and Detector Head available | “Laser Control, Measurement & Diagnostic” on page 3-17 and Section Four: Control Interfaces<br><br>DIAMOND E/G/K OEM/ Industrial Laser Remote Controller Operator’s Manual, part number 1235412 (external document)<br><br>“Power Meters and Sensors” on page E-1 |
| Laser Safety | [ ] Laser Safety Officer (LSO) identified (recommended)<br>[ ] Laser Safety Training completed<br>[ ] Laser Controlled Area established<br>[ ] Personal Protective Equipment (laser safety eyewear) available | “Laser Safety” on page 3-18<br><br>Section Two: Laser Safety |

## Confirm Laser Environment

The laser must be installed and operated in a temperature and humidity-controlled environment. The operating temperature must be 5 – 45ºC (41 – 113ºF). The humidity must be 5 – 95%, non-condensing, for the laser system coolant inlet temperature. Operating altitude must be <2,000 m (6,600 ft.).

Additionally, the laser environment should be clean and free of air-borne particles, and mounted such that vibrations are within specification. If possible, create a “clean” area for the laser and initial beam delivery optics and a “dirty” area for the final beam delivery system and work piece.

Since the laser and/or associated beam delivery systems may be nitrogen purged and the cutting/marking processes generally create noxious fumes, make sure to provide adequate ventilation for all operators in the area.

## Operation in Humid Environments

The cooling fluid of the E-400 Series lasers can condense moisture from the air when the temperature of the cooling fluid is at or below the dew point of the air.

***NOTICE!***
**The system must not operate in a condensing environment since this condition will lead to catastrophic failure in both the laser head and the RF power module. Doing so will void the warranty. It is the responsibility of the customer to ensure an E-400 Series laser system is never operated in a condensing environment. Failed laser heads and RF power supplies must be returned to the factory for repair.**

Condensation may form on any component surface when the surface temperature is at or below the dew point of the air. The typical condition that leads to condensation is warm, humid weather combined with fluid that is cooler than the surroundings.

High risk conditions which are likely to lead to condensation are:

- Operating the laser in a room that is not air conditioned in high humidity environments
- Using cooling fluid that is not temperature controlled
- Leaving the cooling fluid system on when the laser is not operating for extended time periods

Risk of Condensation: The information required to determine if the cooling fluid temperature will lead to condensation is:

- Room temperature
- Relative humidity

Since weather conditions change, these factors need to be periodically checked especially in spring, summer, or wet seasons. In environments that are air conditioned, Coherent recommends setting the cooling fluid temperature to 23°C (73.4°F). For environments that are not air conditioned, Coherent recommends that the cooling fluid temperature be increased to the air temperature to avoid condensation in humid climates, but no higher than 26ºC (78.8ºF) and not less than 20ºC (68ºF).

## Receive and Inspect

The E-400 Series laser system packaging has been designed for robust shipment. Upon receiving the system, inspect the outside of all containers immediately to ensure no damage occurred during transit. If there appears to be visible damage (holes in the containers, fluid damage, crushing, etc.), immediately notify Coherent and a representative of the carrier. Request that a representative of the freight company be present when unpacking the contents.

---

***NOTICE!***
**To avoid damage to the system, keep the original shipping containers and packing materials for transporting the E-400 Series laser system from one location to another. If the system is to be returned to Coherent for repair, it must be transported in the original shipping container.**

---

The containers may appear to be in good condition, but the contents may be damaged. Inspect all major components as they are unpacked. Unpacking procedure instructions are found in “Installation” on page 3-18.

To unpack the laser system, at least two people and the following tools will be required:

- Scissors or a package cutting knife
- 8” adjustable wrench
- Large Pliers (may be required to loosen 2 wing-nuts)
- Forklift or pallet jack able to lift and move at least 143 kg (315 lbs.) - total weight of a fully loaded shipping crate
- Forklift or hoist capable of lifting the 75 kg (165 lbs.) laser system out of the crate
- Cart capable of supporting and transporting the 75 kg (165 lbs.) laser system to the installation area

---

***NOTICE!***
**While in transit, the shipping container and its contents may be exposed to cold temperatures. To prevent condensation from developing on and within the laser system and causing damage, move the crate to a location near the installation area and allow it to acclimate before unpacking the laser.**

---

## Laser Installation Area

It is assumed that the laser will be integrated into a laser cutting or marking tool designed and manufactured by a third party. Because each system installation is unique, only general guidelines will be discussed.

### Service Access

It is highly recommended that the system integrator follow Coherent's recommendation for laser orientation with respect to service access within the customer's equipment (see Figure 3-25a "Laser Head" mounting dimensions).

If placing the laser inside a cabinet or enclosure, make sure to design sufficient access to all lifting and mounting points. Additionally, make sure to provide adequate service clearance at the rear (interface connectors), the front (coupling to beam delivery system), top and sides (to remove covers for service access), and above and around the RF power module, as the RF power module is field replaceable.

- Mount the laser system with the RF power module readily accessible through service access panels.
- Provide easy access to all electrical and signal connections.
- Provide easy access to cooling and purge connections.

***NOTICE!***
**Providing the recommended service access will provide ease and speed of service and repair of the E-400 Series laser system.**

Also, consider the interface/connection point locations at the rear end of the laser system and the length of cables, hoses and tubing, including service loops, when placing the DC power supply, chiller and control system.

### Mounting Feet

Since all E-400 Series laser beams are precisely aligned with reference to three kinematic mounting feet, it is recommended that laser integrators utilize this mounting feature. Refer to the mechanical drawing in Figure 3-25d "Mounting Foot Detail".

Because beam pointing is virtually identical for all lasers referenced to these feet, re-alignment of delivery system optics, in the event of a laser replacement, will greatly be minimized if aligned to the reference position. Since the laser is precisely aligned to these mounting features, a laser can be replaced with minimal or potentially no delivery system re-alignment.

## Laser System Cooling

The E-400 Series laser head and the RF power module require a continuous flow of constant temperature cooling fluid. Because the properties of the cooling fluid are important for laser performance, ensure that the conditions remain within the tolerance limits listed in Table 1-2 on page 1-10 at all times.

A closed-loop cooling system (chiller) should be used to obtain consistent and stable laser performance. The chiller must be able to remove up to 8.5 kW of heat, plus an additional 2 kW if the liquid-cooled DC power supply option is used. The coolant composition for the closed-loop chiller is described in the following section.

A typical flow diagram is shown in Figure 3-1. The delivery system and/or laser power detector may be connected in parallel auxiliary loops as long as they do not reduce the required flow to the laser, or they may be cooled by a separate chiller.

If using the optional liquid-cooled power supply, it is to be connected in series *after* the laser system. The liquid-cooled power supply must be installed with the provided bypass loop to maintain the high flow required by the laser (as the power supply alone will restrict the flow).

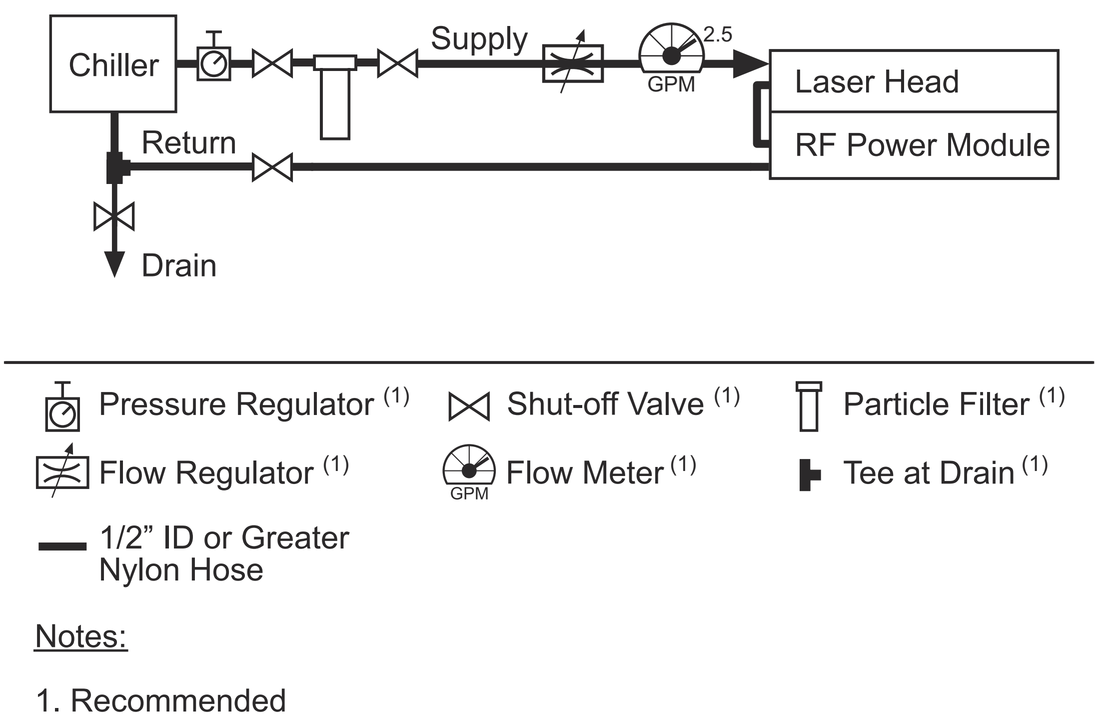


***Figure 3-1. Coolant Flow Diagram***

## Coolant Temperature

At the laser head, the inlet temperature of the cooling fluid should always be above the dew point to prevent condensation from developing inside the laser head or RF power module.

## Coolant Filtering

To prevent accumulation of debris in the cooling system, the coolant should be filtered at the inlet to the laser system. Coherent recommends the use of a particle filter that traps particles larger than 30 µm in diameter. However, if the chiller manufacturer recommends a finer filter, follow their recommendation.

A coolant kit is provided with each laser system, which contains ¾" NPT to Male GHT (Garden Hose Thread) and ¾" NPT to Female GHT fittings. This permits the use of off-the-shelf garden hose to connect the laser system to the chiller system. In general, Coherent recommends the use of hose with an ID of 1/2" (12.7mm) or greater to minimize the pressure drop from the chiller to the laser system. Hose fittings and clamps to connect hoses to the chiller are not included. Do not exceed the maximum hose length specified by the chiller manufacturer.

Shut-off valves on the supply and return lines are recommended to facilitate maintenance to the cooling system filters and laser system.

## Coolant Composition

The recommended coolant composition is a mixture of clean distilled or de-ionized water and OPTISHIELD®, a low toxicity, corrosion inhibitor. OPTISHIELD is available from OptiTemp, Inc. and can be shipped worldwide. Contact information is provided in Table 3-2. Visit the Opti Temp, Inc. website (**www.optitemp.com**) for complete product information on OPTISHIELD®.

The required mixture is a 10% solution of OPTISHIELD and distilled or de-ionized water (Example: 1 liter of OPTISHIELD into 9 liters of distilled water). Contact OptiTemp for detailed water quality recommendations and for complete product information.

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**NOTICE!**
**To prevent damage to the laser head and RF power module, never operate the E-400 Series liquid-cooled laser using untreated tap, distilled, or de-ionized water as a coolant. The laser contains materials which will suffer corrosion damage when exposed to water without corrosion inhibitors. Corrosion caused by improperly treated coolant voids the warranty.**

---

***Table 3-2. Recommended Coolant for E-400 Series Lasers***

| **PRODUCT NAME** | **MANUFACTURER'S NAME & CONTACT INFORMATION** | **HEAT TRANSFER FLUID TYPE** | **REQUIRED HEAT TRANSFER FLUID CONTENT** | **FREEZING BURST PROTECTION** |
|---|---|---|---|---|
| OPTISHIELD® | OptiTemp, Inc.<br>www.optitemp.com<br>US/Canada<br>(231) 946-2931 | Corrosion Inhibited Water | 10% Solution in Water | Does not reduce water freezing point! |
| TRAC100 | Nalco<br>www.nalco.com<br>US<br>(630) 305-1000 | Corrosion Inhibited Water | 2500 ppm in Water (2.5 ml per 1l of water) | Does not reduce water freezing point! |

It is important to add the right amount of corrosion inhibitor in the coolant mix. Too much may result in poor cooling performance and too little will result in reduced protection against corrosion. Levels lower than the recommended amount may also encourage microbial growth, which can result in fouling and blockage of the cooling system. Also, only use fresh, clean coolant mix (OptiTemp recommends that the coolant be drained and replaced annually).

OPTISHIELD is the recommended corrosion inhibitor, however it may not be readily available outside the US, or may be regulated by local environmental legislation. Coherent suggests using TRAC100 by Nalco as an alternative. Please visit **www.nalco.com** for more information.

## Freeze/Burst Protection

The recommended coolant mixture does not provide freeze protection; therefore the coolant temperature must be maintained above the freezing point of water. Since lower temperatures may occur during shipment and storage, the DIAMOND E-400 Series laser system (or separate laser head or RF power module components) should never be stored or transported unless the coolant has been completely removed by using a compressed air supply to blow out all coolant passages.

***NOTICE!***
**Never store or ship a complete E-400 Series laser system or laser head or RF power module (or liquid-cooled DC power supply, optional) with coolant installed, as the coolant may freeze and cause permanent internal damage. Always remove the coolant prior to storage or shipment by using a compressed air supply to blow out all coolant passages. Plug or cap coolant inlet and outlet fittings after draining to prevent residual coolant leaks during storage or shipment. Damage to the laser during storage or shipment, as a result of failure to remove coolant and plug the inlet and outlet fittings after coolant removal, is specifically excluded from the product warranty.**

## Flow Direction

At the laser system, the flow direction must be as follows: coolant is to flow to the laser head first, then out to the RF power module before being returned. Do not reverse flow direction or split the flow into two separate parallel circuits at the laser system. Refer to Figure 3-2.

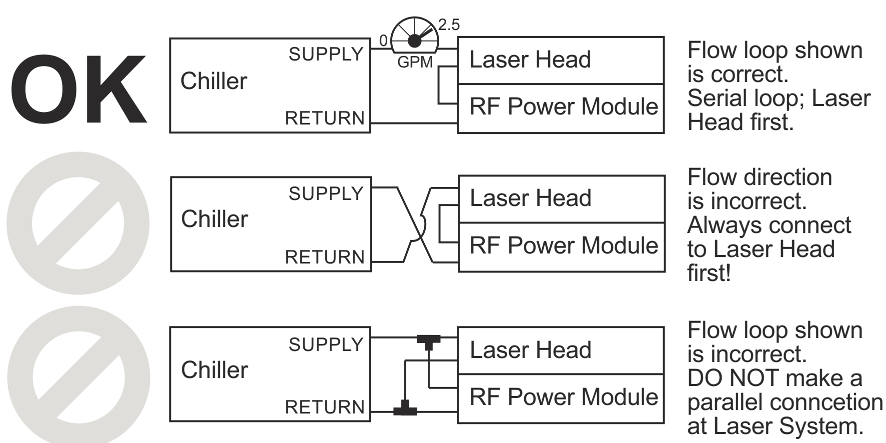


***Figure 3-2. Coolant Flow to Laser System***

If any other components are included in the cooling loop (e.g. DC power supply, as shown in Figure 3-1), they must not reduce the coolant flow to the laser head, and any heat absorbing/generating components must come after the laser system.

### Chiller Electrical Supply

A large industrial chiller normally requires a 230 or 480 VAC, 3-phase electrical supply with its own circuit breaker or fuse protection and an electrical disconnect. Refer to the chiller manufacturer's installation guide for electrical requirements and installation instructions.

### Electrical Disconnect

It is recommended that the chiller have a main power disconnect to electrically isolate it from mains power for maintenance and service. Consult a qualified electrician to select and install this hardware. A typical disconnect switch with fuse protection is shown in Figure 3-3.

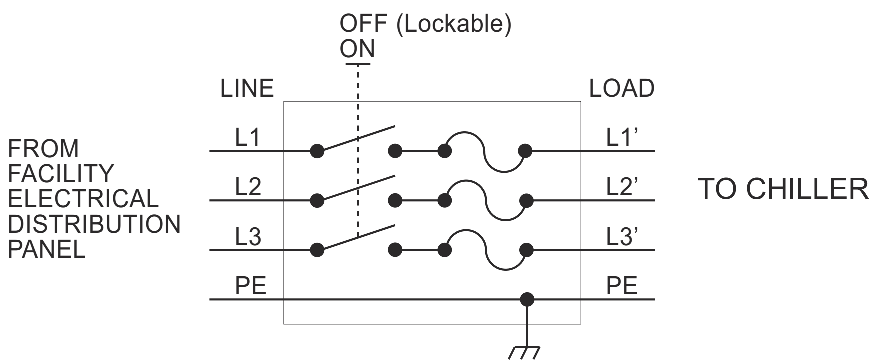


***Figure 3-3. Electrical Disconnect Switch (with Fuse Protection)***

## Laser System Purge Gas

*NOTICE!*
**The use of specified purge gas will extend the life and reduce cost of ownership of the E-400 Series laser systems.**

The quality of the purge gas is extremely important factor for trouble free operation of the laser. While the preferred purge gas is nitrogen with a purity of 99.95%, clean, dry air (CDA) is also acceptable.

E-400 Series lasers are used in a wide range of material processing which often has by-products of dust, smoke, fumes, oil, and various gases. These by-products can cause contamination of the laser head optics as well as the beam delivery optics and electronic components. Contamination will severely degrade the system performance and can lead to damage or failure of sensitive components.

Passing a purge gas through the laser head and RF power module can prevent component damage by creating an internal positive pressure. Also, under some conditions of high humidity, the laser beam can be distorted by optical absorption of the laser beam by fluid vapor. This effect can be totally eliminated by use of a proper gas purge.

### Delivery System Purge Gas

Purge gas may be connected to the port on the rear of the laser head. The gas purge to the laser head exits primarily via the beam output aperture. While this is the primary exit path for the purge gas, small gaps in the interfaces between the component comprising the protective housing result in additional purge exit paths. Therefore, the user should not rely on purge gas exiting the beam output aperture to provide purge gas to the user's beam delivery optics. A separate purge should be used for external beam delivery optics.

Threaded holes in the output end plate provide a convenient means to connect the user's beam delivery optics while maintaining a gas seal at this interface.

*NOTICE!*
**Do not rely on purge gas exiting the beam output aperture to purge the external beam delivery optics. A separate purge line should be used to purge the external beam delivery optics.**

If a shared purge gas supply is directed to both the laser system and the beam delivery system, make certain the supply and supply line is properly sized to provide an adequate flow rate to the laser system.

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*NOTICE!*
**Other inert gases such as argon (Ar) must not be used. Use of inert gases will result in damage to the RF laser head. Only nitrogen as described above or compressed air as described below should be used as a purge gas.**

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### Guidelines for Use of Compressed Air for Purge

If nitrogen is not available, the alternative is clean, dry, oil-free compressed air. Compressed air is available in many facilities but typically is contaminated with water and oil vapors. The purity requirements for the compressed air are:

1. Filtered to remove particles larger than 1 micron.
2. Dried so that dew point is 10°C (18°F) lower than the inlet cooling fluid temperature to the E-400 Series laser.
3. Oil free to better than 99.995%.

Recommended purge gas configurations are shown in Figure 3-4.

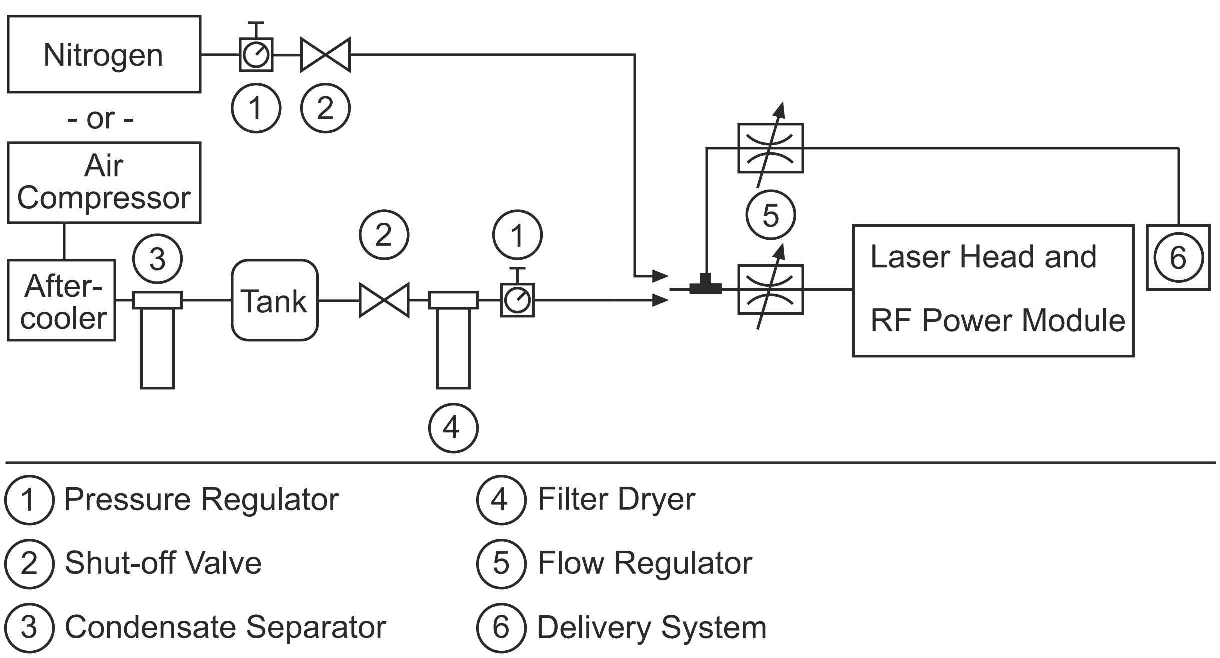
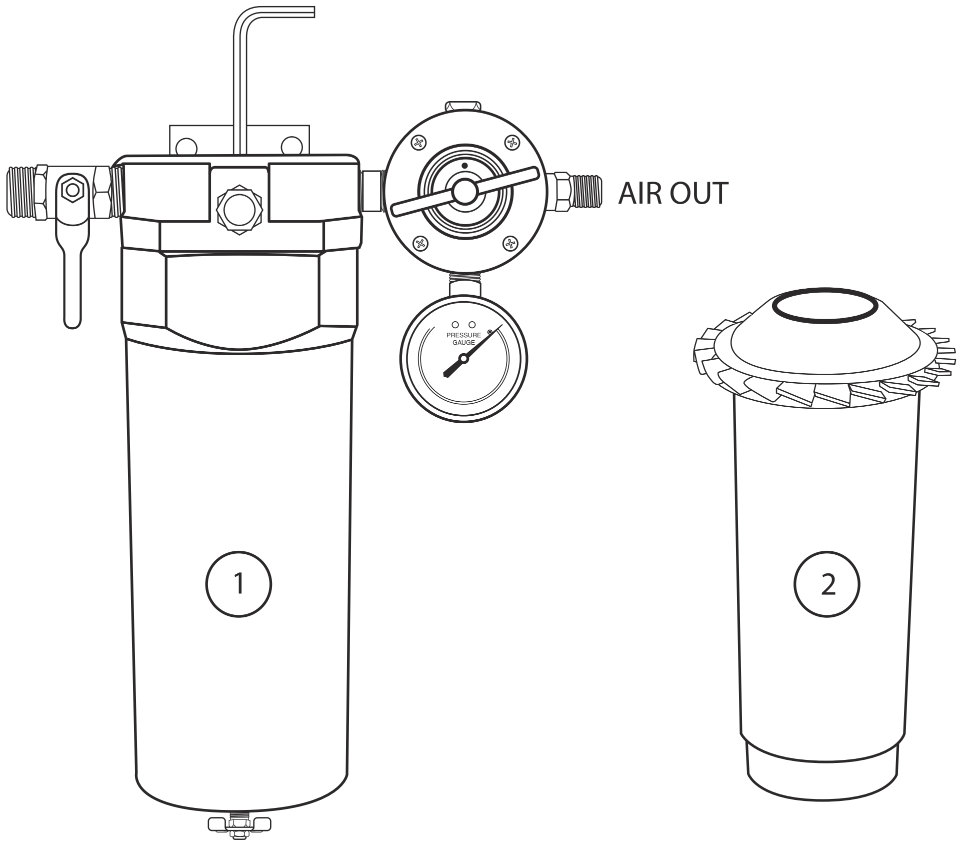



***Figure 3-4. Purge Gas Diagram***

Coherent has identified a suitable dry air purge filter which filters to 0.1 microns and dries the air to a dew point of -40°C (-40°F). The filter is shown in Figure 3-5 and is widely available.




1. Air Purge Filter Assembly; Part Number: 1232642
2. Replacement Dessicant Filter Cartridge; Part Number: 1236040

***Figure 3-5. Air Filter Dryer Unit***

For additional information on the Purge Filter/Dryer Assembly, refer to the "Air Filter Dryer Unit" on page E-2 of this manual.

***NOTICE!***
**It is the responsibility of the customer to provide purge gas of either nitrogen or compressed air that meets the specifications stated above, and clean flexible tubing to carry the purge gas. Failure to comply with these specifications will void the warranty and the customer is responsible for all cost of repair or damage to the laser.**

See "Preventive Maintenance" on page 6-1 in Section Six: Maintenance and Troubleshooting for the routine maintenance required for the purge gas filters.

## DC Power Supply

Coherent has qualified the DC power supplies listed in Appendix E: Accessories and Options for use with the E-400 Series laser systems. These DC power supply recommendations include both air-cooled and liquid-cooled options. The air-cooled type requires proper ventilation, while the liquid-cooled type requires a continuous supply of liquid coolant. Both types require an electrical disconnect to reset faults and to provide a disconnection for service.

Coherent can provide the DC power cables that connect the DC power supply output to the +48 VDC and 48 VDC return terminals on the RF power module.

### DC Power Supply Electrical Service

Consult the instruction manual provided by the DC power supply manufacturer for electrical service requirements. Also, consult local electrical codes to determine the current rating for fuses or circuit breakers for the electrical service to the power supply.

### Electrical Disconnect

Both supplies require an electrical disconnect to reset faults and to provide a disconnect for service. Coherent recommends that a main power disconnect (to the DC power supply) be located in the same room as the laser system. Consult a qualified electrician to select and install this hardware. Refer to Figure 3-6.

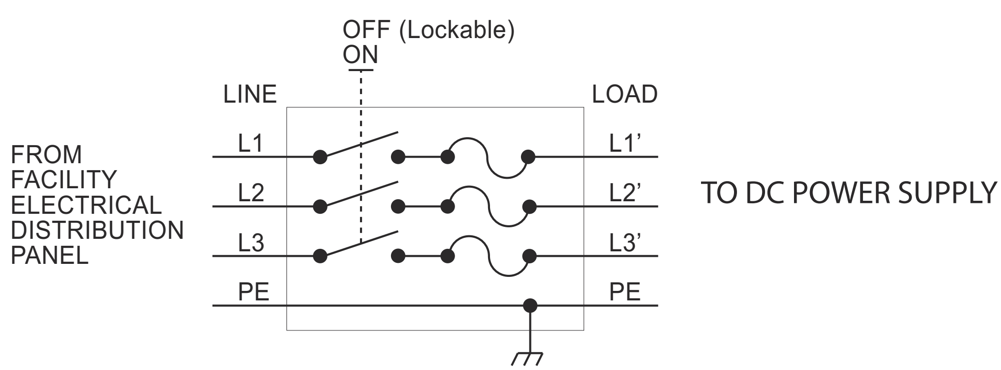



*Figure 3-6. Electrical Disconnect Switch (with Fuse Protection)*

### Mains Power Cord

The integrator must provide the AC mains cable of suitable size (gauge) for the chosen length and current carrying requirement. Depending upon local electrical code, the power cord may need to be hard-wired into a junction box or electrical disconnect switch, or may be connected to mating plug and receptacle. Consult a qualified electrician and wire to local electrical code.

## Beam Delivery System

The beam delivery system is typically designed and built by the system integrator.

Verify that the beam delivery system is designed for the E-400 Series laser’s beam specifications: wavelength, beam diameter, power density, divergence, output beam height (with respect to base-plate or mounting ball), mirror cooling, etc.

### Shutter

If the laser is equipped with the optional internal shutter assembly, a red (visible) aiming laser is provided whenever 48 VDC is on and the shutter is closed. This aiming beam serves as a visual indicator of the process beam path, and can be used to align the beam delivery system. This optional internal shutter is intended to be a safety device - it is not to be used as a process shutter.

If the optional internal shutter assembly is not installed, it is recommended to provide an external safety shutter or beam block near the laser aperture to prevent laser exposure when servicing the delivery system. Make sure the beam block is made of suitable material to safely trap and dissipate the laser power.

### Accessory Coupler

The laser head output aperture provides accommodation for a 50 mm (2”) OD beam tube to couple to the laser head. Enclosing the beam within gas-purged metallic tubes is a safe and recommended method of transmitting the beam from the laser head to the work piece.

### Purge

Providing a constant flow of purge gas to the delivery optics is recommended to keep optical surfaces clean and moisture free. If sharing a purge gas supply between the laser and deliver system, make certain that the laser system purge gas flow rate is maintained at the specified volume. See “Laser System Purge Gas” on page 3-12.

***NOTICE!***
**If cutting or marking reflective materials, an optical isolator must be installed between the laser and the process material to prevent work piece reflections from returning to the laser head and causing damage.**

## Optical Isolation

An optical isolator must be installed between the laser and the process material if cutting or marking reflective materials. This must be done to prevent work piece surface reflections from returning to the laser head.

Coherent has qualified the optical isolators listed in Appendix E: Accessories and Options for use with the E-400 Series laser systems.

## Laser Control, Measurement & Diagnostic

There are several methods of controlling and monitoring the laser. Some offer limited control, while others allow total control. Depending upon the end-user application, one or a combination of methods may be employed.

- Built-in Java Applet running on a PC
- Coherent E/G/K Remote Controller (optional)
- Java Applet + Coherent Remote Controller
- TCP/IP via LAN/Internet Connection and TCP Client Software
- 3rd Party/Customer Designed Controller (Real-time control interface)

Laser control methods are discussed in Section Four: Control Interfaces. Please consult with Coherent's Applications Department to determine which control method is best suited to requirements, schedule, and budget.

## External Interlock Circuit

Regardless of which control method is used, the laser requires that an external interlock (user supplied) be satisfied (closed) for operation. It is highly recommended to incorporate a serial interlock loop consisting of switch contacts on all service access doors and panels, and interlock switches or light curtains on all material access gates and doors.

### Laser Power Measurement

To accurately measure delivered laser power, a calibrated optical power meter (detector head plus display console) is necessary. Liquid (water) cooling is generally required for the detector head at E-400 Series power levels. Make sure to provide adequate cooling for the detector head.

Coherent manufactures a wide range of power meters (display consoles and sensor heads). Refer to Appendix E: Accessories and Options for recommended measurement tools.

## Laser Safety

Safety First! Read and understand the contents of Section Two: Laser Safety. Accidents can generally be reduced or eliminated by following all recommended safety guidelines.

Coherent recommends that each facility appoint and train a Laser Safety Officer (LSO) responsible for overseeing all aspects of laser safety.

Design systems with safety in mind. Use engineering controls such as: enclosed beam paths, interlocked covers, and safety shutters.

Designate a laser controlled area and keep all untrained and non-essential personnel out. Provide beam blocks, light shields, and/or curtains, as required, to establish a controlled area.

Insist that all operators and maintenance personnel receive proper training (and re-training) in laser and electrical safety. Require all personnel to have appropriate Personal Protective Equipment (PPE), especially laser safety eyewear suited to the laser in use and the job at hand.

# *Installation*

The installation procedure consists of performing the following steps:

1. Prepare facility and ensure that all items on the "Preinstallation Checklist" on page 3-1 are satisfied.
2. Receive and unpack the shipment.

   Allow the laser system temperature to equilibrate.

   Remove laser, DC power supply, loose parts, and accessories from shipping crates.

   Inspect system components.
3. Mount the laser system and the DC power supply.
4. Connect optics purge gas line and perform a laser system purge (mandatory).

5. Connect the coolant lines and perform a leak check.
6. Connect the electrical cables.
7. Remove the output aperture cover and mount output accessories (couple beam delivery system to laser head).
8. Connect a laser controller.

## Required Tools

To following tools will be required to unpack and install the laser system:

- Scissors or a package cutting knife
- Forklift or pallet jack to lift 143 kg (315 lbs.) - the weight of a fully loaded shipping crate
- A hoist capable of lifting at least 75 kg (165 lbs.) - the weight of the laser system
- A cart capable of supporting and transporting at least 75 kg (165 lbs.) - the weight of the laser system
- Metric hex wrench set (Allen keys)
- 1/4” flat-blade (–) screw driver
- #1 Phillips (+) screw driver
- Roll of 1/2” wide Teflon tape (included in coolant filter kit)
- 9/16” open end wrench (or 8” adjustable wrench)
- 3/4” open end wrench (or 8” adjustable wrench)
- Common hand tools

## Required Parts and Equipment

Table 3-3 lists parts and equipment required to perform the installation. Note that some items are supplied with the laser system while others must be obtained locally.

***Table 3-3. Parts and Equipment Required for Installation***

| ITEM | QUANTITY | PURPOSE | INCLUDED W/LASER SYSTEM |
|---|---|---|---|
| +48 VDC power supply | 1 | Provides +48 VDC power to the RF power module and the laser head. | No |
| AC power cord for DC power supply | 1 | Connects AC electrical supply to DC power supply input | No |
| Electrical disconnect for DC power supply | 1 | Disconnects power cord (to DC power supply) from AC electrical supply; can be mating plug/receptacle (if allowed by local code), or panel mounted disconnect | No |
| DC power supply cables | 2<br>each 3 m (10 ft.) in length | 48 VDC cables<br>Qty. 2, 3/0 AWG cables (2 red & 2 black - each color to be connected in parallel)<br>Transmits 48 volts to RF power module. | No |
| Mounting bolts/feet | 3 feet, 3 bolts and 3 washers | Coherent supplied mounting feet & bolts used to secure the E-400 Series.<br>• Mounting Kit (P/N 1174342)<br>• Bolts: M8 X 75 mm length (high strength steel) torque to 23.7 N·m (210 lb-in)<br>Customer must prepare the mounting surface and supply hardware to mount the feet to the mounting surface (refer Figure 3-25c) | Yes |
| Liquid-cooling System/Chiller | 1 | Provides temperature regulated liquid coolant to laser system | No |
| Coolant filter | 1 | Filters particles from coolant - 30 micron or better | Yes |
| Hose fittings | 1 | 3/4" male NPT to male GHT (garden hose thread) | Yes |
| Hose fittings | 1 | 3/4" male NPT to female GHT (garden hose thread) | Yes |
| Coolant kit | 1 | Coolant kit (if supplied) contains particle filter, fittings and coolant hose required to provide coolant to the laser system from the liquid-cooling system | Model Specific |
| Coolant hoses | as required | Provides coolant to the laser head and RF power module (and to optional liquid-cooled DC power supply) 5/8" ID or greater hose is recommended | No |

***Table 3-3. Parts and Equipment Required for Installation (Continued)***

| ITEM | QUANTITY | PURPOSE | INCLUDED W/LASER SYSTEM |
|---|---|---|---|
| Coolant | Amount varies | The heat transfer medium used to remove heat from the laser system; consists of a mixture of distilled (or de-ionized) water and corrosion inhibitor | No |
| Corrosion inhibitor | Amount varies | Prevents corrosion of metal parts in contact with the coolant | No |
| Purge Gas (Regulated Supply) | 1 | Used to displace atmosphere of air within the laser head and the RF power module; typically $N_2$ or clean, dry air (CDA) | No |
| Purge Gas Filter | N/A if using $N_2$; required if using CDA | Removes water vapor, oil, and particulates from compressed air; see Appendix E: Accessories and Options | No |
| Purge Gas tubing (between laser head and RF power module) | 1 piece | A short length of 1/4 inch (6 mm) OD Teflon, polyethylene or polypropylene tubing to connect the purge gas line between the laser head and RF power module | Yes |
| Tee | 1 | 1/4 inch (6 mm) OD Tee for splitting the purge gas tubing at the laser head and RF power module | Yes |
| Purge Gas tubing (between purge gas supply and laser system) | as required | 1/4 inch (6 mm) OD Teflon, polyethylene or polypropylene tubing to connect the purge gas supply to the laser head | No |

## Facility Preparation

Prepare the facility (installation site) as described in Table 3-1 on page 3-2.

## Unpacking and Inspection

The E-400 Series laser system packaging has been designed for robust shipment. Upon receiving the system, inspect the outside of all containers immediately for damage that may have occurred during transit. If there appears to be any visible damage (holes in containers, fluid damage, crushing, etc.), immediately notify Coherent and a representative of the carrier. Request that a representative of the freight company be present when unpacking the contents.

***NOTICE!***
**To avoid damaging the laser system during transport, keep the original shipping crates, lifting hardware and packing materials for shipping the E-400 Series laser system from one location to another. If the system is to be returned to Coherent for repair, it must be in the original shipping container.**

Carefully unpack the crate in a clean, dry area. Inspect all major components as they are unpacked.

**WARNING!**
**The E-400 Series laser system is not designed to be lifted or carried by hand. To avoid personal injury or damage to the system, always lift, move, and place the laser using equipment approved for lifting and properly rated for the weights listed.**

**WARNING!**
**To avoid personal injury, never place any body parts below a lifted or suspended laser.**

## Unpacking Instructions

This section contains photos representative of unpacking a typical E-400 Series laser system. Some laser models may be packed differently.

1. Unlock all six (6) clasps of the top cover (Figure 3-7).


*Figure 3-7. Removing Crate Cover*

2. Remove the top cover (Figure 3-8).


***Figure 3-8. Top Cover Removed***

3. Remove the water hose/filter kit, if provided (see Figure 3-9).

***Figure 3-9. Water Hoses and Filter Removal (if provided)***

4. Unstrap the system by releasing both (2) securing ratchet straps (Figure 3-10).

***Figure 3-10. Unstrapping the System***

5. Unlock all six (6) clasps securing the side panels to the bottom of the crate (Figure 3-11).

***Figure 3-11. Removing Side Panels***

6. Two people are required to carefully lift the wooden side panels up and over, exposing the system (Figure 3-12).

***Figure 3-12. E-400 Series Laser System in Moisture Seal Bag***

7. Cut the tape securing the top end of the user documents bag from the laser moisture seal bag (Figure 3-13).


***Figure 3-13. Opening the User Documents Bag***

8. Locate the two eyebolts underneath the user documents bag (Figure 3-14).

***Figure 3-14. Lifting Eyebolts in Documents Bag***

9. Cut moisture seal bag at both ends of the laser system as shown in Figure 3-15 to expose the eyebolt holes.

***Figure 3-15. Exposing the Eyebolt Holes***

10. Install eyebolts to each end of the laser system (Figure 3-16).


***Figure 3-16. Installation of Eyebolts***

11. Ensure both ratchet straps are clear of the laser system (Figure 3-17).

***Figure 3-17. Clear Straps from Laser System***

12. Using an adjustable wrench, loosen the two (2) bolts that clamp the spreader bar to the underside of the top cover (Figure 3-18). Remove the spreader bar from the crate cover.

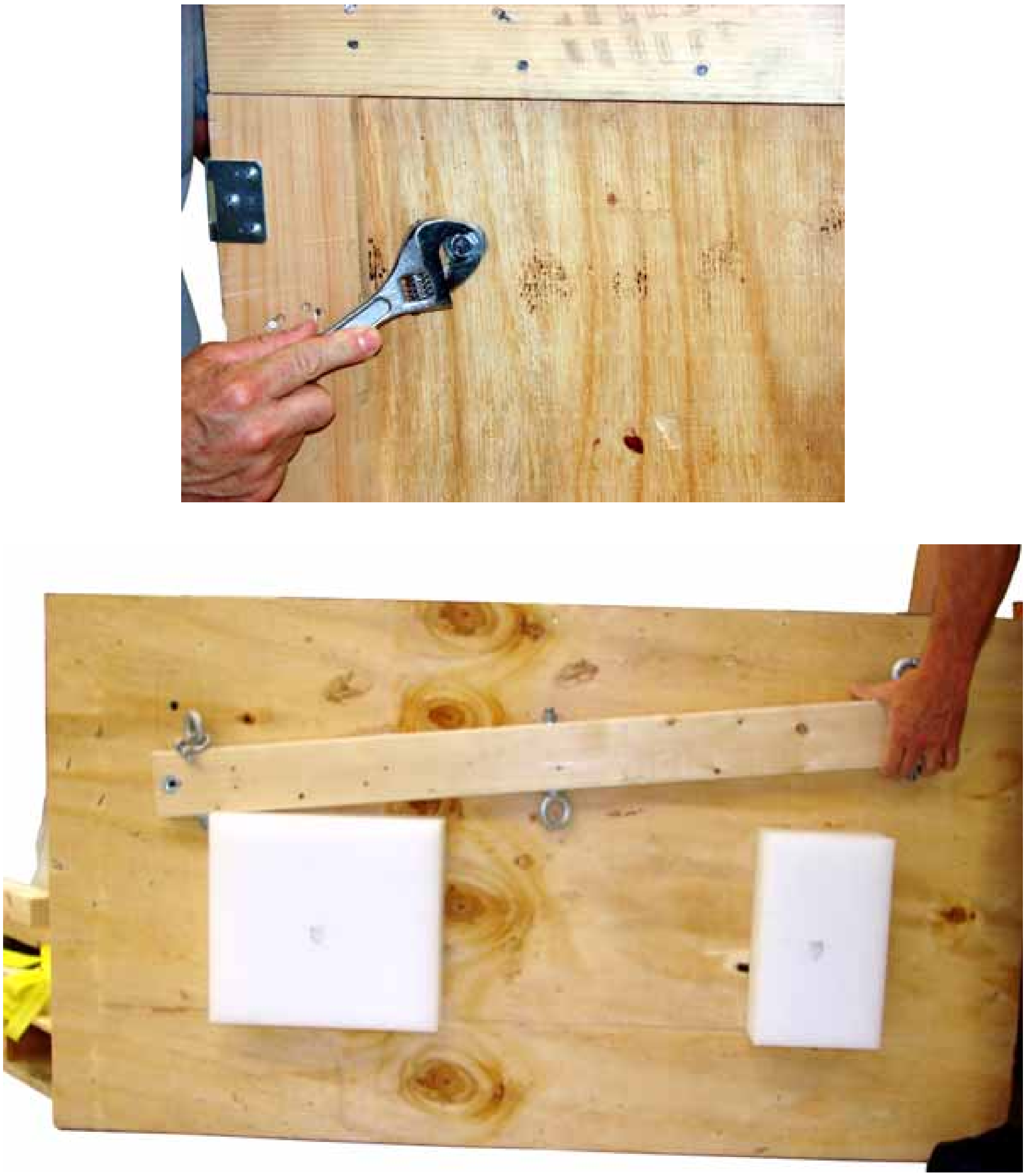


***Figure 3-18. Removing Spreader Bar from Crate Cover***

13. Using the shackles provided, latch both eyebolts to the spreader bar as shown in Figure 3-19. Fully tighten the shackle pin.

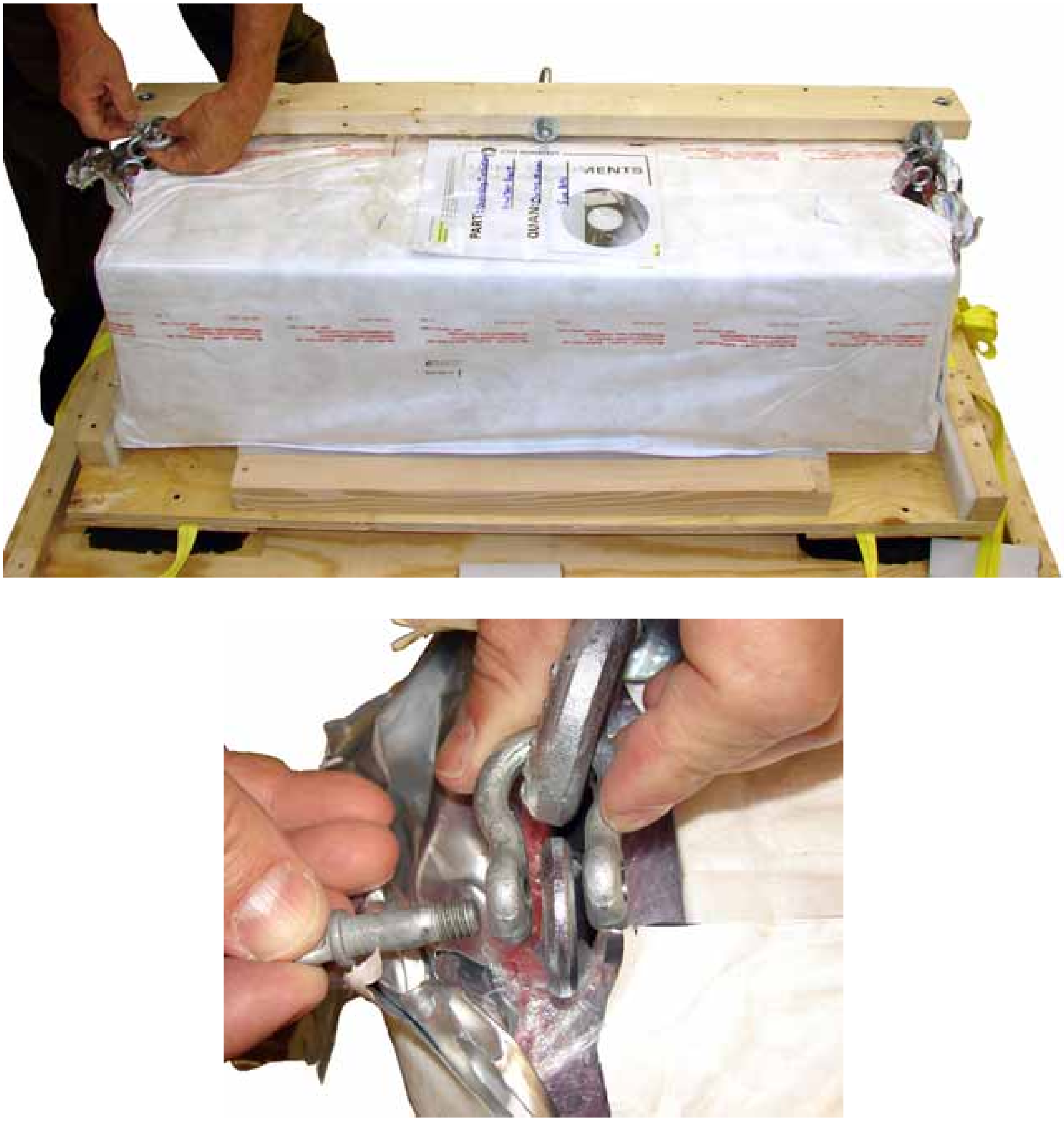


***Figure 3-19. Attaching Eyebolts to Spreader Bar***

14. Secure the spreader bar to the forklift or hoist capable of lifting 114 kg (250 lbs.). Carefully lift the laser onto a cart as shown in Figure 3-20.

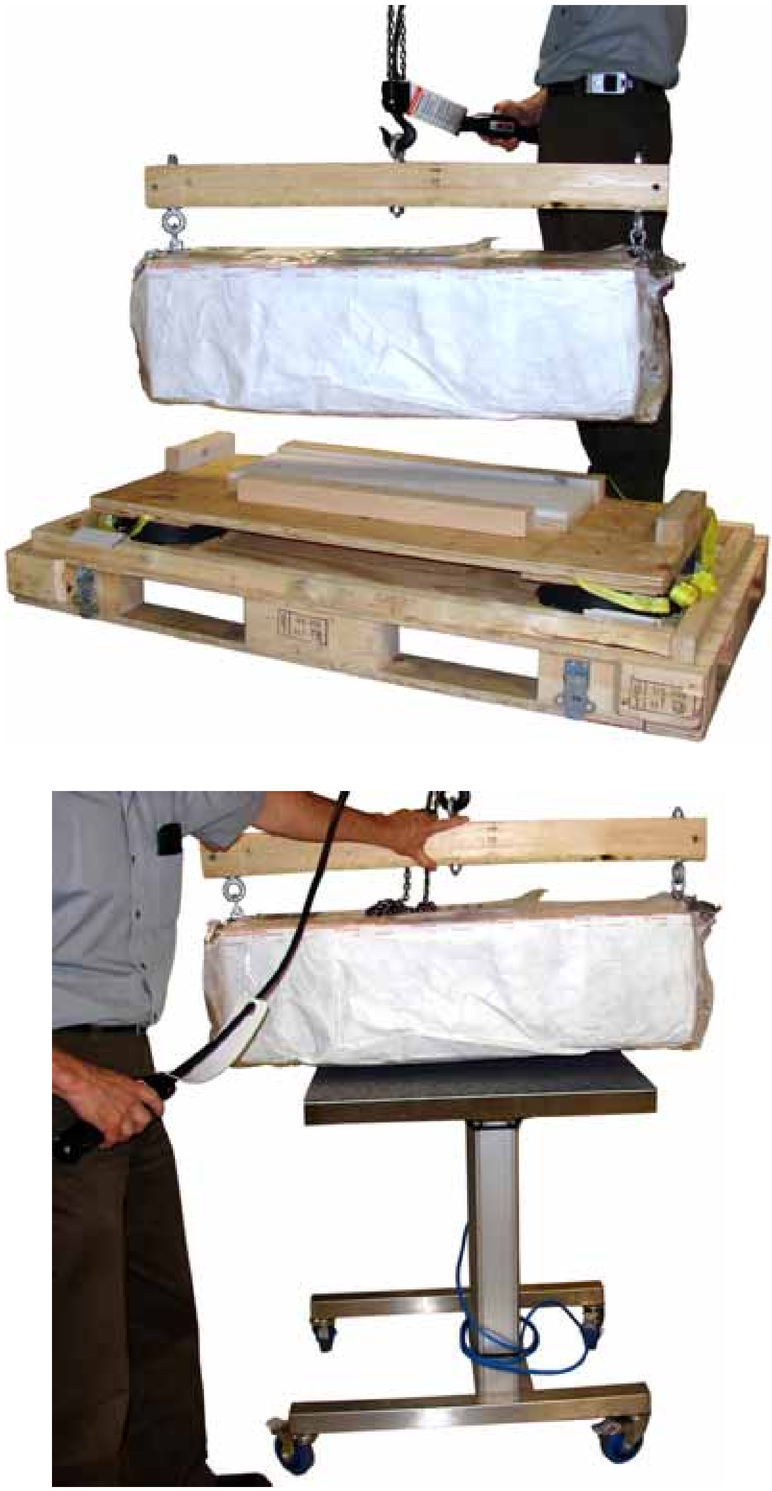


***Figure 3-20. Lift and Place the E-400 Series Laser***

15. Carefully cut open and remove the moisture seal bag (Figure 3-21).

***Figure 3-21. Opening the Moisture Seal Bag***

---

***NOTICE!***
**To avoid damage to the laser system, let the system equilibrate to room temperature before opening the moisture seal bag.**

---

16. Locate and remove the sealed plastic bag containing the RF power module system cable (Figure 3-22).

***Figure 3-22. RF Power Module System Cable***

17. Remove the bubble-wrap from the ends of the laser system (Figure 3-23).

***Figure 3-23. Removing Bubble-wrap***

18. Using the necessary personnel, remove and carefully set the laser equipment on a clean and flat surface, such as an optical table (Figure 3-19).


***Figure 3-24. E-400 Shown Unwrapped***

## Mounting Laser System Components

The integrated laser system has provisions for stress free kinematic mounting. This mounting includes mounting features (supplied with the laser) that facilitate laser replacement. Since the laser is precisely aligned to these mounting features, a laser can be replaced with minimal or potentially no system re-alignment.

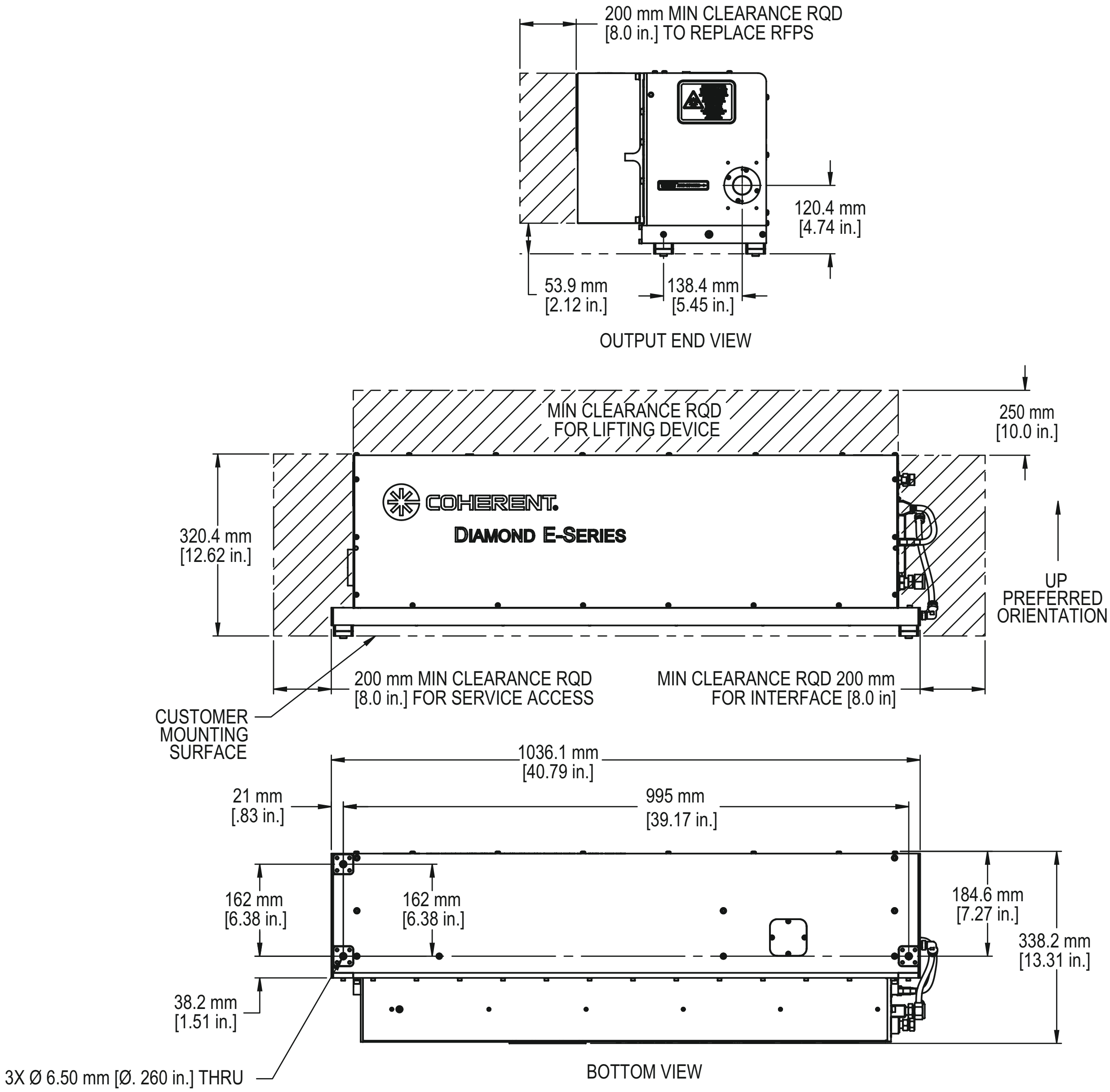
A protective cover is mounted to protect the beam output aperture of the laser during shipment. This must be removed before mounting the laser as it blocks the access to one of the mounting holes.

Mount the laser using mounting feet as shown in Figure 3-25d. The M6 x 65 mounting bolts must be torqued to 11.3 N·m (100 lb.-in.). Do not over torque the mounting bolts as doing so will distort the mounting feet.

***NOTICE!***
**Torque specification for the M6 X 65 mounting bolts is 11.3 N·m (100 lb.-in.). Do not over torque. Over torquing will damage mounting feet.**

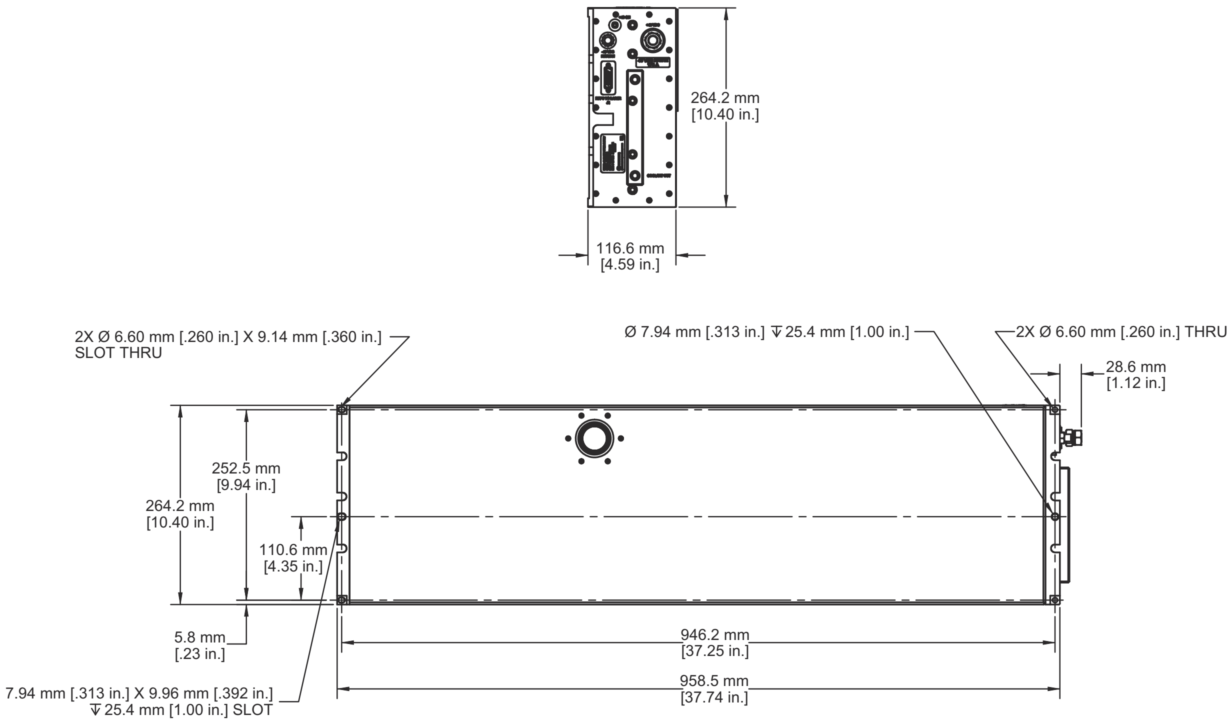
**CAUTION!**
**To avoid the risk of injury, never lean on the RF power module while placed on a horizontal surface and not fixed by mounting screws as this could cause the laser to tip over. In the event that the laser is on a bench in a non-fixed state, temporary support of the RF power module is recommended.**

See Figure 3-25a, b, c & d.

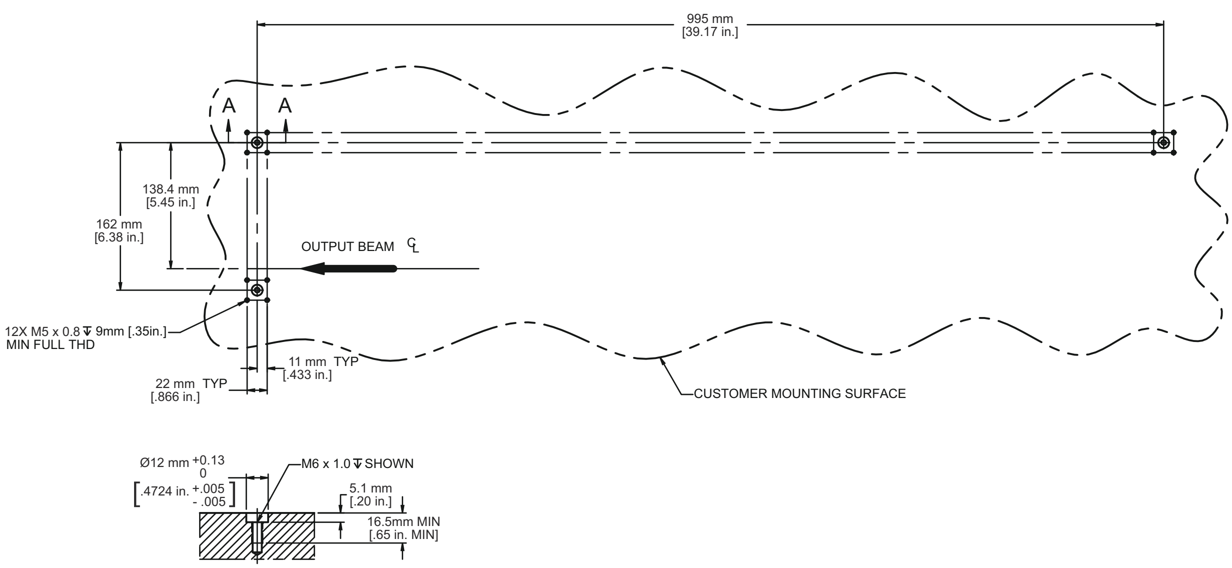



a. Laser Head

***Figure 3-25. E-400 & E-400i System Installation in OEM Equipment (Dimensions in mm [inches] and Required Clearances)***

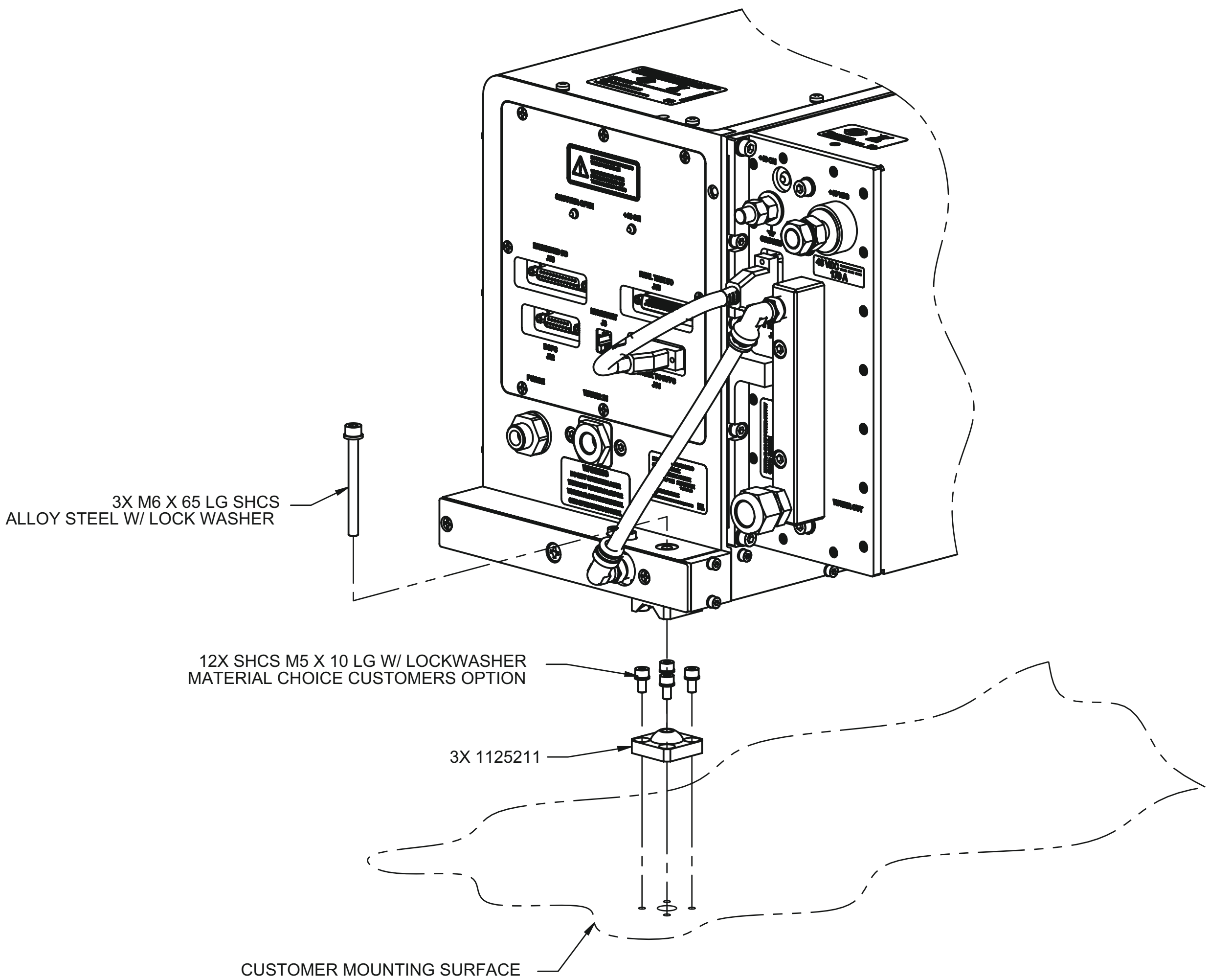



b. RF Power Module




c. Interface Mounting Dimensions

***Figure 3-25. E-400 & E-400i System Installation in OEM Equipment (Dimensions in mm [inches] and Required Clearances) (Continued)***




d. Mounting Foot Detail

***Figure 3-25. E-400 & E-400i System Installation in OEM Equipment (Dimensions in mm [inches] and Required Clearances) (Continued)***

## Set-up Purge

Setup Purge is required in order to eliminate moisture from the system prior to use. This is required even though the system packaging is designed to ship the laser in a 'dry condition'. Note that system purge is required whenever the system has been off for an extended period of time without purge.

Purge the system with nitrogen or clean, dry air for a minimum of two hours. Failure to purge the system leaves the system at substantial risk of optics failure. Guidelines for system purge are found in Table 1-2 in Section One: System Description.

## Service Access

It is highly recommended that the system integrator follow Coherent's recommendation for laser orientation with respect to service access within the customer's equipment (see Figure 3-25a "Laser Head" mounting dimensions):

- Mount the laser system with the RF power module readily accessible through service access panels in OEM's system
- Provide easy access to electrical connections:
  - – Control interface
  - – Diagnostic interface
- Provide easy access to cooling connections
- Provide easy access to the optics purge gas connection

---

***NOTICE!***
**Following these recommendations will provide ease of service for E-400 Series laser systems.**

---

The laser head can be mounted in any orientation. If mounted vertically with the beam tube up, ensure no dust or other particulates fall into the output aperture during installation.

---

***NOTICE!***
**Customers mounting the laser in a 'non-horizontal' feet down configuration are responsible for properly supporting the laser during installation (and de-installation). Great care must be taken that the laser (75 kg or 165 lbs.) plus weight of hoses, cables, and externally mounted accessories is supported without damage to the laser structure. The top eye-bolts cannot be used for vertical installation.**

---

## Vertical Mounting

1. Install eye-bolts into screw holes. Do NOT use the top eye-bolt locations during vertical lift (refer to Figure 3-27).

Front View (Aperture Up) Rear View (Aperture Down)

***Figure 3-26. Vertical Mounting***

2. Securely connect appropriate slings or chains to the eye-bolts and spreader bar. Chains/slings must be vertical when under load. See Figure 3-27.

---

**The eye-bolts with hex nuts and shackle can be removed from the provided spreader bar and installed on the user supplied vertical lifting spreader bar.**

---

3. Carefully lift the laser system while preventing the free end from moving around. See Figure 3-27.

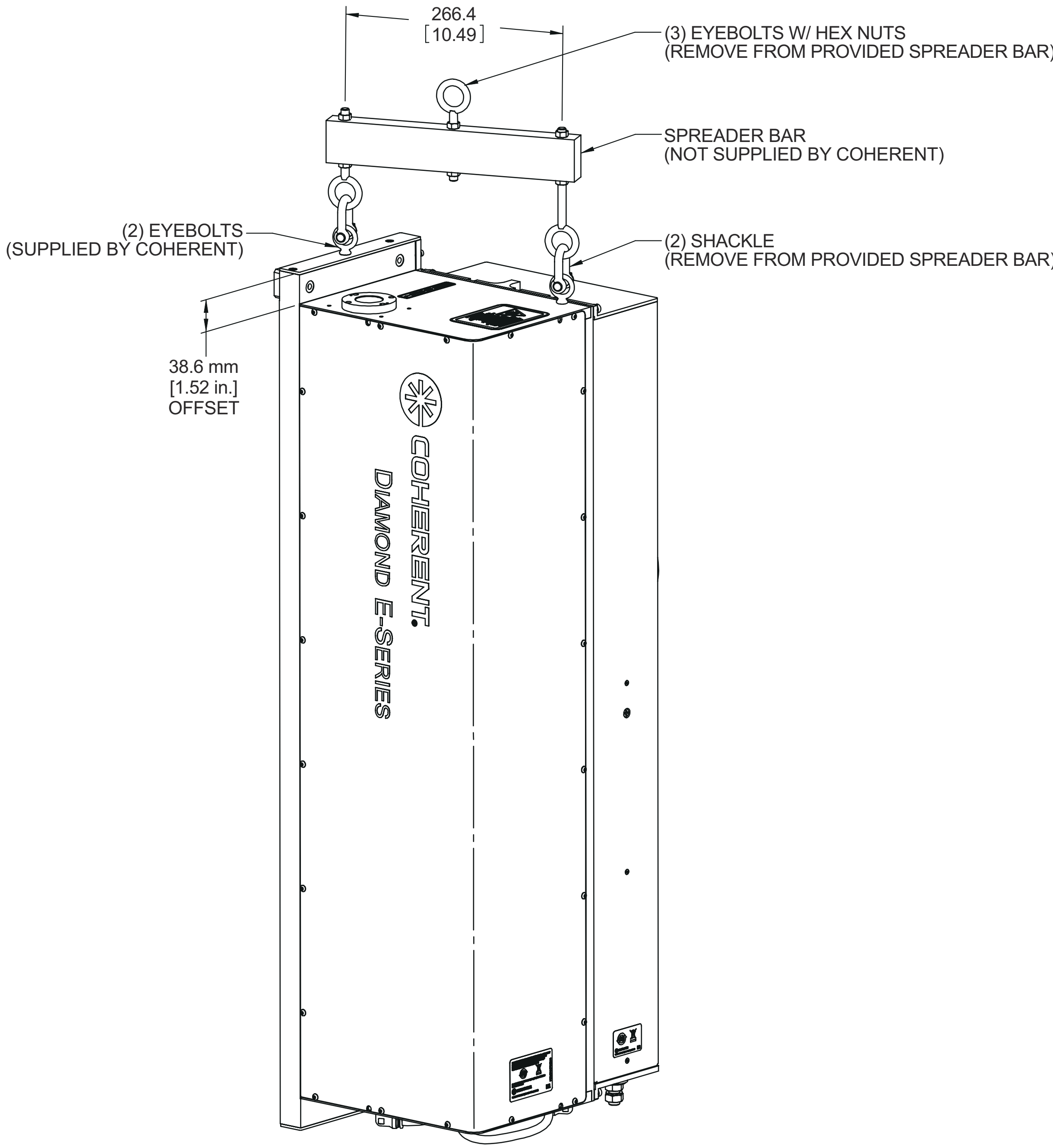



***Figure 3-27. Vertical Mounting Illustration***

## Customer Mounting of Attached Accessories

E-400 Series lasers have a provision for the customer to mount optics/accessories via the laser front plate. The following provisions must be followed:

- Accessory mount maximum load: 2.3 kg (5 lbs.) at 254 mm (10 in.) or equivalent.
- The customer must provide a continuation of optical purge through the added components using a separate purge line.

## Coolant Line Connections

The direction of fluid flow is first into the laser head module and then through the RF power module.

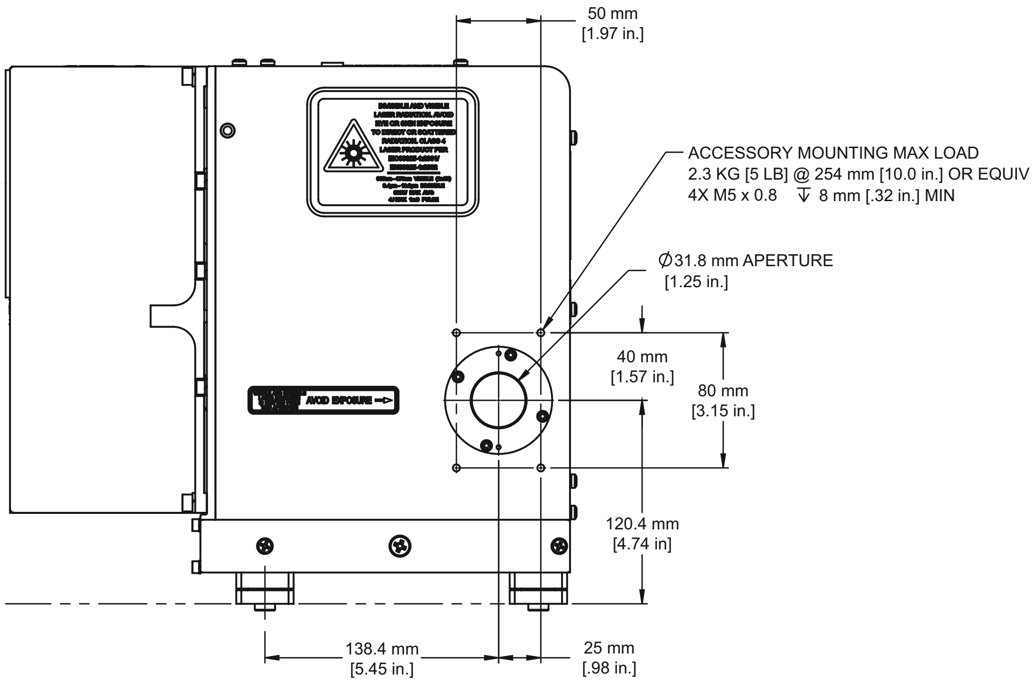



***Figure 3-28. Output End View***

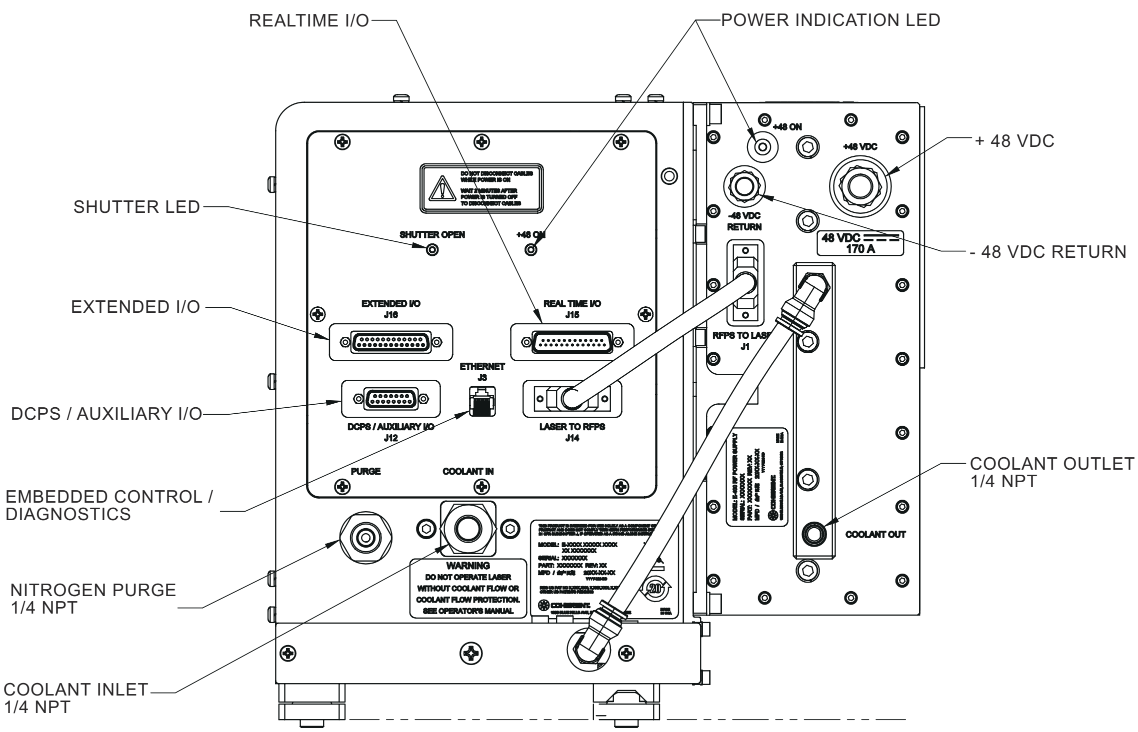



***Figure 3-29. Interface Connectors End View***

***Table 3-4. E-400 Head Indicators and Connectors***

| CONTROL | FUNCTION |
|---|---|
| Output aperture | The output beam exits the laser head from this aperture. |
| Purge gas input | Provides for optional gas purge of the beam conditioning optics. Requires 1/4 inch (6.3 mm) OD Teflon, polyethylene or polypropylene tubing.<br>Standard gas fitting for purging the optics in the laser head. Nitrogen is not required for tube operation. Refer to "Laser System Purge Gas" on page 3-12 for additional information on purging the laser head.<br>Also note that the purge line on the laser head has a small filter. This filter protects the laser optics from any particles that are generated as a result of connecting the purge gas tubing to the laser head. |
| Cooling fluid inlet | Connection for the cooling fluid hose that supplies coolant from the coolant source. |
| Cooling fluid outlet | Connection for the cooling fluid hose. Cooling fluid travels from the laser head through the RF power module and out to the drain. |
| From DC supply (+) | Connects +48 VDC from the DC power supply to the RF power module. Apply 190 in.-lbs. (21.4 N·m) torque to nut supplied. |
| From DC supply (–) | Connects the RF power module - 48 VDC return to the DC power supply. Apply 190 in.-lbs. (21.4 N·m) torque to nut supplied. |
| Real-time control connector | Connector for a DB25 interconnection cable.<br>This connector supplies control and input modulation signals from the user to the RF power module and supplies status information from the laser system. |
| Embedded control/diagnostic interface connector | LAN connector for diagnostics and troubleshooting. |
| Extended I/O | DB25 connector that provides extended capability (including shutter control and additional fault signals). |
| DCPS/Auxiliary/IO | DB-15 connector provides for an auxiliary 48 VDC input to permit operation of control/diagnostic electronics without application of main 48 VDC power supply and reserved I/O to support advanced control options. |
| Laser to RF power module connector cable | Connector cable provides internal laser head to RF power module signals. |

**WARNING!**
**Do not plug or unplug the laser to RF power module connector cable when the laser is powered on. This could serious electrical shock and/or damage the laser system.**

***NOTICE!***
**To avoid damaging the laser system, the coolant inlet and outlet must always be connected as specified. Any other connection method, e.g. connecting the laser head and RF power module in parallel with 2 separate inlets and outlets, will void the warranty.**

The recommended coolant source is a closed-loop cooling system. Coolant composition must meet the requirements stated in Table 1-2 on page 1-10. Refer to "Laser System Cooling" on page 3-7 and for additional information.

The recommended hose for coolant consists of a 1/2 inch (12.7 mm) minimum ID hoses up to 15 m (50 ft.).

After connecting the water hoses, verify that there are no water leaks as follows:

- Close supply and return valves, then turn the chiller on.
- Open the valve in the water return (drain) line.
- Slowly open the valve in the water supply line.
- With the water supply pressure and water line differential pressure in accordance with Table 1-2 on page 1-10, check all connections for leaks.

## Grounding of E-400 Laser RF Module

The E-Series RF module - 48 VDC return is internally grounded directly to the chassis ground of the laser system. DC power supply cables from the DC power supply are to be connected directly to the marked connectors on the rear panels, see Figure 3-29 on page 3-42.

These connections ensure correct grounding for the system. As an added precaution, an additional safety ground may be configured using a direct connection to the - 48 VDC return terminal. Please refer to Figure 3-30.

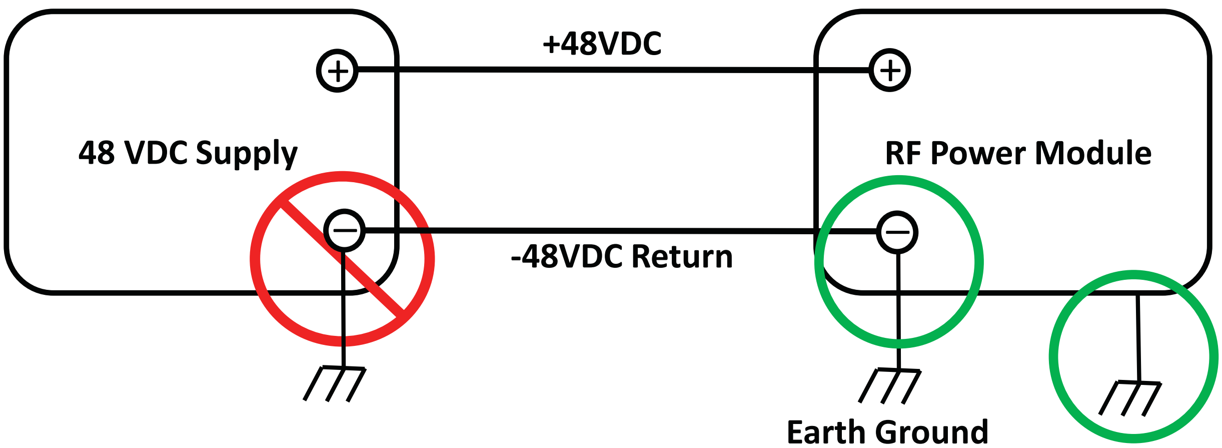



*Figure 3-30. Grounding of E-400 Laser RF Module*

**WARNING!**
**Never connect a safety (earth) ground to the - 48 VDC terminal of the DC power supply. This terminal's potential will rise above safety (earth) ground potential due to current flow through the return cable. The - 48 VDC terminal of the DC power supply is electrically isolated and must always be allowed to float above safety (earth) ground potential.**

## Optics Purge Connection

To connect the optics purge gas use clean polyethylene, polypropylene, Teflon tubing. A 1/4 inch outside diameter tube fitting is provided on the laser head for connecting the optics purge gas. There is a small filter within the laser head is to prevent any particles generated, as a result of connecting to this fitting, from contaminating the laser head. The purge gas at this input must meet the requirements discussed earlier in this chapter.

# SECTION FOUR: CONTROL INTERFACES

## *Introduction*

This section describes the electrical interfaces required to operate E-400 Series lasers. As shown in Figure 4-1, there are four control interfaces for the E-400 Series consisting of:

1. Real time I/O
2. Extended I/O
3. DCPS/Auxiliary I/O
4. Embedded control/diagnostic interface

Figure 4-1 and Table 4-1 provide a brief description of these interfaces and manual locations providing complete information. Also, Table 4-1 provides a description of LED indicators. Critical signals, which control laser power, are the pulse width and pulse period. Typical laser output power for various operating pulse widths and periods is shown in Section Five: Operation.

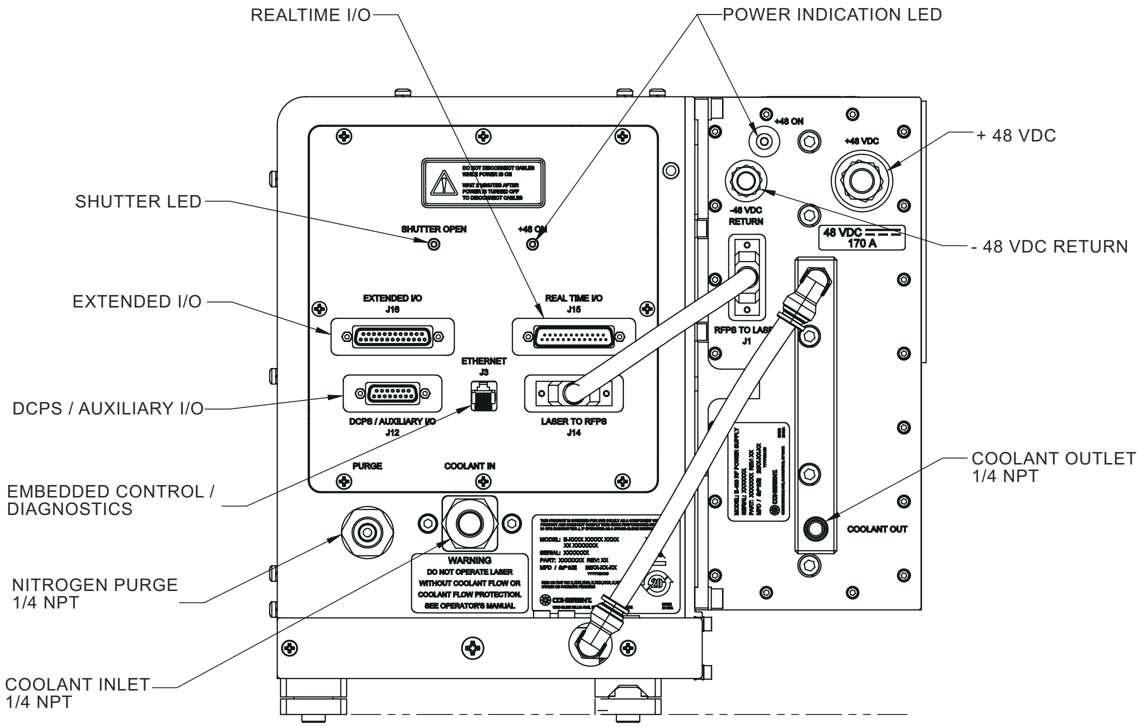



***Figure 4-1. E-400 Series Laser Electrical Interfaces***

***Table 4-1. E-400 Series Laser Electrical Interfaces***

| INTERFACE OR INDICATOR | DESCRIPTION | OPERATOR'S MANUAL SECTION |
|---|---|---|
| Real-time Control and Status I/O | DB-25 connector (male)<br>Similar to existing K series OEM interface<br>(see differences in Table 4-2). | Table 4-3 on page 4-6 and<br>Table 4-4 on page 4-6 |
| Extended I/O | DB-25 connector (female).<br>Contains shutter interface signals and status, interlocks, low speed faults, and system faults. | Table 4-7 on page 4-19 and<br>Table 4-8 on page 4-20 |
| DCPS Auxiliary I/O | DB-15 connector (female)<br>Provides auxiliary 48 VDC (2 A max.) input to permit operation of control/diagnostic electronics without application of main 48 VDC power supply and reserved I/O to support auxiliary control/diagnostic options. | Table 4-9 on page 4-23 |
| Embedded Control/Diagnostics | RJ-45 LAN connector<br>Java based remote diagnostics, control, and status information. | Appendix A: Embedded Control and Diagnostics |
| Power Indication LEDs | Green emission indicates DC power is on (48 VDC). | Figure 4-1 (above) |
| Shutter LED | Amber emission indicates potential hazard condition when lit (either shutter is open or not installed). | Figure 4-1 (above) |

## Real-time Control and Status Interface

For users familiar with K-Series OEM lasers, the real time control and status interface is very similar to the K-Series interface, but it is not identical. Table 4-2 provides a concise description of the differences between both interfaces.

***Table 4-2. Differences in Real-Time Interface Between K Series OEM and E-400 Series***

| STATUS OR CONTROL | K-SERIES OEM | E-400 |
|---|---|---|
| Faults and Warnings | All faults are non-latching (laser will resume operation upon correction of fault condition). | E-400 Series has latching faults. Latching faults require system reset. |
| Faults | A K-Series OEM laser will resume operation upon correction of fault condition. | An E-400 Series latching fault requires system reset in order to resume operation. |
| Enable/Fault Reset Signal (Pin #3 and #16) | Required for operation. | Enable: Required for operation. Enable must be asserted after system 48 VDC power-up.<br>Fault Reset: Required for system reset in the case of fault condition. |
| System Fault (Pins #4 and #17) | N/A | This (added) signal indicates a latching system fault. Signal is high speed. |
| Test Modulation Function | Pins 5 and 18 | Not available - use embedded control and diagnostics. |

## Fault Types

One key difference between the K-Series and E-Series products highlighted in Table 4-2 is how faults are handled and the different types of faults. Provided is a detailed definition and description of the E-400 Series faults as illustrated in Figure 4-2.

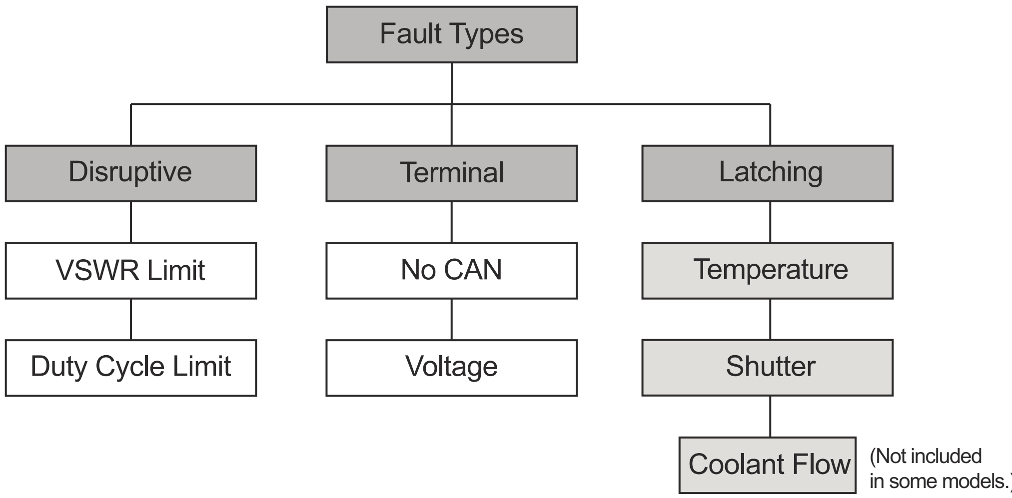



***Figure 4-2. Types of E-400 Series Faults***

- **Disruptive (VSWR and DC Limit)** - These faults indicate that a fault condition occurred during operation. These are high speed fault types. They indicate that the E-400 Series control circuitry detected a fault condition and corrected it automatically. The user should check the output of the equipment to ensure that the end product was properly produced in the case of a disruptive fault. These faults are indicated on dedicated pin assignments.
- **Terminal (Controller Area Network or CAN, Voltage)** - These faults are detected on system power-up. Detection of a terminal fault condition will prevent system operation. These faults are identified through the Ethernet interface.

- **Latching (Temperature, Coolant, Shutter)** - These faults indicate a serious E-400 Series problem and cause immediate system shutdown. These faults are latched and system operation can only be restored by correcting the fault condition and toggling the enable/fault reset signal. These faults are indicated on dedicated pin assignments. (Note: Coolant flow sensing is being phased out. Contact Coherent for additional information on specific models.)

The latching faults and both disruptive faults have dedicated pins on the Real Time Input Output connector. The other two types of faults require an Ethernet connection to diagnose fully.

## Real Time Control and Status I/O Description

The control and status signals are summarized in Table 4-3 and are accessed through the Real Time I/O DB25 connector on the control panel. To operate the laser, two input signals are required, as indicated in Table 4-3. In order to monitor the condition of the system, five output signals are provided and recommended for use in the user's control system. Detailed descriptions and pinouts of the control connector interface are provided in Table 4-4.

***Table 4-3. Real-time Control and Status Interface***

| IDENTIFICATION | BRIEF DESCRIPTION | CONNECTION |
|---|---|---|
| **INPUT SIGNALS** | | |
| MODULATION | Controls laser average output power through input of pulse width and pulse period. | Required |
| ENABLE/FAULT RESET | Enables laser operation.<br>System reset after fault condition. | Required |
| **OUTPUT SIGNALS** | | |
| DUTY CYCLE LIMIT | Warning indicating that the system has exceeded the maximum duty cycle. | Recommended |
| VSWR LIMIT | Warning indicating an abnormally high amount of reflected RF power. | Recommended |
| ANALOG FORWARD | Signal proportional to the forward RF voltage. | Recommended |
| ANALOG REFLECTED | Signal proportional to the reflected RF voltage. | Recommended |
| SYSTEM FAULT | Indicates a system fault. | Recommended |

***Table 4-4. Real-time Control and Status I/O Pinouts***

| PIN | FUNCTION | DESCRIPTION |
|---|---|---|
| 1 | ANALOG FORWARD —Output signal | Analog output signal representing forward voltage from the RF amplifier to the laser head. +5V full scale. |
| 2 | ANALOG REFLECTED —Output signal | Analog output signal representing reflected voltage from the laser head +5V full scale. |
| 3 | ENABLE/FAULT-RESET —Input signal | Enable is required in order to operate system. Enable must be asserted after 48 DC power is applied. This is accomplished by connecting pin #3 to a RETURN.<br>Fault reset is required in order to re-establish operation after a system fault occurs. This is accomplished by opening then reconnecting pin #3 to a RETURN.<br>This pin should not be used for safety interlock. Shutter assembly (either E-400 Series option or customer supplied) should be used for safety interlock. |

***Table 4-4. Real-time Control and Status I/O Pinouts (Continued)***

| PIN | FUNCTION | DESCRIPTION |
|---|---|---|
| 4 (+) and 17 (–) | SYSTEM FAULT —Output signal | Active high, differential, digital, output signal indicating that a system fault is present. |
| 7 (+) and 20 (–) | MODULATION —Input signal | Differential input signal that controls the laser output. Laser output power will be present for the duration of this pulse only. Pulse widths should be in the range of 2 to 1000 µs at <60% duty cycle. |
| 10 (+) and 23 (–) | DUTY CYCLE LIMIT —Output signal | Differential digital signal that is only valid when laser output is commanded (MODULATION input high). A logic high on this signal when laser output is commanded indicates that the commanded modulation exceeds 60% duty cycle or the commanded pulse width exceeds 1 ms. This signal goes high only for that portion of the input modulation command which is in violation of the 60% duty cycle or 1 ms maximum pulse width limits. Therefore, this signal indicates which portion of the commanded modulation input is being inhibited due to the fault condition. A logic low on this signal when laser output is commanded indicates that the input modulation command is within acceptable limits. This signal is at logic low when laser output is not commanded (MODULATION input low). |
| 11 (+) and 24 (–) | VSWR LIMIT —Output signal | Differential digital signal that is only valid when laser output is commanded (MODULATION input high). A logic high on this signal when laser output is commanded indicates that the reflected RF power exceeds the safe operating limit and that the protection circuit is active. This signal goes high only for that portion of the input modulation command when the VSWR protection circuit is active. Therefore, this signal indicates which portion of the commanded modulation input is being inhibited due to the fault condition. A logic low on this signal when laser output is commanded indicates that the input modulation command is within acceptable limits. This signal is at logic low when laser output is not commanded (MODULATION input low). |
| 14, 15, 16 | RETURN | Reference for pin 1, 2, and 3 |
| 5, 6, 12,13, 18,19, 25 | NOT USED | DO NOT CONNECT |
| 8 & 21<br>9 & 22 | DIGITAL REFLECTED<br>DIGITAL FORWARD<br>—Output signals | Legacy signals (optional). |

## Input Signal Requirements

The two inputs required to operate the laser are the ENABLE and MODULATION signals. Figure 4-3 shows the schematic of the input circuit for these two signals.

After the application of DC power, connecting the ENABLE to RETURN enables laser system operation. The ENABLE/RETURN connection must be opened and then closed to clear a latching fault.

The second function required to operate the laser is the MODULATION signal. This signal will determine the laser "on" interval typically called the pulse width. The time interval between the start of one "on" period and the next "on" period is called the pulse period. The pulse width must be in the legal range for the specific model type. MODULATION pulse widths longer than allowed will automatically be limited to the maximum allowed pulse width by the protection circuit in the RF power module. The duty cycle must be no greater than the maximum allowed. The duty cycle is the ratio of the pulse width divided by the pulse period and then multiplied by 100. If either the duty cycle or the pulse width exceeds these limits, a warning will occur on the DUTY CYCLE output. A more complete description of this signal and typical waveforms follow later in this section.

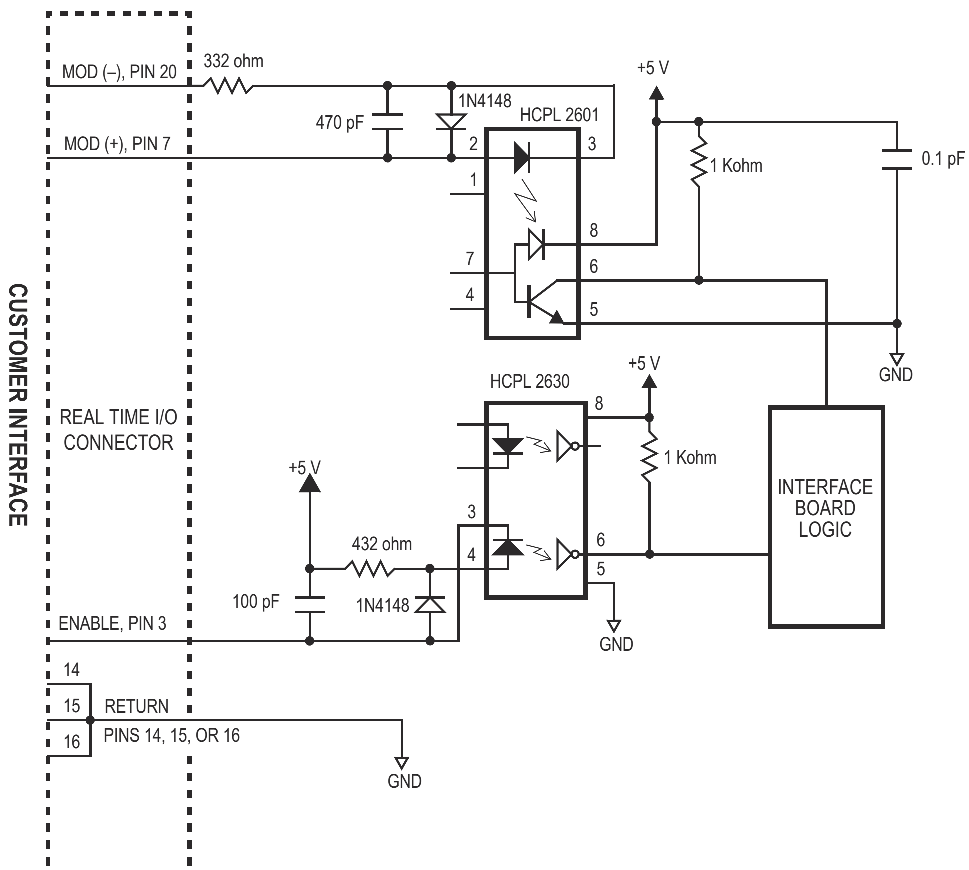



**Figure 4-3. Real Time I/O Input Circuit for Laser Operation**

## Drive Circuit for RF Power Module

An example of a drive circuit to interface to the ENABLE and MODULATION inputs is shown in Figure 4-4.

The MODULATION input interface shown in Figure 4-3 is designed to be driven by a differential line driver meeting the requirements of EIA Standard RS-422A. Common mode voltage on the driver signals should be kept as low as possible and cannot exceed ± 15V relative to the laser system ground. Examples of suitable line drivers are indicated in Table 4-5.

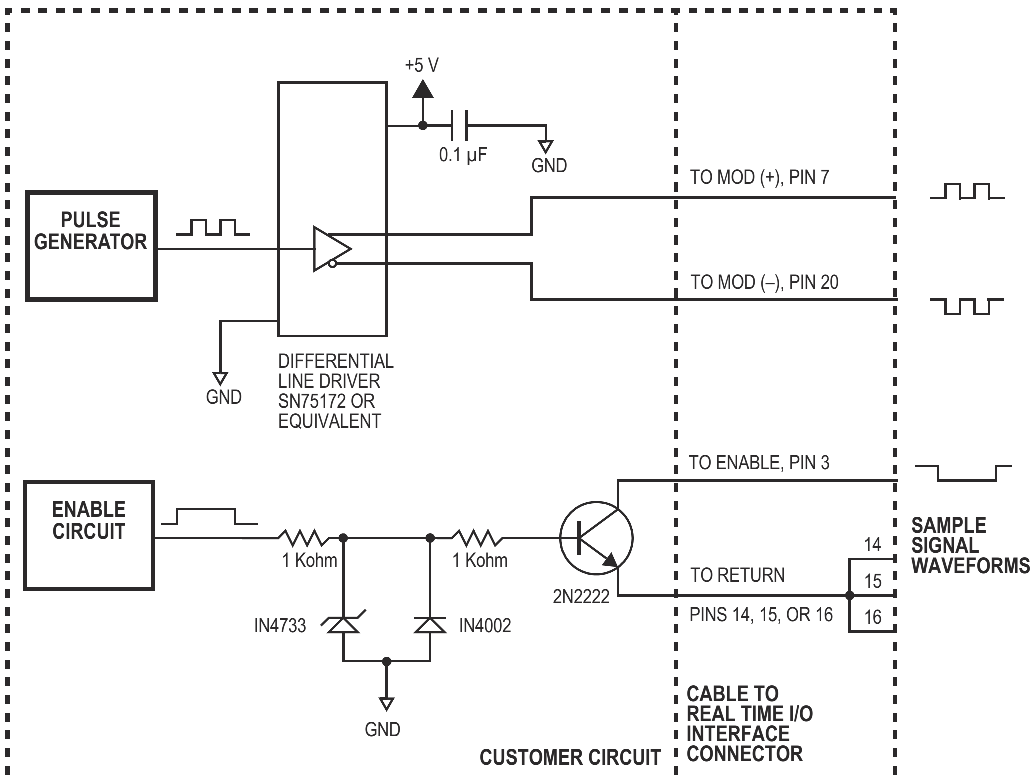



***Figure 4-4. Typical Drive Circuit for Real Time Control***

***Table 4-5. Examples of Line Drivers Meeting RS-422A***

| Device Part Number | Description | Manufacturer | Mfg Web Site |
|---|---|---|---|
| SN75172 | Quad Driver | Texas Instruments | www.ti.com |
| AM26LS31C | | | |
| AM26C31 | | | |
| SN75ALS191 | Dual Driver | | |
| DS26LS31C | Quad Driver | | |
| MC75172 | | On Semiconductor | www.onsemi.com |

## Output Signal Recommendation

There are five output signals from the Real Time I/O Interface Connector. Four of these indicate the status of the laser system. These four outputs (duty cycle limit, VSWR limit, analog forward, and analog reflected) provide useful information to the user on the function of the laser system. Figure 4-5 shows a schematic of the output circuits located in the RF power module interface circuit. Although monitoring of these six outputs is not required, it is strongly recommended for the overall ease of use of the complete system.

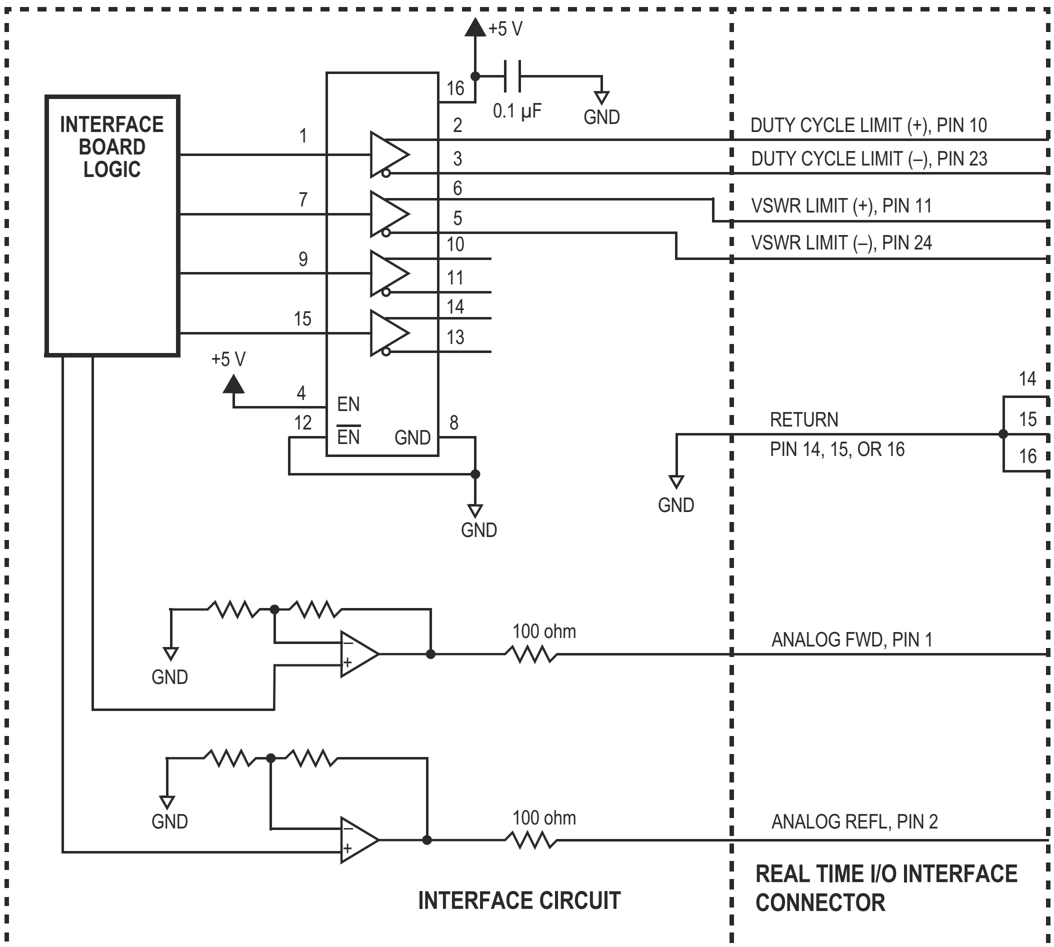



*Figure 4-5. Real Time Control and Status Interface Schematic*

Their purpose is to warn the user of potential faults and can assist in the diagnosis of several types of operating problems. A common situation when these warnings are useful is when incorrect pulse widths and pulse periods have been selected. An example would be selecting a duty cycle of 70% (max. duty cycle = 60%) and the user observing unstable laser performance. The warning indicator DUTY CYCLE LIMIT will show the error and make it possible to rapidly correct this problem.

## Output Signal Description

The DUTY CYCLE LIMIT and the VSWR LIMIT disruptive faults indicate when the control circuitry in the RF power module is activated and limiting the operation of the RF power module. When these functions are activated, the output power of the laser can be unstable or much lower than expected. If there is a DUTY CYCLE LIMIT warning, then check the MODULATION pulse width and pulse period to ensure that they are not exceeding maximum duty cycle limit or 1000 μs pulse width.

The VSWR LIMIT indicates that the ratio of the reflected RF voltage to the forward RF voltage has exceeded a preset limit. In some transient starting situations, the VSWR LIMIT disruptive fault will be activated. Coherent recommends checking the status of this indicator about 100 ms after starting the MODULATION signal. If the disruptive fault signal persists during stable operation, additional diagnostics can be performed using techniques presented in Section Six: Maintenance and Troubleshooting and in Appendix A: Embedded Control and Diagnostics to determine if the problem resides in the laser head or the RF power module. The unit should be replaced if the laser power is low.

Coherent recommends using both VSWR LIMIT and DUTY CYCLE LIMIT to directly monitor disruptive faults. This class of faults allows operation but is disruptive and can lead to unwanted results.

## Monitoring Circuit Example

An example of a monitoring circuit that can be connected to the output of the Real Time I/O interface circuit is indicated in Figure 4-6.

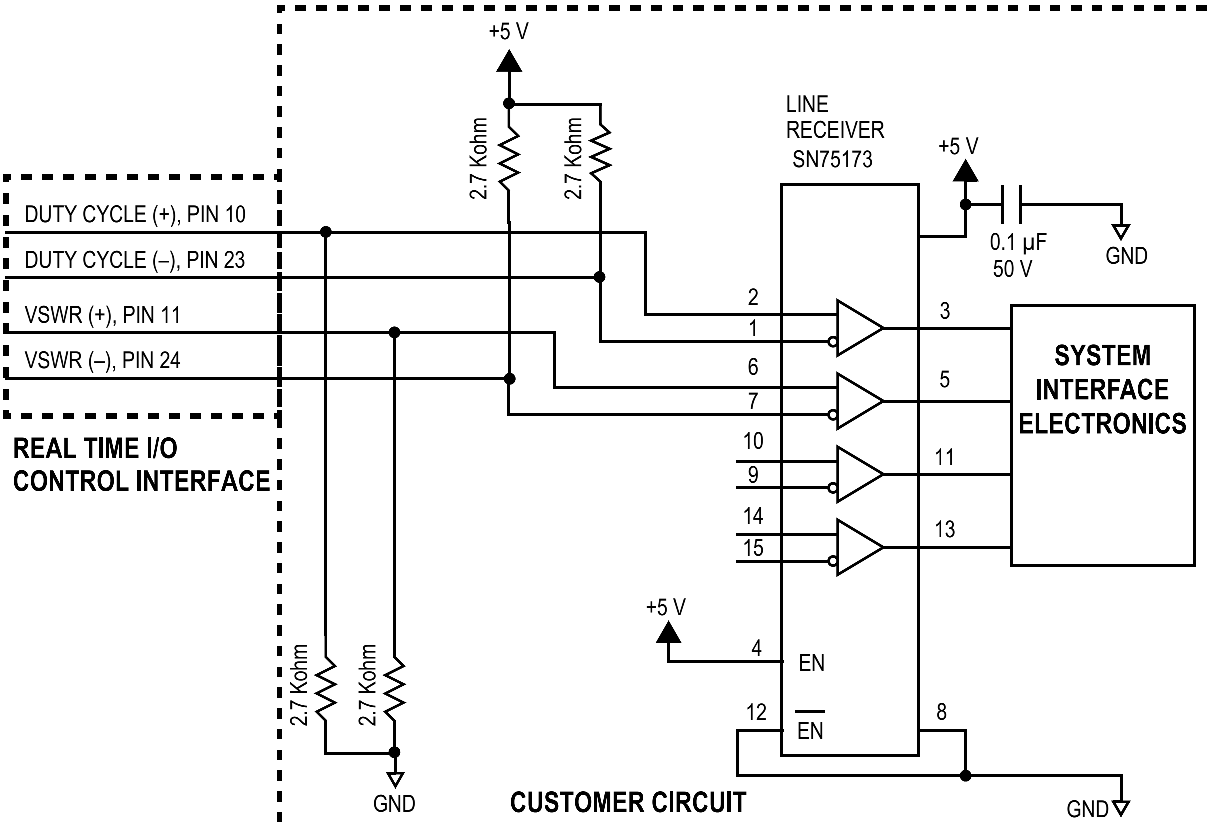



*Figure 4-6. Typical Monitoring Circuit*
*Example Status Monitor (Real Time I/O Control and Status Interface)*

*Table 4-6. Examples of Line Receivers Meeting RS-422A*

| Device Part Number | Description | Manufacturer | Mfg Web Site |
|---|---|---|---|
| SN75173 | Quad Receiver | Texas Instruments | www.ti.com |
| AM26LS32A | | | |
| MC3486 | | | |
| AM26C32 | | | |
| SN75157 | Dual Receiver | | |
| DS26LS32C | Quad Receiver | | |

The E-400 Series output circuits shown in Figure 4-5 are designed to use line receivers meeting the requirements of EIA Standard RS-422A. Common mode voltages on the drive signals should be kept as low as possible and cannot exceed ± 15 Volts relative to the laser system ground. Examples of suitable line receivers are shown in Table 4-6.

## Control Using E/G/K Remote Control

A remote controller is available for use with the E-400 Series laser. Contact Coherent for additional information. For specifications and operating instructions, refer to the DIAMOND E/G/K OEM/Industrial Lasers Remote Control Operator's Manual, part number 1235412.


*Figure 4-7. DIAMOND E/G/K Remote Controller*

## Output Signal Waveforms

The output waveforms of ANALOG FORWARD, ANALOG REFLECTED, and the DUTY CYCLE LIMIT and VSWR LIMIT faults are shown in Figure 4-8 on page 4-15 through Figure 4-10 on page 4-17.

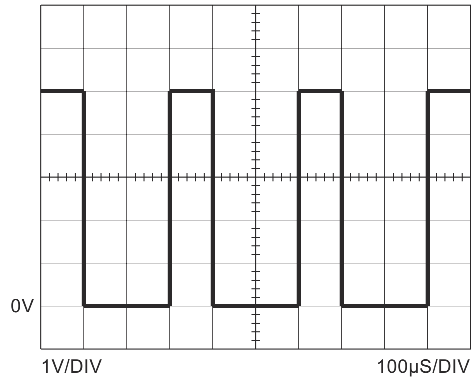
The ANALOG FORWARD signal is shown to clearly indicate when RF power is being delivered to the laser tube under a variety of conditions. All of these signals are at the noted pinout indicated beside the figure and referenced to ground (return).

The first set of waveforms shown in Figure 4-8 depicts normal operation without any faults activated.

Refer to Figure 4-9. Whenever a VSWR fault is detected, the next nine MODULATION pulses are suppressed, with each suppressed pulse appearing as a HI pulse on VSWR LIMIT. As long as the VSWR fault remains, only 1 of each 10 pulses will get through as ANALOG FORWARD. Once the VSWR fault condition is removed, the ANALOG FORWARD signal returns to normal following the MODULATION pulses.

In Figure 4-10, the MODULATION input begins with a pulse width of 500 µs and a pulse period of 1000 µs for a 50% duty cycle (a legal operating point with duty cycle less than or equal to 60%). Then the MODULATION input changes to a pulse width of 700 µs and a pulse period of 1000 µs for a 70% duty cycle (an illegal operating point since the duty cycle exceeds 60%). The controller suppresses the portion of the MODULATION pulse that exceeds the maximum pulse width and/or duty cycle.

It is recommended to sense the status of the output signals from the RF power module near the trailing edge of the MODULATION signal. There are transient starting conditions that will activate these disruptive faults. If possible, design the monitoring system of these signals to neglect the first 100 ms of operation after the laser has been off for a period of time longer than a few seconds. This will minimize the number of faults.



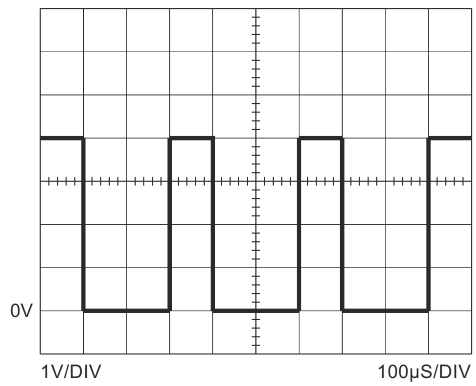

Modulation (+): Input
pin 7 (reference pin 14)

Pulse Width = 100µs

Pulse Period = 300µs

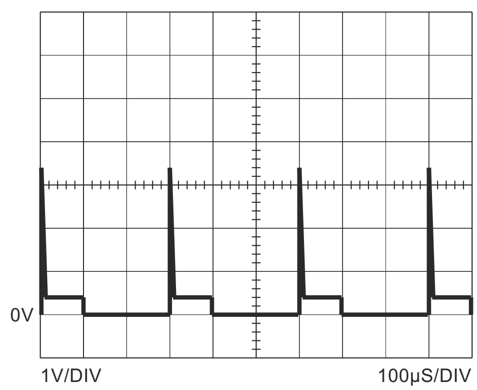
Duty Cycle = 33%

Laser is ON when modulation signal is high




Analog Forward: Output
pin 1 (reference pin 14)

Analog Forward signal is high anytime the modulation signal is active (high) and within specification.




Analog Reflected (+): Output
pin 2 (reference Pin 14)

Analog Reflected signal remains low when the modulation signal is high, except for a short spike at the leading edge of the pulse.

***Figure 4-8. RF Amplifier Output Signals - Normal Operating Conditions***

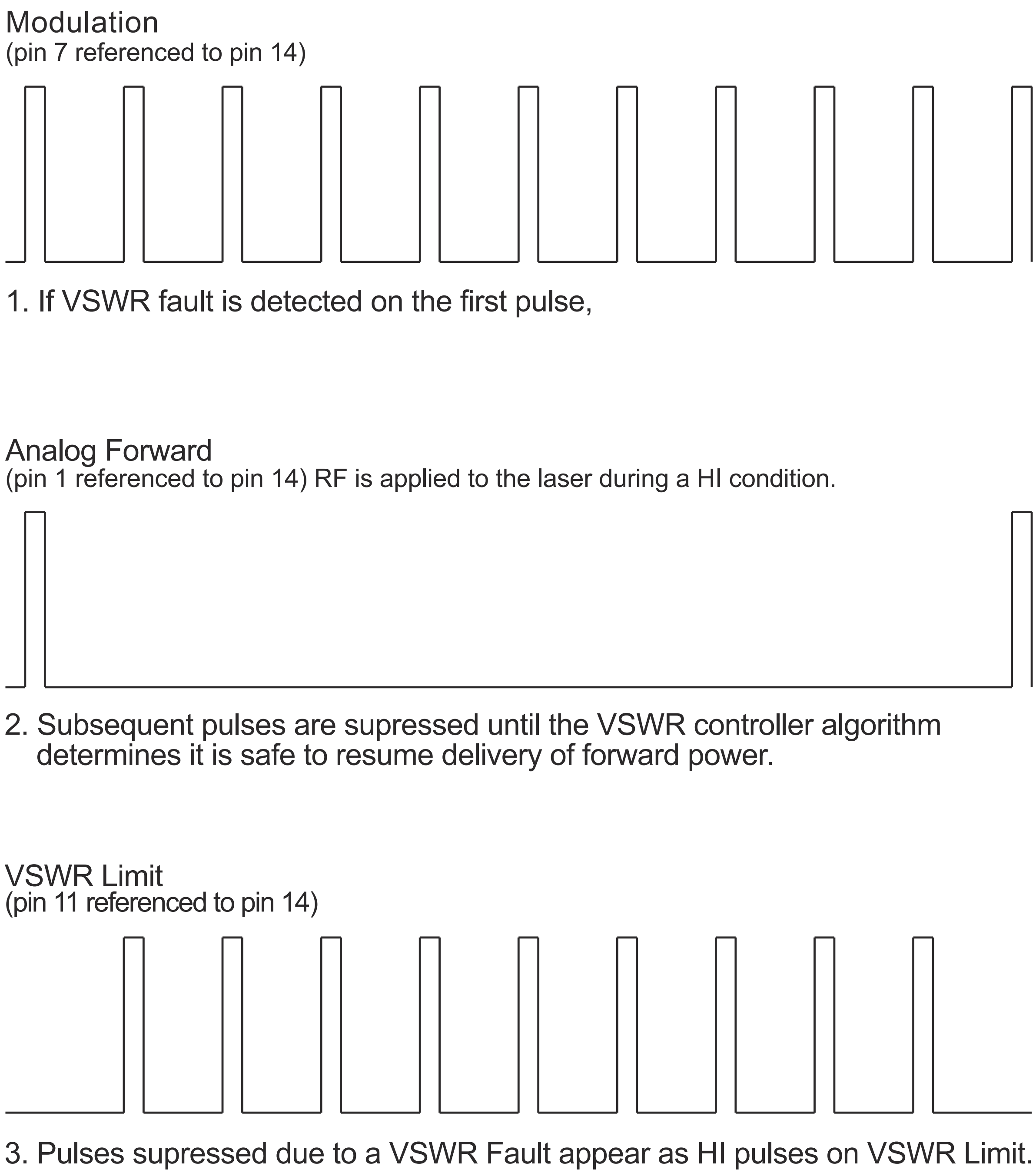



***Figure 4-9. RF Amplifier Output Signals - VSWR Fault***

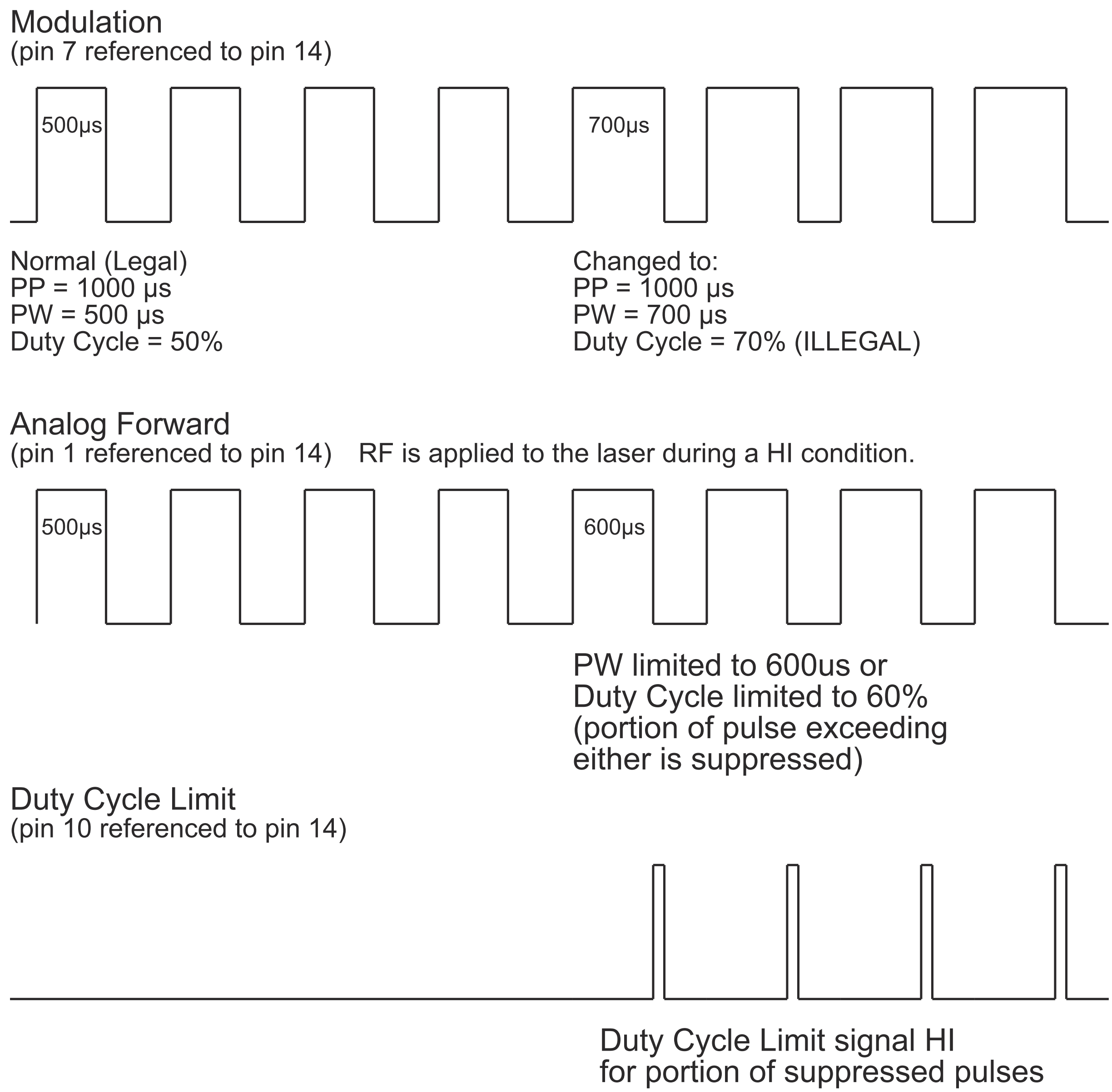



***Figure 4-10. RF Amplifier Output Signals - Duty Cycle Fault***

## Extended Interface Connector and Signal Descriptions

The Extended Interface connector gives the user access to more monitoring and control features of E-400 Series laser systems. There are 4 inputs and 8 outputs on this connector that are described in Table 4-7. Pin assignments and signal specifications are described in Table 4-8 on page 4-20 and the block diagram of the output is provided in Figure 4-11 on page 4-22.

## System Interlock

A System Interlock input signal is required to enable modulation to the laser. This input can also be used to disable modulation when put in series with a safety circuit.

## Shutter Control and Status

The Shutter Interlock input signal is used to indicate to the system that a shutter is available (the shutter is an optional component on some model types) and to enable the shutter. The shutter is commanded to the open or closed state by sending the appropriate signal to the shutter command input. Signals are also available to monitor the shutter's position, one for the Shutter Closed Status and one for the Shutter Open Status. Finally, there is a shutter latching fault signal that indicates if the shutter is in a fault condition or is stuck between opening and closing.

## Flow Fault (Legacy)

If included, the user can monitor the status of coolant flow with this signal. When active high, this output indicates lack of sufficient coolant flow to safely operate the system. The presence of this latching fault will shut down the system. (Note: Coolant flow sensing is being phased out, contact Coherent for additional information concerning specific models.)

## Over Temperature Fault

This output signal indicates that the operating temperature is above a safe operating condition. The presence of this latching fault will shut down the system.

## Analog Laser Power Monitor

The internal Analog Laser Power Monitor is an optional feature on some model types.

If installed, this output provides a voltage that is proportional to the average laser output power. It can be used to monitor the output power, independent of whether the shutter is opened or closed state.

The power monitor is factory calibrated to 0.6V = 400W nominal.

## *Extended Interface Signal Descriptions*

*Table 4-7. Extended Interface Signal Descriptions*

| IDENTIFICATION | BRIEF DESCRIPTION | CONNECTION |
|---|---|---|
| **INPUT SIGNALS** | | |
| Shutter Command | Opens and closes shutter (if shutter option is installed) | Required* |
| Ethernet Control Enable | Disables Real Time I/O (Enable and Modulation) and allows control via Ethernet | Test Function |
| System Interlock | Enables modulation and shutter operation | Required* |
| Shutter Interlock | Enables shutter operation | Required* |
| **OUTPUT SIGNALS** | | |
| Shutter Closed Status | Signals that shutter is closed | Recommended* |
| Shutter Open Status | Signals that shutter is open | Recommended* |
| Shutter Latching Fault | Indicates a shutter fault | Recommended* |
| Flow Latching Fault (Legacy) | Indicates a coolant flow fault | Recommended |
| Over Temperature Latching Fault | Indicates an unsafe temperature condition | Recommended |
| Analog Laser Power Monitor | Analog voltage output proportional to laser power | Test Function |
| *Note: Shutter signals apply if shutter option is installed | | |

*NOTICE!*
**The optional internal shutter is not to be used for beam modulation (as a 'process shutter'). This shutter is provided for laser safety purposes only, but it is not a safety-certified device.**

## Extended Interface Pin Descriptions

*Table 4-8. Extended Interface Pin Descriptions*

| PINS | FUNCTION | DESCRIPTION |
|---|---|---|
| 1, 2, 11 | - | Not currently used on this product. |
| 9 (+) and 22 (–) | Shutter Closed Status | Active high, differential, digital, output signal indicating the shutter is closed.<br>This output signal will be asserted when the shutter is present and closed. During latching faults, this signal will not be present since the shutter is disabled. |
| 12, 13, 14 | Return | Reference for pins 21, 24, 25 |
| 15 (+) and 3 (–) | Shutter Command | Active high, digital, input signal that commands the shutter to open.<br>This input signal is used to command the operation of the shutter. Note that if Ethernet Control Enable is asserted, this signal will not respond. |
| 16 (+) and 4 (–) | Ethernet Control Enable | Active high, digital, input signal that enables laser control via Ethernet.<br>This input signal is used to enable control of the E-400 system via the Ethernet interface. When this signal is asserted the user can operate enable, modulate and command the shutter via Ethernet. The real time input output functions for enable, modulate and shutter command will not be active during this time. **If the system is controlled via Ethernet (for diagnostic purposes), the real-time control interface is disabled.** |
| 17 (+) and 5 (–) | Shutter Open Status | Active high, differential, digital, output signal indicating the shutter is open.<br>This output signal will be asserted when the shutter is present and open. During system faults, this signal will not be present since the shutter is disabled. |

***Table 4-8. Extended Interface Pin Descriptions (Continued)***

| PINS | FUNCTION | DESCRIPTION |
|---|---|---|
| 18 (+) and 6 (–) | Shutter Latching Fault | Active high, differential, digital, output signal indicating that there is a shutter fault.<br>This output signal will be asserted when a shutter fault has been detected. There are two conditions which can cause a shutter fault. First, if the shutter takes too long to swing from open to closed and vice versa. Second, a fault will be generated if the customer is commanding the shutter to be closed and the shutter closed status signal is not detected. For the purposes of fault detection, shutter open, shutter moving, or neither open nor closed are tested for determining a fault condition. A Shutter Latching Fault causes system shutdown. |
| 19 (+) and 7 (–) | Flow Latching Fault (Legacy) | Active high, differential, digital, output signal indicating insufficient coolant flow and/or incorrect coolant flow direction.<br>This signal is not proportional to the coolant flow. The flow switch is either open or closed. A Flow Latching Fault causes system shutdown. |
| 20 (+) and 8 (–) | Over Temperature Fault | Active high, differential, digital, output signal indicating an operating temperature outside an allowed range has occurred.<br>This output signal will be asserted when any peripheral microcontroller detects a temperature channel that is outside the allowed temperature range. Refer to Appendix B: Fault Matrix for ranges. Over temperature latching fault is a system fault that causes shutdown. |
| 21 | Analog Laser Power Monitor | Analog output signal that is proportional to the laser power (0.6V = 400W nominal). |
| 24 | System Interlock | This pin must be connected to pin 12 (return) for laser to operate.<br>It has priority over all other interlocks. |
| 25 | Shutter Interlock | This pin must be connected to pin 13 (return) for the shutter to operate.<br>This signal does not inhibit system operation. If a shutter is not present, the shutter interlock must not be grounded or a shutter fault condition will be present. |

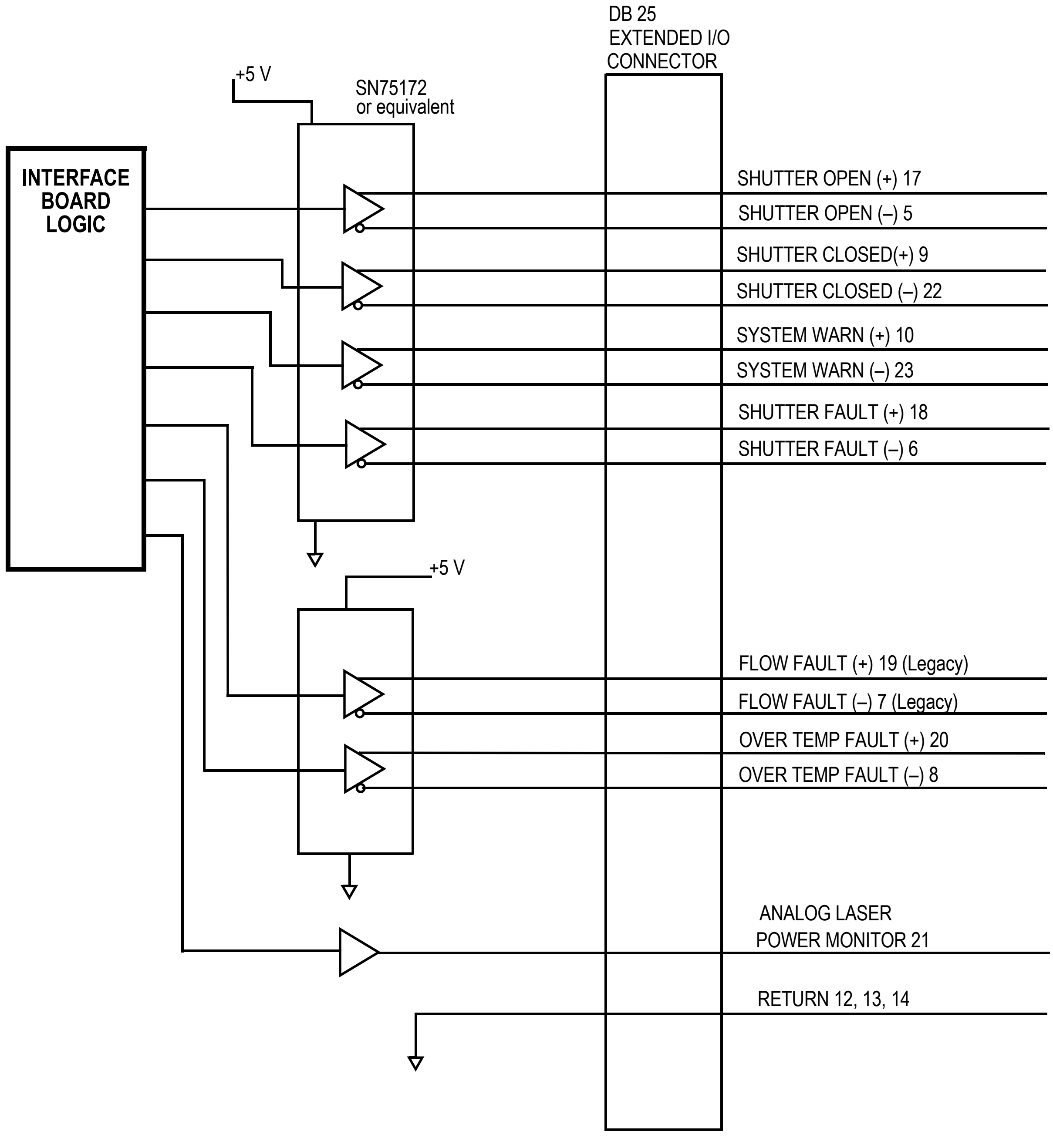



***Figure 4-11. Extended Interface Connector Outputs Block Diagram (representative, not actual schematic)***

## DCPS/Auxiliary Connector Pin Descriptions

The DCPS/Auxiliary I/O connector (J12) provides for an auxiliary 48 VDC input to permit operation of the control/diagnostic electronics without application of the main 48 VDC power supply. This enables the user to monitor the status of all diagnostic readings if there is a loss of the high current primary 48 VDC power or to test the control/diagnostic electronics without the need for a high current DC power supply. The current requirement for the user supplied auxiliary 48 VDC power supply is 2 A maximum. It is not possible to generate laser output when using only the auxiliary supply because no power is applied to the RF power module's oscillator and power amplifiers. If a decision is made to use the auxiliary 48 V input option, Coherent strongly recommends that the main External DCPS be physically disconnected from the input terminals at the laser utilities panel.

This connector also provides for reserved I/O to support the implementation of auxiliary control/diagnostic options. Contact Coherent for additional information on the available E-400 Series options.

Detailed descriptions and pinouts of the DCPS/Auxiliary connector interface are provided in Table 4-9.

***Table 4-9. DCPS Auxiliary Connector Pin Descriptions***

| PIN | FUNCTION | DESCRIPTION |
|---|---|---|
| 1-9, 12-15 | Auxiliary Control/ Diagnostic Options | Reserved - do not connect. |
| 10 | +48V Aux DC Input | Auxiliary +48 V input (2 A max.) for diagnostics power. This input can be used to apply power to the controller circuit without powering up the high current circuits in the laser system. |
| 11, 12, 13 | Return | Return for +48 V Aux DC. |

# SECTION FIVE: OPERATION

## *Introduction*

This section provides startup and shutdown procedures. Also included is a description of E-400 Series laser system controls, indicators, and interface connectors.

## *Startup Procedure*

This procedure assumes that the laser has been installed in accordance with the procedures in Section Three: Utility Requirements and System Installation.

**WARNING!**
**To avoid serious eye injury, ensure all personnel in the area are wearing laser safety eyewear appropriate for the wavelengths and power levels produced.**

Refer to Section Six: Maintenance and Troubleshooting to resolve any faults or problems encountered during startup.

**WARNING!**
**Before proceeding, ensure all safety practices are in effect including those in Section Two: Laser Safety of this manual and that the laser is directed in a safe manner so that the output beam will not strike an unintended target, causing damage or serious injury.**

1. Turn on the laser system coolant supply. To avoid over-pressurization of the cooling system, open the drain valve before opening the supply valve. Let coolant temperature stabilize to set point temperature.
2. Verify that the purge gas is on and is flowing at the correct flow rate.
3. Place a suitable power meter head or a beam stop in front of the laser to block the output beam.

**WARNING!**
**Failure to perform the next step could result in the beam exiting the laser when power is applied and causing damage or serious injury.**

4. Ensure the laser functions in Table 5-1 are observed. (Note: Laser turn-on functions may vary by specific model type, contact Coherent for additional information.)

***Table 5-1. E-400 Series (Standard) Laser Turn-on Functions***

| FUNCTION | COMMENT |
|---|---|
| DC Power Supply | Off |
| Modulation Enable | Off. Table 4-4 lists pinouts for the Real Time Control. The RF power module is disabled when pin 3 is not connected to return. |
| Pulse Width | 120 µs<br>A 120 µs pulse width in combination with a 6000 µs pulse period is recommended for initial turn-on. This combination should result in 10 to 20 Watts output power. |
| Pulse Period | 6000 µs<br>A 6000 µs pulse period in combination with a 120 µs pulse width is recommended for initial turn-on. This combination should result in 10 to 20 Watts output power. |

5. Turn on the facility circuit breaker and facility On/Off switch (if installed).
6. Verify that the system interlock (pin 24 on the Extended Interface Connector) is connected to a RETURN (pin 12) and the shutter interlock (pin 25) is connected to a RETURN (pin 13). If there is no shutter installed, do not connect the shutter interlock to a RETURN. Doing so will result in a shutter fault.
7. Turn on the DC power supply. The +48 V green LED indicators on the RF power module and laser head interface should now be on. Wait at least 10 seconds before proceeding to next step.
8. Enable the laser system by connecting the ENABLE function to RETURN.
9. If the shutter option is installed, open the shutter by applying an active high signal to pins 15(+) and 3(–) of the Extended I/O Interface. See Table 4-8 for a complete list of the Extended I/O Interface pinouts.

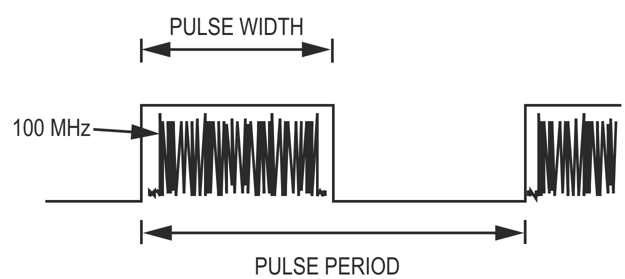
10. Turn on the modulation signal. Adjust the output as required. Refer to "Adjusting the E-400 Series Laser Output" for additional information.

## Adjusting the E-400 Series Laser Output

E-400 Series laser systems can operate using various pulse formats which allows full user control of the output depending on the application. Parameters that can be controlled by the operator that affect the output include:

- Pulse period (or pulse frequency)
- Pulse width

A graphical definition of the pulse width is shown in Figure 5-1. During the time interval of the pulse width, the RF power is directed to the laser head. In E-400 Series lasers, the RF frequency is 100 MHz. The pulse width is the time that the RF is turned on and the pulse period is the time between the leading edges of these repetitive pulses. Another way to describe the pulse period is the pulse frequency, which is just the inverse of the pulse period. A pulse period of 1000 µs corresponds to an operating frequency of 1000 Hz.




$$\text{DUTY CYCLE} = \frac{\text{PULSE WIDTH}}{\text{PULSE PERIOD}} \times 100\%$$

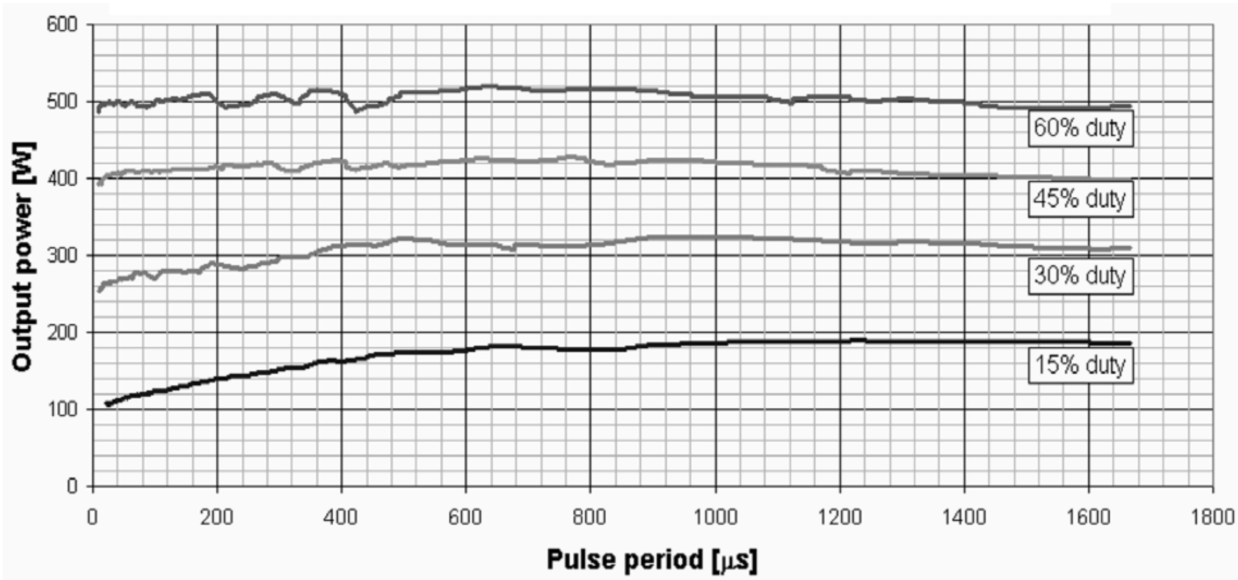
***Figure 5-1. Typical Pulse/Modulation***

Varying one or both of these parameters (i.e., pulse period and pulse width) impacts the following output characteristics:

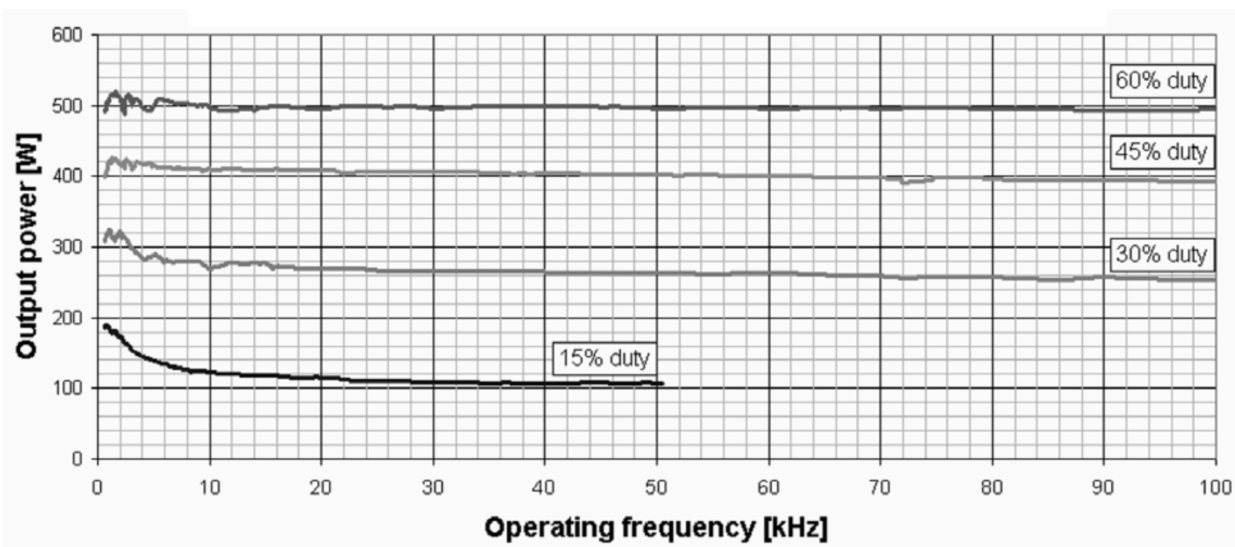
- Average output power
- Peak pulse power (pulse energy)
- Duty cycle

The total number of possible input parameter variations and the resulting output is quite large. Some representative examples of performance for various input modulation conditions are illustrated in Figure 5-2 through Figure 5-5.

In order to have an efficient laser, all the power that is developed by the RF power module must be delivered to the laser tube. In practice, over 99% of the power that is developed by the RF power module is delivered to the laser tube and the remaining power is reflected back toward the RF power module. These parameters are important in the function of the laser system and they have several related warning functions discussed in Section Six: Maintenance and Trouble-shooting.




A. OUTPUT POWER AS FUNCTION OF PULSE PERIOD DURATION.
DUTY CYCLE IS NOTED FOR EACH CURVE.




B. OUTPUT POWER AS FUNCTION OF OPERATING FREQUENCY.
DUTY CYCLE IS NOTED FOR EACH CURVE.

Note: Each curve represents the pulse period.

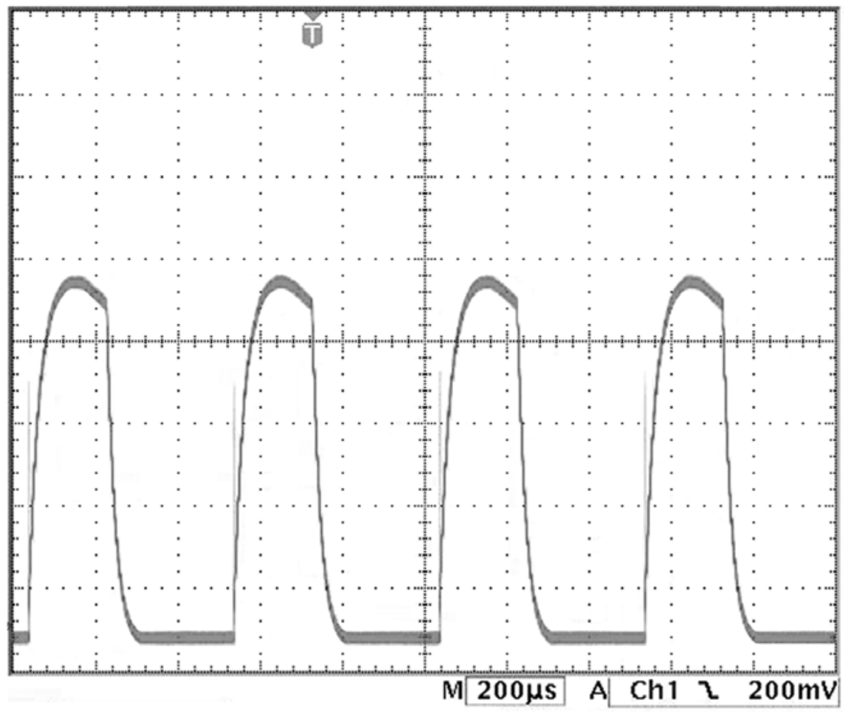
***Figure 5-2. Representative Output Power (E-400 Standard Model)***

Figure 5-2A provides representative average output power for four duty cycle conditions in which the modulation pulse period is varied from 10 μs (100 kHz PRF) to 1.66 ms (600 Hz PRF). Note that the average power has some variability over this wide operating range, especially at the low duty short pulse period condition.

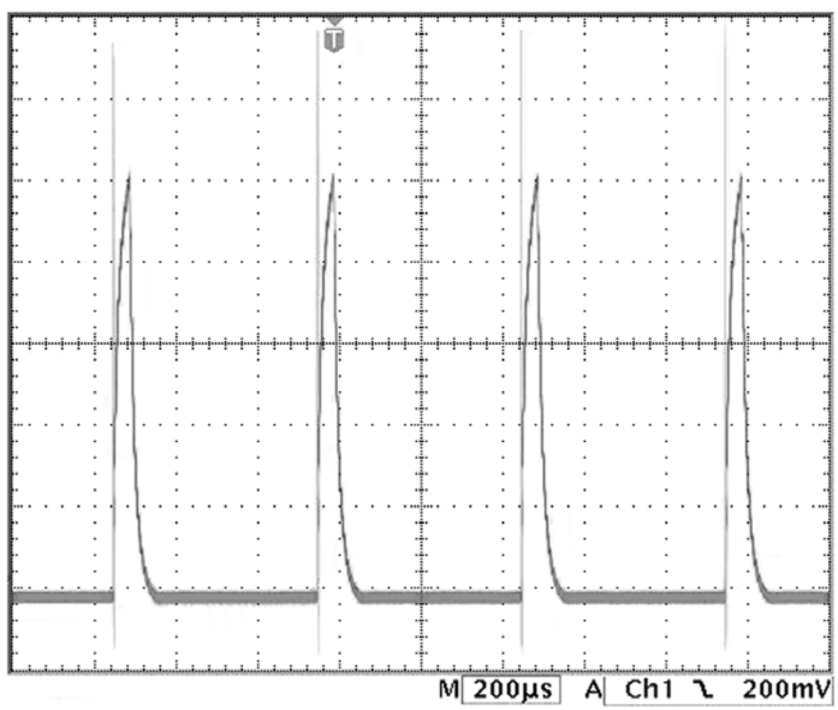
Figure 5-2B provides representative average output power for the same duty cycles shown in Figure 5-2A, but in this case the modulation pulse repetition frequency is varied from 600 Hz to 10 kHz. Note that the 15% duty curve stops at 50 kHz to avoid the 2 μs minimum pulse width limitation of the laser system control logic.

As evident in Figure 5-2, there are a large number of pulse widths and pulse periods that can deliver the same average output power. The specific pulse parameters choice will depend on the specific application. The processing speed will determine the desired pulse period. As the processing speed increases, then the pulse period will need to be decreased. Often there are other factors such as edge finish which will be important in selecting both the pulse parameters and the average operating power for a specific process.

As the pulse width is varied, there are also effects on the peak power available from the laser. An example of the instantaneous output power temporal shape is shown in Figure 5-3A. Each laser pulse has a ~ 60 μs rise time to full power and on the trailing edge a similar ~ 60 μs decay time from full power to no laser output. For laser pulses of several hundred microseconds duration, there is little impact on the laser performance due to this rise and fall time. But for pulses of about 100 μs and less, the actual laser output is more triangular in shape than square as shown in Figure 5-3B. Under this operation condition, the peak processing power decreases due the rise and fall time. For many applications, this operating condition provides a means to achieve fine process control. As the pulse period is reduced for these triangular shaped peaks, the bases of the triangles merge into each other. This results in quasi CW operation. Quasi CW operation occurs for pulse periods ≤100 μs and duty cycles >30%.




**A. PULSE WIDTH: 200 μS, PULSE PERIOD: 500 μS**



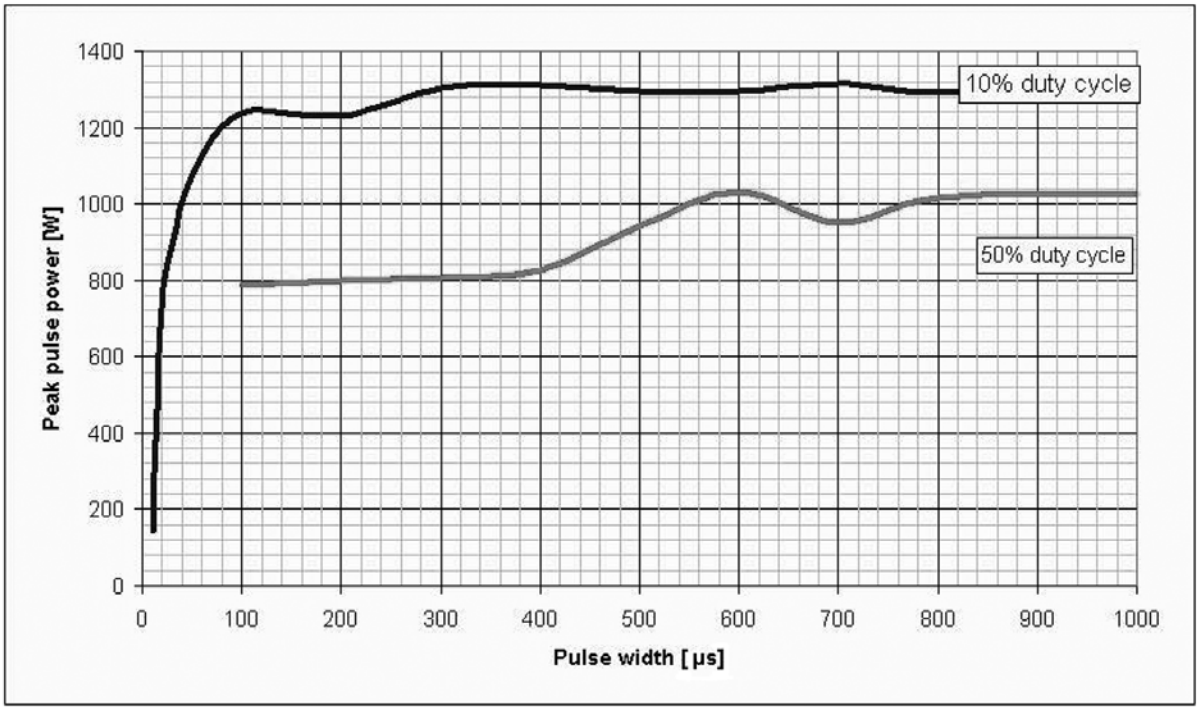

**B. PULSE WIDTH: 50 μS, PULSE PERIOD: 500 μS**

***Figure 5-3. Instantaneous Laser Output Power Showing Rise and Fall Times***

There can be some operating frequencies which cannot produce the minimum output power of 40 W and still have a pulse width in the range noted above. For example, when operating the laser at 50 kHz at the minimum pulse width will produce an output greater than 50 W. It is possible to select a combination of pulse width and pulse period that will produce less than 40 W of output power from standard E-400 system. Under these conditions, the power stability generally will exceed the value in Table 1-2 on page 1-10. Performance including such parameters as power stability can be achieved when the laser is operated over the power range noted in the specifications and for pulse widths between 2 µs and 1,000 µs.

The high effective processing power of any E-400 Series laser system results from its peak pulse performance. The primary variables that control peak are the pulse width and the duty cycle. Figure 5-4 shows the range of the peak power during a pulse for various pulse widths. The pulse power shown in this figure is the peak power during a fixed pulse width for various repetition rates. Increasing the duty cycle has the effect of moving vertically down on this graph (i.e., lowering the peak power).

As is evident in Figure 5-4, the peak power capability of a standard E-400 is substantially above its 400W rated long term average power.




Values shown are obtained from a representative standard E-400 with less than 500 hours of operation. They are not intended to reflect performance for each individual laser.

***Figure 5-4. Effective Processing Peak Power vs. Pulse Width***

More complex "pulse burst" is also allowed. An example of a complex "pulse burst" output is illustrated in Figure 5-5 which shows the temporally resolved output power generated by a modulation input consisting of a high frequency pulse train modulated by a lower frequency pulse train. The specifics of pulse train used to generate this example is provided in the figure caption.

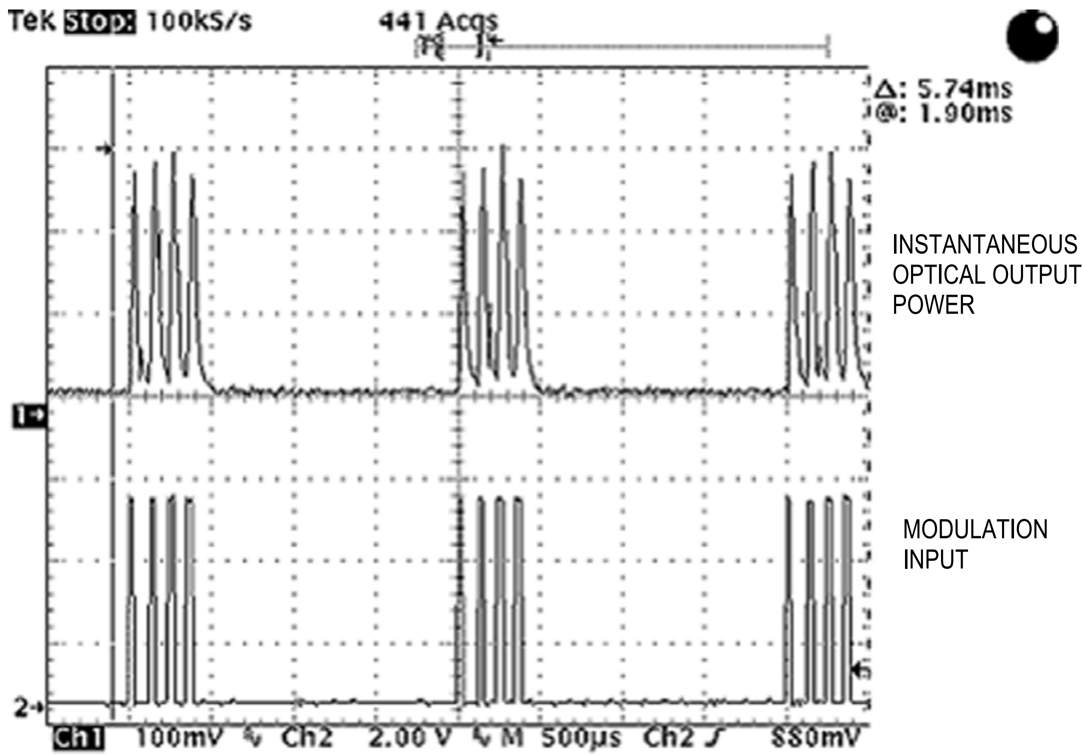



***Figure 5-5. Example of a Complex Output Pulse (Burst Width = 480 µs, Burst Period = 2 ms [500 Hz PRF] Pulse Width = 50 µs, Pulse Period = 120 µs [8.3 kHz PRF])***

With this type of waveform, the integrated energy delivered in a specific pulse burst can be controlled by varying the duty cycle of the high frequency pulse train. This type of waveform is used in many perforation, engraving, and drilling applications.

## *Shutdown Procedure*

**WARNING!**
**Failure to perform the next step could result in the beam exiting the laser when power is applied during the next turn-on, causing damage or serious injury.**

1. Set the laser system functions as indicated in Table 5-2.
2. Turn off the facility circuit breaker and facility On/Off switch (if installed).
3. Turn off the laser system cooling fluid. To avoid over pressurization of the cooling system, close the supply valve before closing the drain valve.

***Table 5-2. Control Unit Settings for Laser Shutdown (All Models)***

| CONTROL UNIT SWITCH | INDICATION |
|---|---|
| Modulation | Off |
| Shutter (option) | Closed |
| Output beam | Position a beam absorber or suitable power meter head to block the output beam |
| AC Power | Off (the +48 VDC indicators turn off) |
| Cooling fluid | Off |

# SECTION SIX: MAINTENANCE AND TROUBLESHOOTING

## *Introduction*

This section contains preventive maintenance procedures, troubleshooting information, and corrective actions. The electrical interface that these are based on includes the mandatory functions and the recommended warning functions. Without these functions available in some form, troubleshooting the laser system is extremely difficult.

**WARNING!**
**To perform the procedures in this section, there is potential access to laser output power. To avoid radiation exposure and serious injury, follow these safety guidelines:**

**Safety Guidelines**

- Perform the shutdown procedure before performing functions that will lead to laser output.
- Ensure the laser beam is directed at a suitable beam block (beam dump) or into a power meter.

## *Preventive Maintenance*

Monthly inspection of coolant and electrical connections will assist in keeping the laser system in good operating condition.

### Coolant System Inspection

Inspect coolant hoses, fittings, and connections for signs of wear, cuts, nicks, corrosion, or leaks. Coolant connections are located on the RF power module and on the laser head (refer to Figure 3-29 on page 3-42). In addition, inspect laser system connections to facility water supply and drain lines. Repair leaks and replace worn hoses immediately.

It is also recommended that the input coolant screen be periodically inspected for debris collection. See “Coolant (Strainer) Screen Cleaning” on page 6-18.

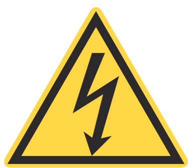
## Drain and Replace Coolant

The coolant mixture should be drained and replaced annually as recommended by the corrosion inhibitor manufacturer, OptiTemp. Dispose of old coolant per local recycling/recovery regulations.

## Optics Inspection and Cleaning

Since the optical train is sealed, periodic inspection and cleaning of optical components is not required. The purge gas assists in keeping optics clean.

## Electrical Inspection



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**DANGER!**
**Perform the "Shutdown Procedure" on page 5-11 and Lock-out/Tag-out the electrical disconnect switch or disconnect the electrical power source to the DC power supply prior to performing the electrical inspection.**

---

- Inspect electrical connections to ensure good contact.
- Check that wiring and insulation are in good condition, free of cuts, nicks, and excessive wear. Look for discoloration on the wire insulation, a sign that excessive heat is building up in the wire. In addition, inspect the wiring to the connector and the facility AC hook-up for signs of overheating.
- Inspect electrical connections on the laser head.

## Purge Gas System Maintenance

Maintenance will depend upon the type of purge gas system used.

If using the optional purge gas filter, as shown in Appendix E: Accessories and Options, replace the filters annually or sooner (depending upon quality of inlet air and hours of operation). On the two coalescing filter housings, press the automatic bowl drain up to make sure the drain valve moves freely.

Replacement filters are available from CT Components Inc. or from Parker (Filtration Division). See the Appendix E: Accessories and Options for contact information.

If using another filter assembly, contact the supplier for specific maintenance instructions.

## Troubleshooting

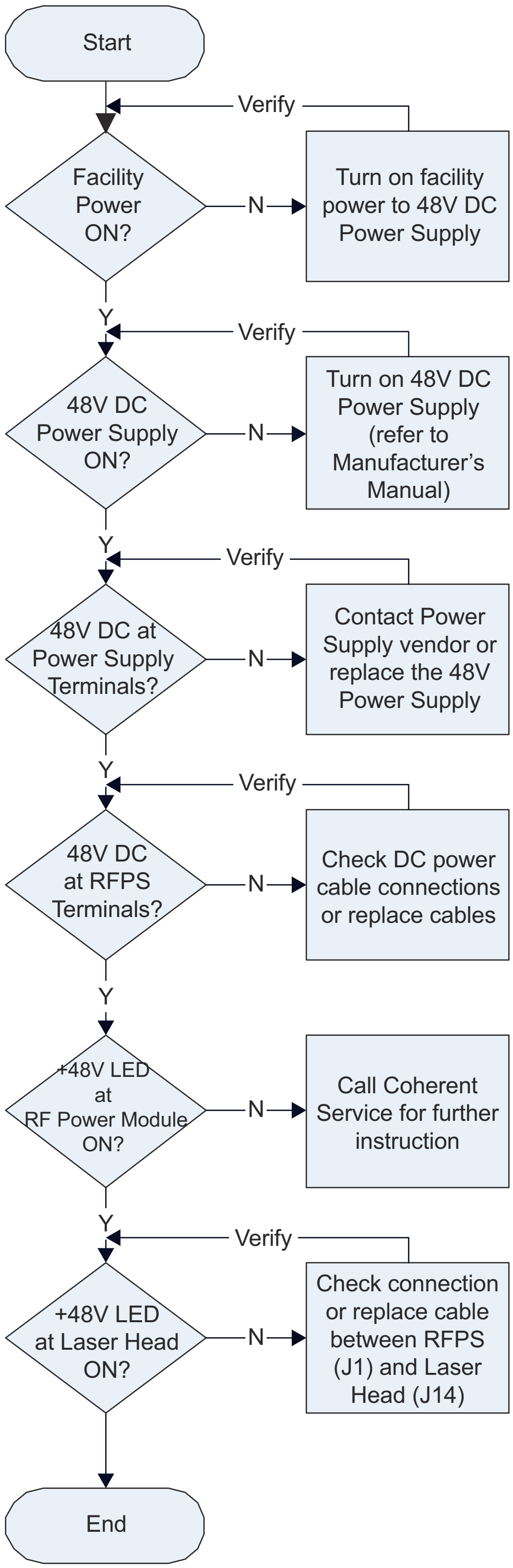
Charts 1 through 5 provide troubleshooting flow charts with supplemental information referenced to the numbered paragraphs that are also part of the chart. The charts and symptoms are summarized in Table 6-1.

***Table 6-1. System Faults and Warning Indications***

| FAULT INDICATION | EXPLANATION/REMEDY |
|---|---|
| +48V LED (either or both) off | Refer to Chart 1 |
| Laser does not start (no output power) | Refer to Chart 2, then see Chart 2A - 2E (controller specific) |
| Coolant flow switch tripped | Refer to Chart 4 |
| Laser power low or unstable | Refer to Chart 5 |
| Beam mode/shape/quality questionable | Refer to Chart 6 |
| The DUTY CYCLE LIMIT (pins 10 and 23) on the REALTIME I/O DB25 connector is active. | The duty cycle is limited to (refer to model specific data sheet) and the pulse width must be less than (refer to model specific data sheet). Exceeding the duty cycle or a pulse width will cause this function to become active. Increase the modulation pulse period or reduce pulse width to correct this problem. |
| The VSWR LIMIT (pins 11 and 24) on the REALTIME I/O DB25 connector is active. | The VSWR LIMIT indicates that the ratio of the reflected RF voltage to the forward RF voltage has exceeded a preset limit. This problem can be caused by either a defective laser tube or RF power module. In some transient starting situations, the VSWR LIMIT warning will be activated. Check the status of this signal about 100 ms after starting the modulation signal. |

When troubleshooting any E-400 Series laser system, ensure that the laser output beam will be safely contained. One practical method is to direct the output power into a thermal sensor such as a Coherent LM-1000. Always start with short pulse widths and high pulse periods as a starting point for troubleshooting.

# Chart 1. +48V LED is Off



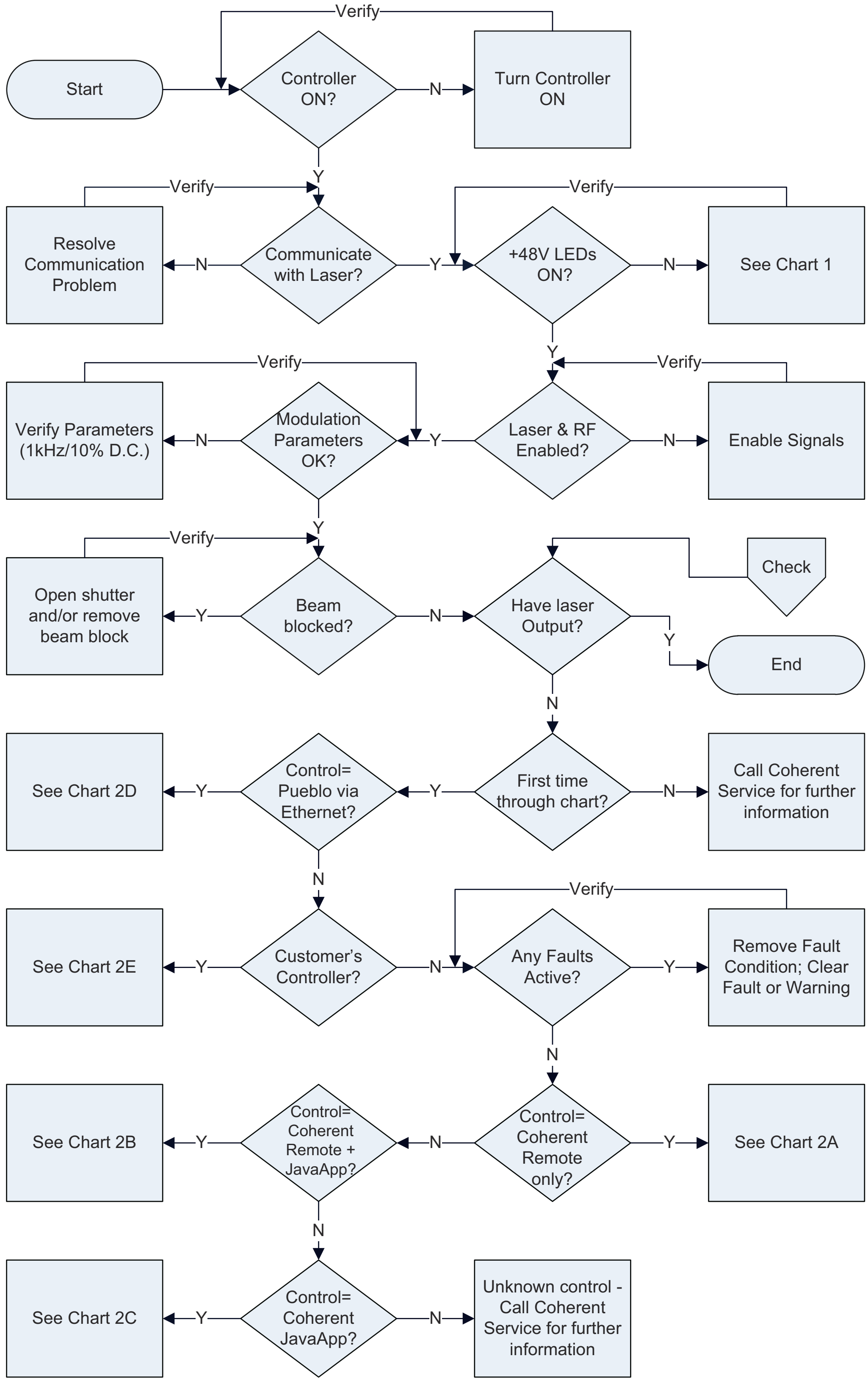

Note:

There are 2, +48V LEDs (green) on the E-400.
During normal operation, both must be ON (green):

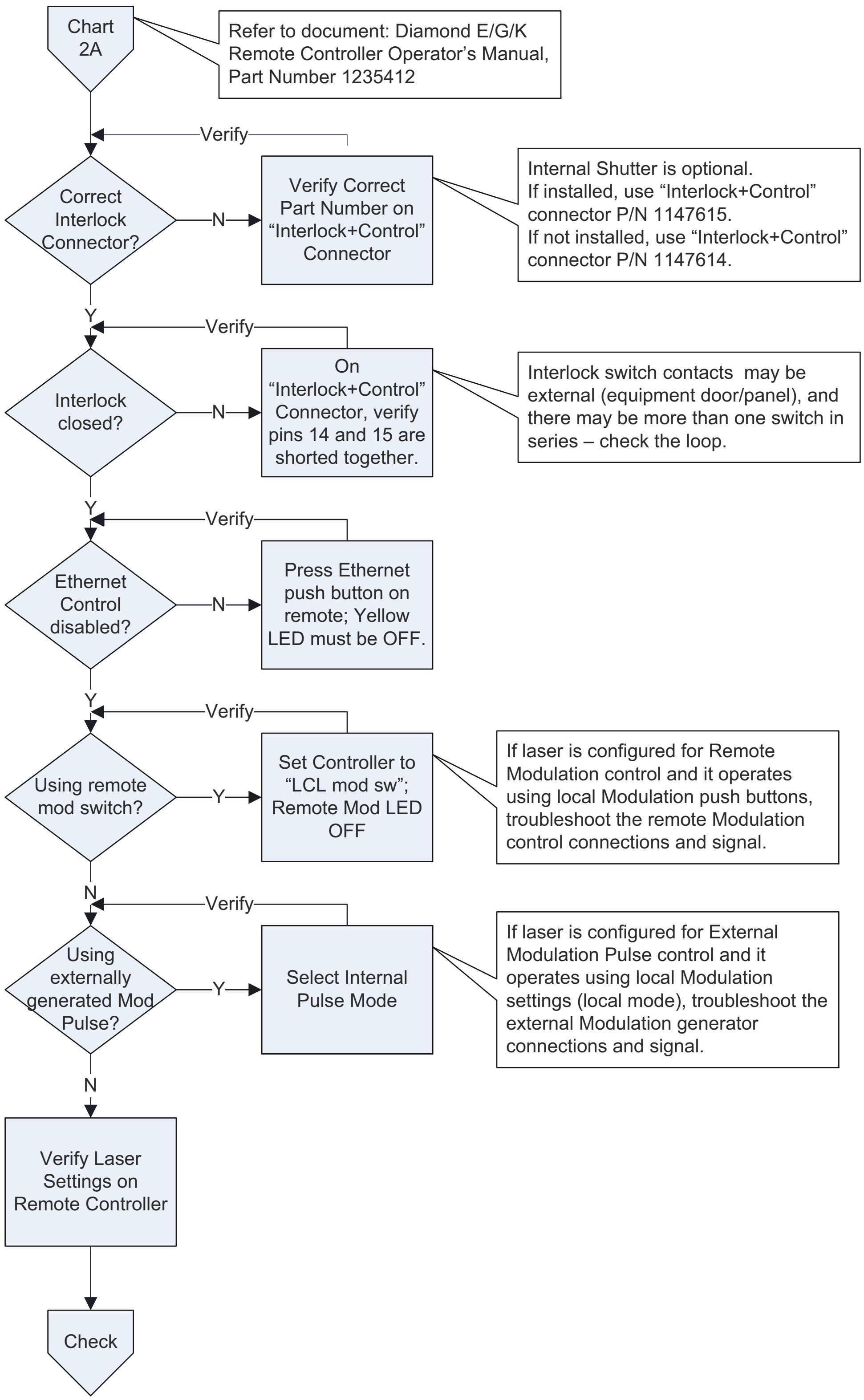
1 LED is on the RF power module
1 LED is on the laser head

Refer to Figure 3-29 on page 3-42 for LED locations (identified as Power Indicator LEDs).

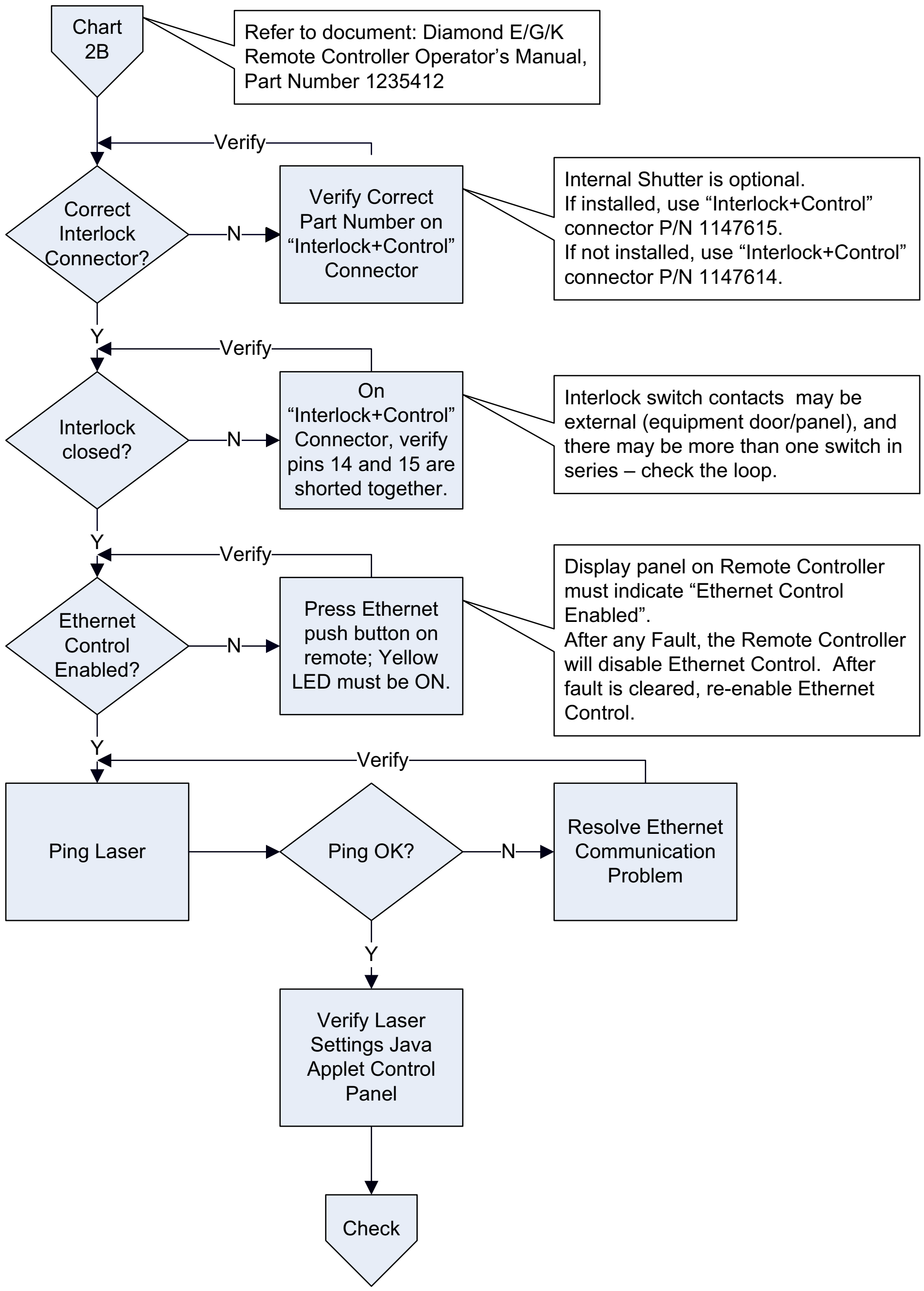
# Chart 2. Laser Does Not Start



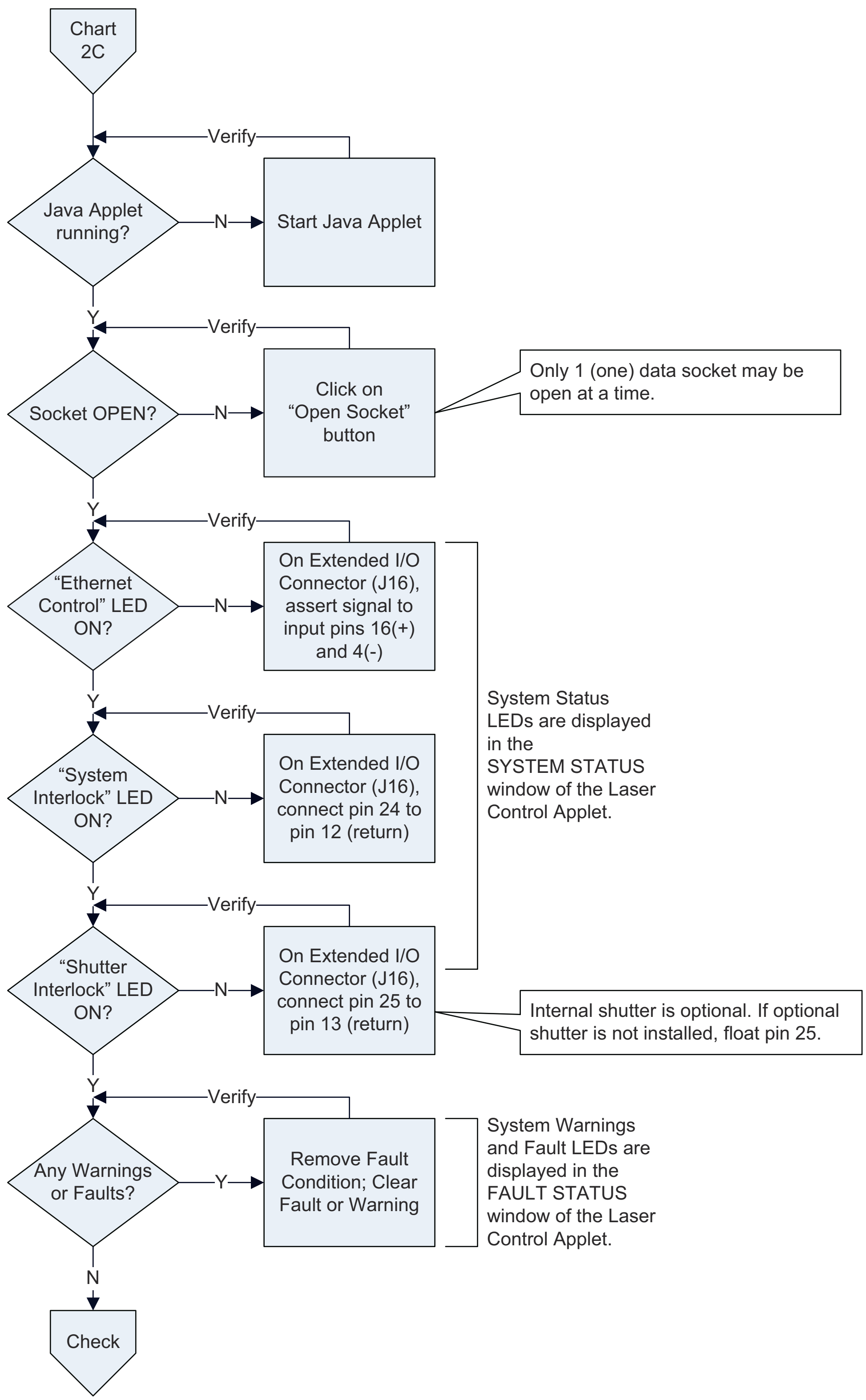
# Chart 2. A - Laser Does Not Start Using Coherent Remote Control Only



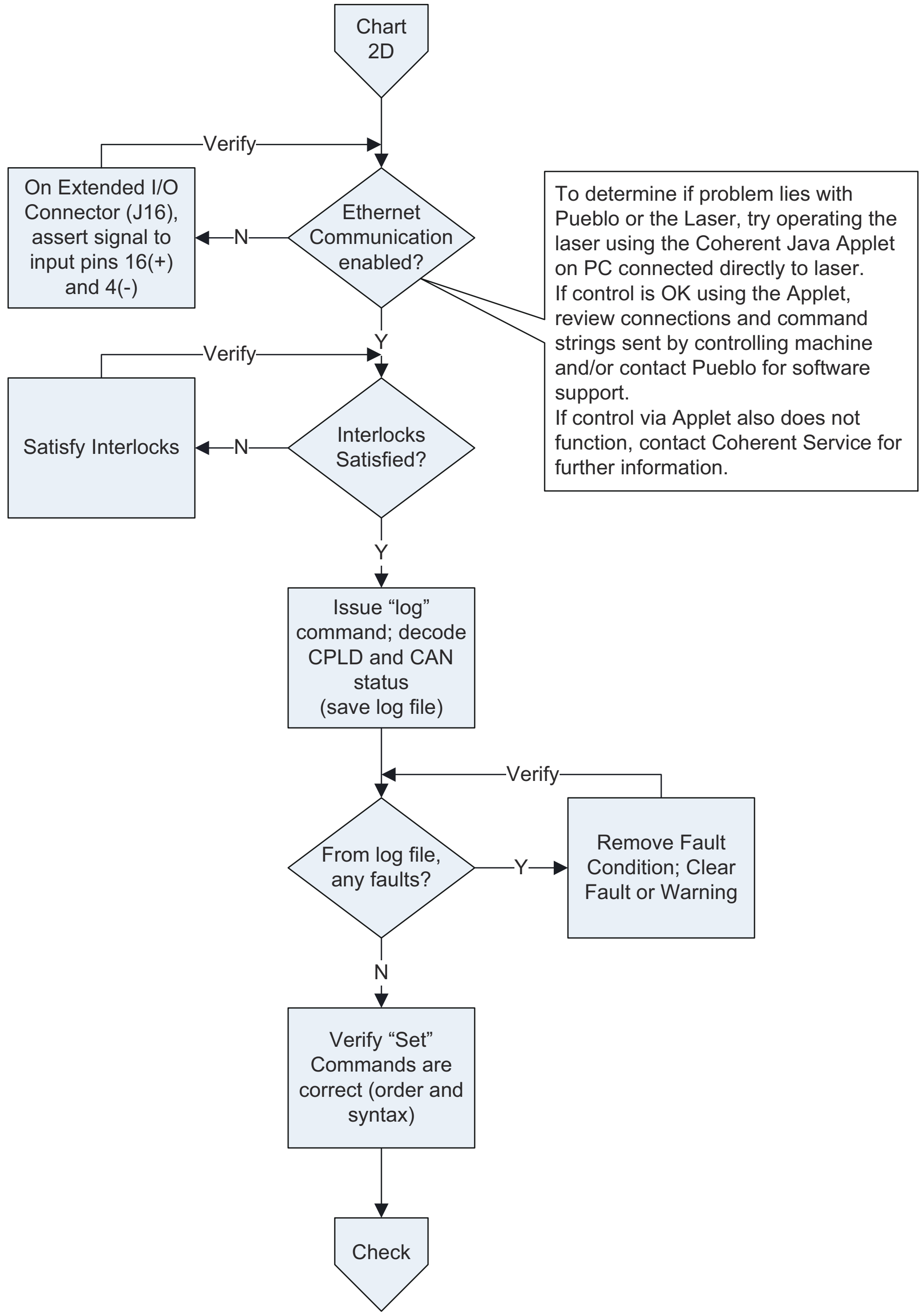
# Chart 2. B - Laser Does Not Start Using Coherent Remote and Java Application (Ethernet)



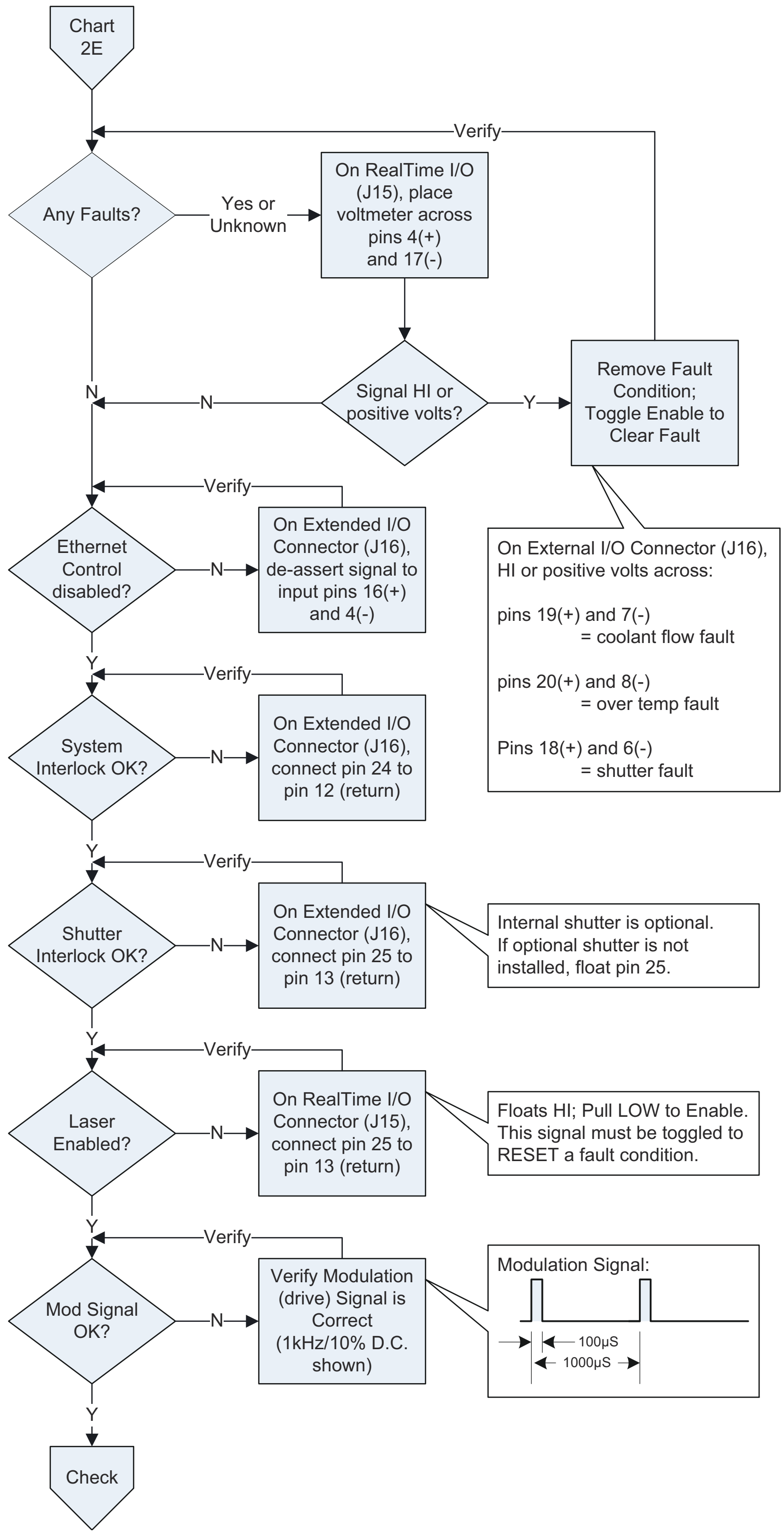
# Chart 2. C - Laser Does Not Start Using Java Application (Ethernet) Only



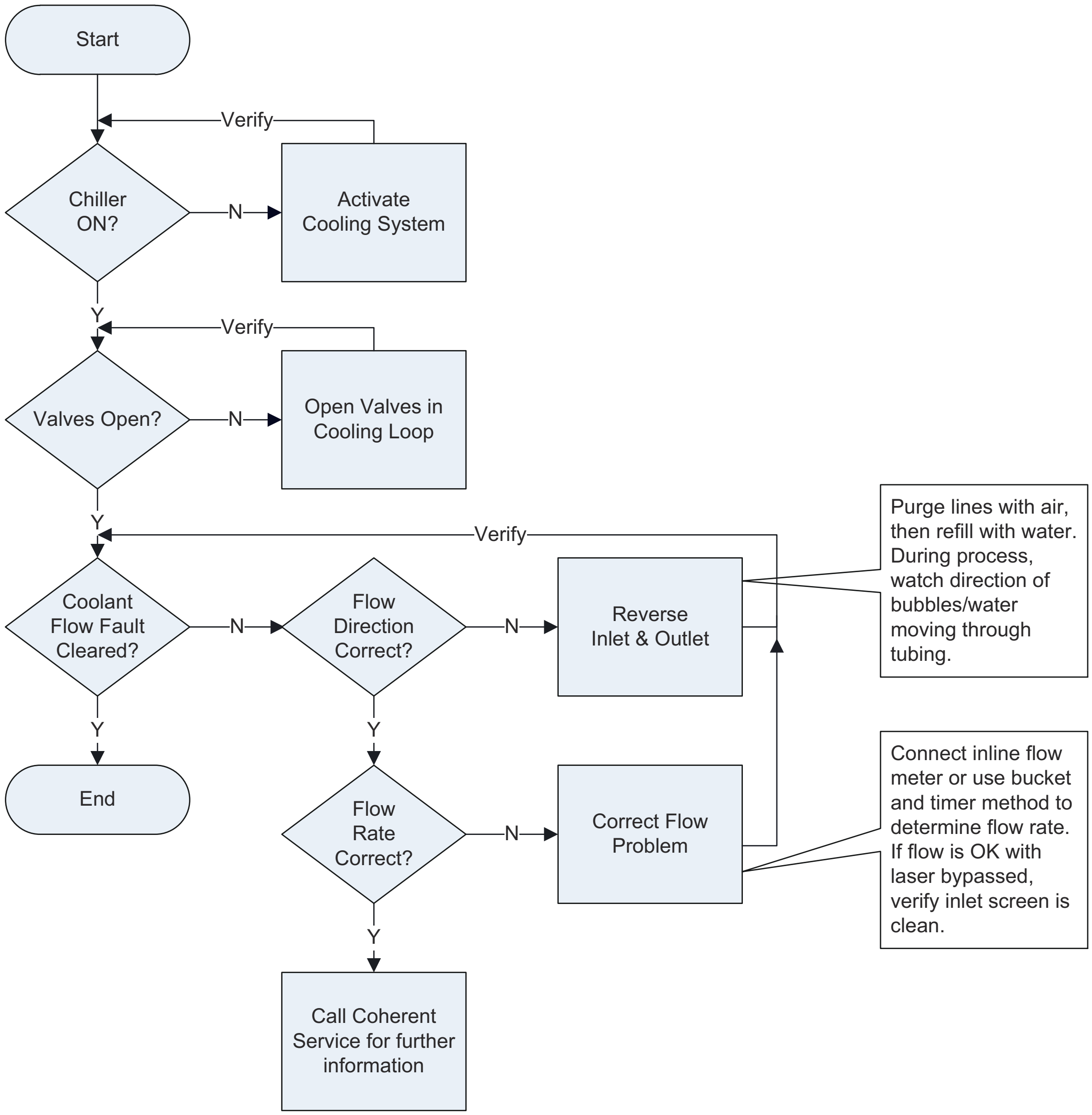
# Chart 2. D - Laser Does Not Start Using Pueblo (Ethernet) Only



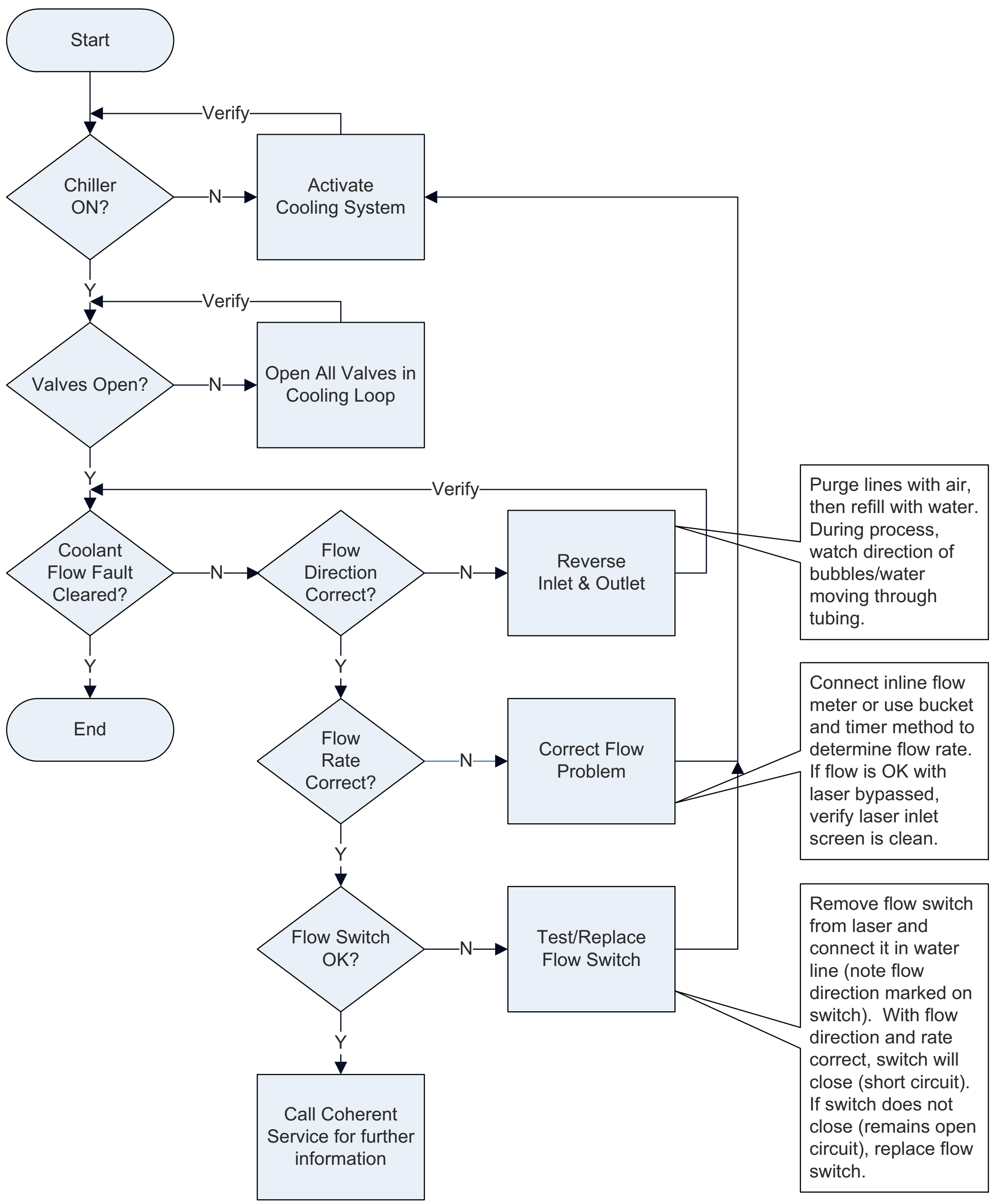
# Chart 2. E - Laser Does Not Start Using Customer-designed or 3rd Party Controller



# Chart 3. Coolant Temperature Out of Limit



# Chart 4. Coolant Flow Switch Tripped (Legacy)

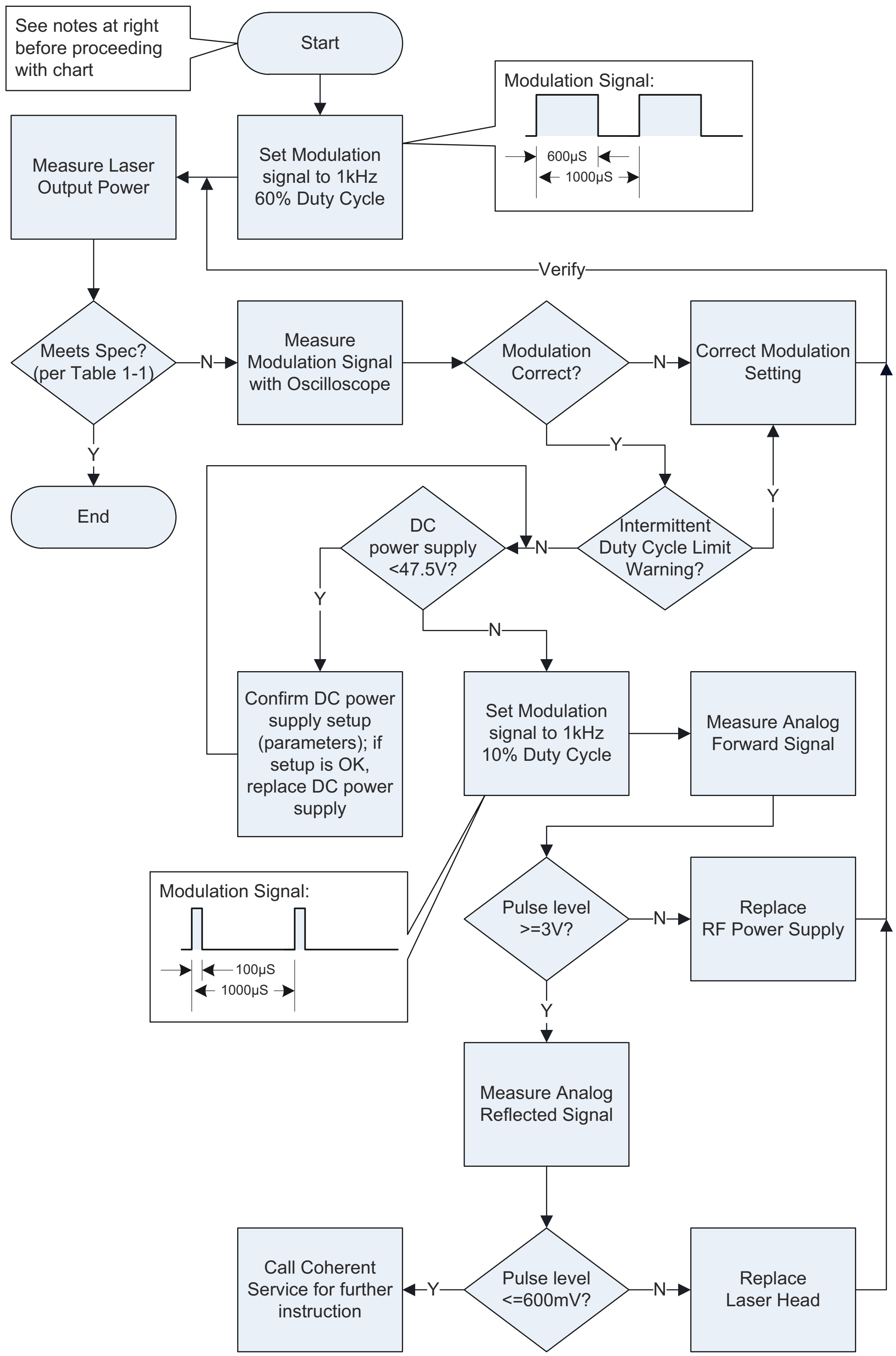


## Additional Notes on Flow

If coolant flow rate is below or only slightly above (+10%) specification, increase the coolant flow. If coolant flow fluctuates, investigate whether there are other water uses connected to the water source. For example, another device on the same water line may cause a sudden drop in supply coolant flow.

If the laser system is connected to a closed-loop cooling system, as recommended, the coolant flow rate test may not give a valid result. If the drain back-pressure of the closed-loop system is too high, the coolant flow rate through the laser system will not be as high as your measurement indicates. In this case, increase the input pressure of water going to the laser system.

# Chart 5. Laser Power Low/Unstable



## Notes on Troubleshooting Low or Unstable Laser Power

**[1]** The following must be considered when evaluating system output:

- An accurate power meter capable of handling the output power must be used. The power meter should be verified using a known good source or be calibrated on a periodic basis.
- Note that output power may degrade with tube age. For example, a tube with 4000 operating hours may not have the same output power as the same tube with 300 hours.

**[2]** When requesting full power, measure the output of the DC power supply across the terminal studs labeled +48 VDC and 48V_Return on the RF power module. Refer to Figure 3-29 on page 3-42 for the location of the studs. If the voltage sags to <47.5 VDC, then the power supply is not producing full power (and the RF power module is current starved). Either the DC power supply is not properly configured or it has an internal fault. Confirm the DC power supply parameters and limits are properly set. For short term operation, limit the duty cycle and resume operation. Replace the DC power supply to achieve full power operation.

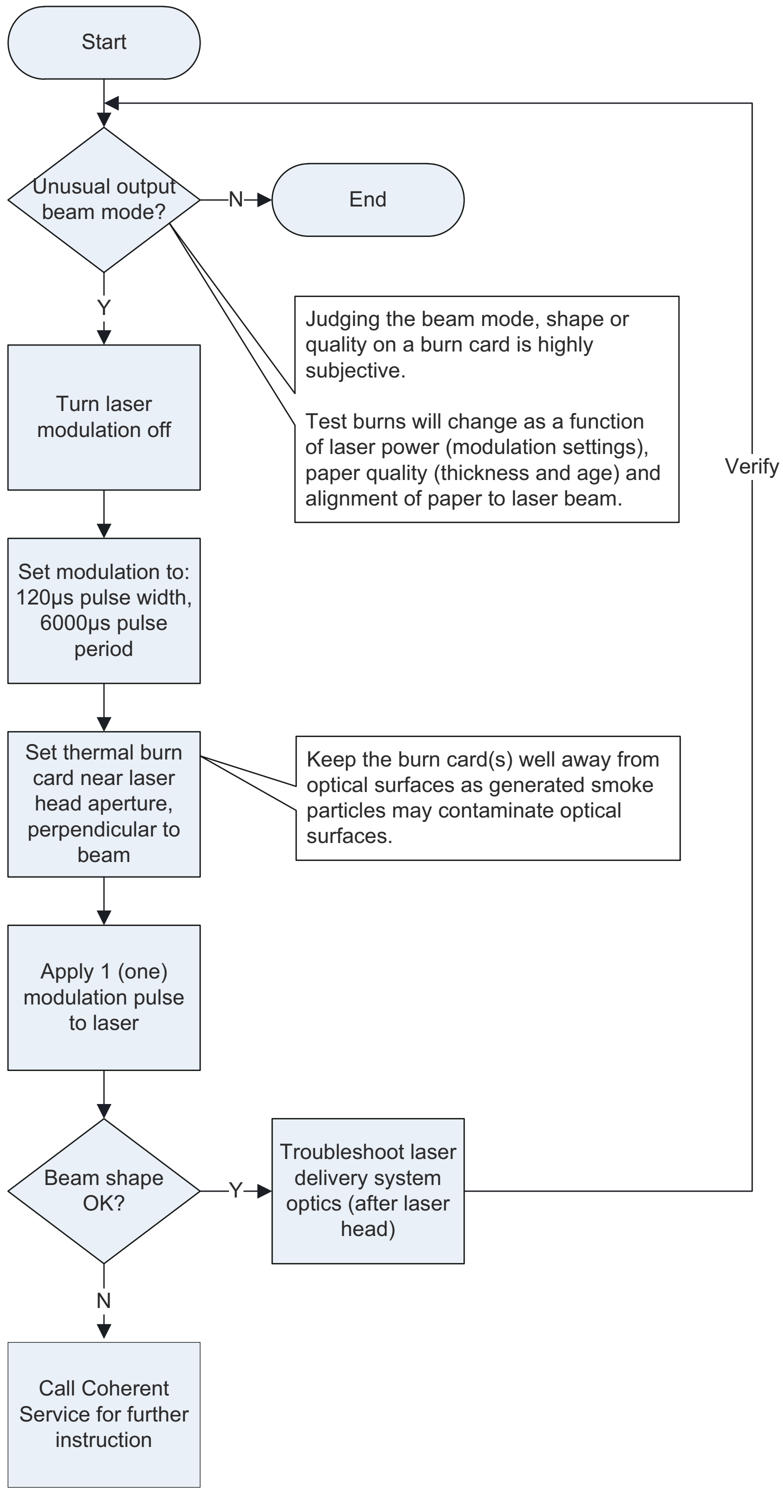
**[3]** The VSWR LIMIT indicates that the ratio of the reflected RF voltage to the forward RF voltage has exceeded a preset limit. This typically indicates a problem with the tube or RF power module. In some transient starting situations, the VSWR LIMIT warning will be activated. Check the status of this signal about 100 ms after starting the modulation signal to avoid the transient starting period.

**[4]** Check mode quality as follows:

- Turn off modulation to the laser.
- A low output power setting is recommended.
- Position a mode card approximately 3 meters in front of the output beam. A thermal image plate can also be used to inspect mode.
- Apply a single modulation pulse to the laser. The output beam will mark the mode card. Inspect the card for an asymmetric mode.

If there are rings or partial rings surrounding the central beam, the laser beam is misaligned to the optical system and might require re-alignment. Re-alignment is a factory procedure which requires the system to be returned to Coherent.

# Chart 6. Beam Mode Questionable



## Laser Generated Log File

The laser constantly records and reports detailed internal operational data that may be extracted and used for troubleshooting purposes. In order to collect data in a log file, the laser must be connected to a personal computer running a TCP Client software application.

For information on downloading a TCP Client software application, making a connection to the laser, creating and generating a log file, and interpreting data saved in the log file, see "TCP Client Connections" on page A-18.

## Replacement Procedures

If the item to be replaced will be returned to the supplier, use the original shipping containers. In general, the supplier is not responsible for damage incurred during shipping and the carrier is not responsible for improper packing.

### Laser System Removal

1. Perform system shut-down in accordance with the shut-down procedures in Section Five: Operation.
2. Disconnect the DC power supply power cable from the facility power outlet.
3. Disconnect the +48 VDC and 48 VDC return connections from the laser head. Disconnect all control cables. Refer to Figure 3-29 on page 3-42 and Figure 6-1 on page 6-19 for the location of these connections.
4. Disconnect the purge gas lines from the laser head and RF power module.
5. Use a bucket for water drainage and have a supply of paper towels on hand while disconnecting the water lines as follows (refer to Figure 3-29 on page 3-42 and Figure 6-1 on page 6-19):
   - Disconnect the coolant inlet line.
   - Disconnect the coolant outlet line.
   - Remove the remaining water in the laser head by using pressurized clean, oil-free air (30–45 psi).

## Laser System Installation

Installation instructions are provided in Section Three: Utility Requirements and System Installation. Do not turn on the laser system until all electrical and cooling fluid line connections are complete. Then perform the turn-on procedures in Section Five: Operation.

## Coolant (Strainer) Screen Cleaning

1. The coolant strainer (screen) is located on the laser head inlet coolant hose connector (Figure 3-29 on page 3-42 and Figure 6-1 on page 6-19). The screen should be cleaned when troubleshooting a low coolant flow condition. The screen should also be cleaned as part of the user's periodic maintenance. The frequency of cleaning will be determined by the condition of the facility coolant source. Perform system shut-down in accordance with the shut-down procedures in Section Five: Operation.
2. Have a bucket for coolant drainage.
3. Remove the coolant inlet line (refer to Figure 3-29 on page 3-42 and Figure 6-1 on page 6-19).
4. Loosen and remove the nut the coolant inlet line was screwed into.
5. Carefully remove and clean the water screen. Inspect the O-rings to ensure they are free from damage and in good condition. Replace if necessary.
6. Installation is the reverse of removal. Make sure to remove all old tape from all threads before adding new. Only use Teflon pipe tape on the coolant line threads. After re-assembly, turn on the cooling system and verify that there are no coolant leaks.

## Coolant Flow Switch Replacement Procedure (Legacy)

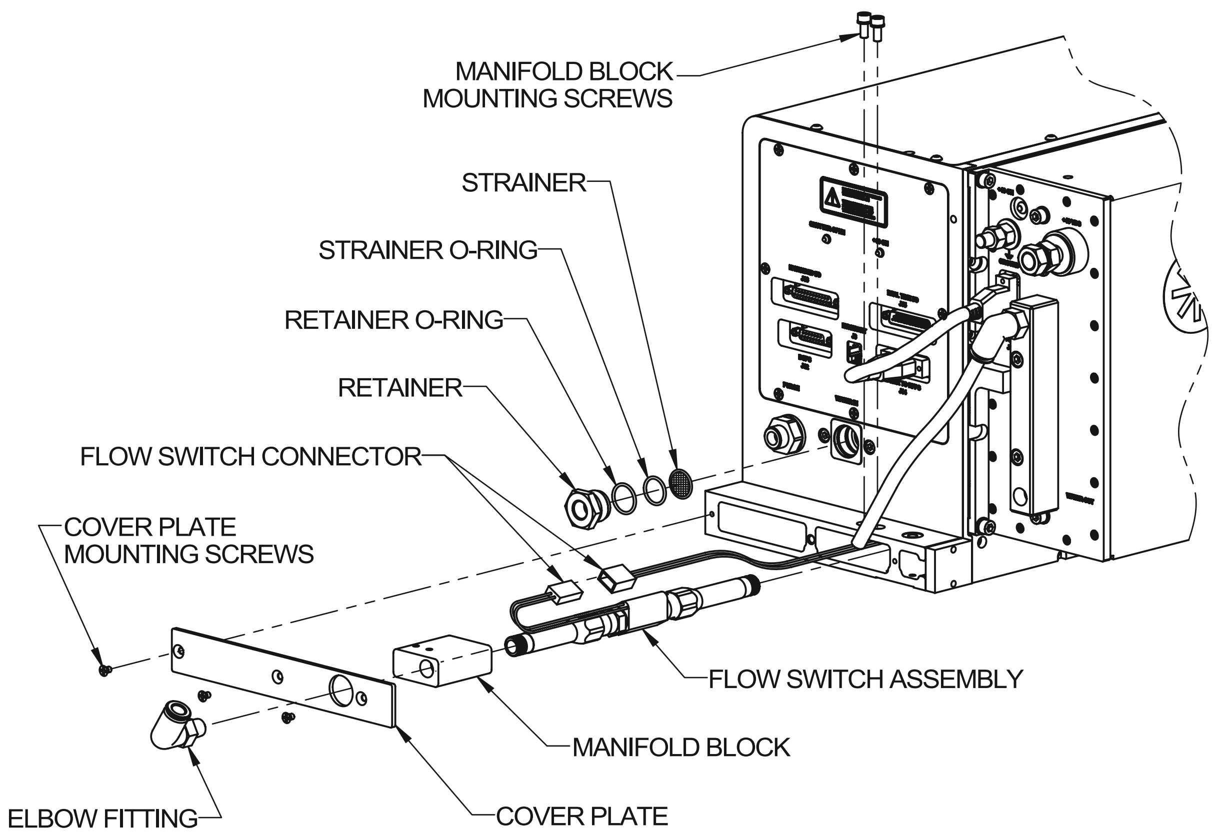



*Figure 6-1. Coolant Flow Switch Replacement*

### Removal

1. Perform system shutdown in accordance with shutdown procedures in Section Five: Operation.
2. Use a bucket for coolant drainage. Remove inlet and outlet hoses and drain coolant from laser system.
3. Remove the coolant hose from the elbow fitting as shown in Figure 6-1.
4. Remove the elbow fitting from the manifold block.
5. Remove the cover plate by removing the cover plate mounting screws as shown in Figure 6-1.
6. Remove the manifold block by removing the manifold block mounting screws as shown in Figure 6-1.
7. Pull out the coolant flow switch as shown in Figure 6-1.
8. Disconnect the flow switch connector as shown in Figure 6-1.
9. The coolant flow switch can now be removed from the laser system. Make note of direction of the coolant flow switch as it needs to be reinstalled in the same direction.

### Replacement

1. Reinsert the coolant flow switch into the laser system base plate just enough so that the flow switch connector can be re-connected.
2. Push the coolant flow switch into the receptacle located within the system base plate.
3. Replace the manifold block on the coolant flow switch and mount using the manifold block screws as shown in Figure 6-1.
4. Replace the cover plate using the cover plate mounting screws as shown in Figure 6-1.
5. Replace the elbow fitting into the manifold block as shown in Figure 6-1.
6. Re-insert the coolant hose into the elbow fitting
7. Reinstall coolant hoses, circulate coolant through laser system and check for coolant leaks.
8. Procedure complete.

## Shipping

When shipping an E-400 Series laser system, follow the reverse procedure of “Unpacking and Inspection” on page 3-22.

---

***NOTICE!***
**If the system is to be shipped from one location to another, it must be drained and packed in the original shipping container to avoid any possible damage to the laser system.**

---

***Table 6-2. Shipping Information***

| Parameter | Value |
|---|---|
| Laser System in Crate | 143 kg (315 lbs.) |
| Laser System (Laser Head and RF Power Module) | 75 kg (165 lbs.) |
| RF Power Module | 19 kg (41.5 lbs.) |
| Laser Head Module | 56 kg (124 lbs.) |
| E-400 Series Laser System Crate (empty) | 68 kg (15 lbs.) |
| Shock (shipping survival) | 13 cm free drop any axis<br>3 G RMS vibration |

# APPENDIX A: EMBEDDED CONTROL AND DIAGNOSTICS

## *E-400 Series HTTP and TCP Server*

### Introduction

The E-400 Series Control Electronics have embedded control and integrated sensors that allow remote monitoring of the E-400 Series system status via TCP/IP over Ethernet. The system is capable of serving HTTP (web) pages to a client via a local area network (LAN) or by direct connection using a crossover cable. Using the LAN connection, it is possible to interrogate or control an E-400 Series system remotely via the Internet. As every end-user is slightly different, the details of enabling Internet access are left to the end user. Check with the network administrators for strategies that make the most sense in your organization.

In addition, the E-400 Series can serve a Java Applet that can monitor the E-400 Series operation (live) or perform simple control of the E-400 Series. This functionality allows operation of the E-400 Series with only a computer, a network interface card (NIC) and a web browser compatible with HTTP and Java.

The next few subsections will:

- Illustrate a simple connection to the E-400 Series
- Test the connection using the ping utility
- Go over the various pages available to the connected client
- Go into a few advanced connection schemes

# Initial Connection and Configuration

## Connections

Using an Ethernet crossover cable, connect the computer's Network Interface Card port to the Ethernet port on the E-400 Series.

Connection to a LAN is not recommended before the proper IP address for the LAN can be programmed into the E-400 Series Control Electronics. A utility web page is provided to allow the end-user to do this. Each E-400 Series is also pre-programmed with a unique MAC (Media Access Control) address. An example of the full MAC address for the E-400 Series is:

00:1B:1C:00:10:00

where 00:1B:1C is the OUI (Organizational Unique Identifier) assigned to Coherent and will not change.

## Client Configuration

The next few illustrations are geared towards clients running Microsoft Windows Operating Systems, but most modern operating systems are very similar. Begin by navigating to the Control Panel (START -> CONTROL PANEL). Double click on NETWORK CONNECTIONS to get to the Network Connections screen (Figure A-1).

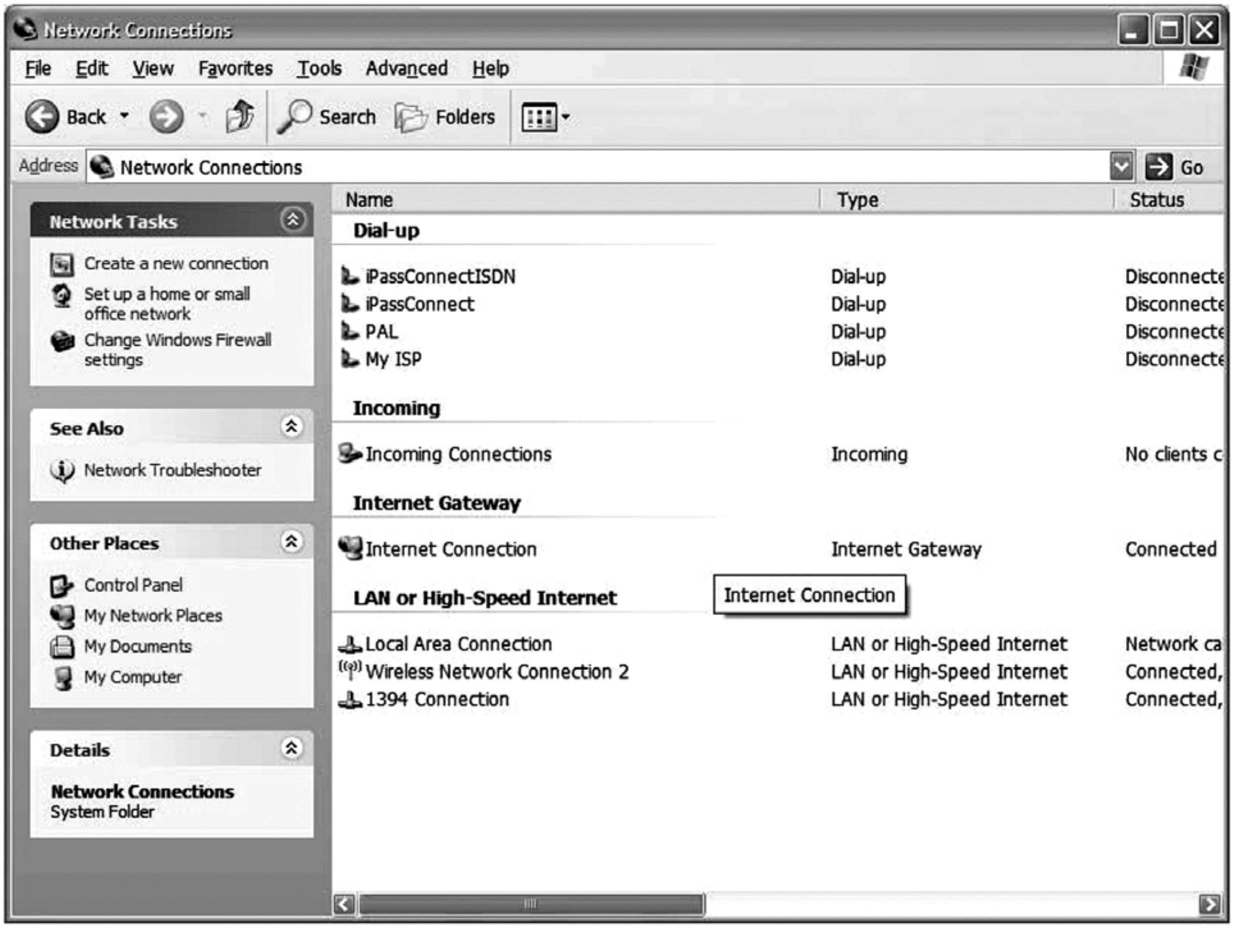



*Figure A-1. Network Connections Screen*

Double click on LOCAL AREA CONNECTION to get to the Local Area Connection Properties screen (Figure A-2).

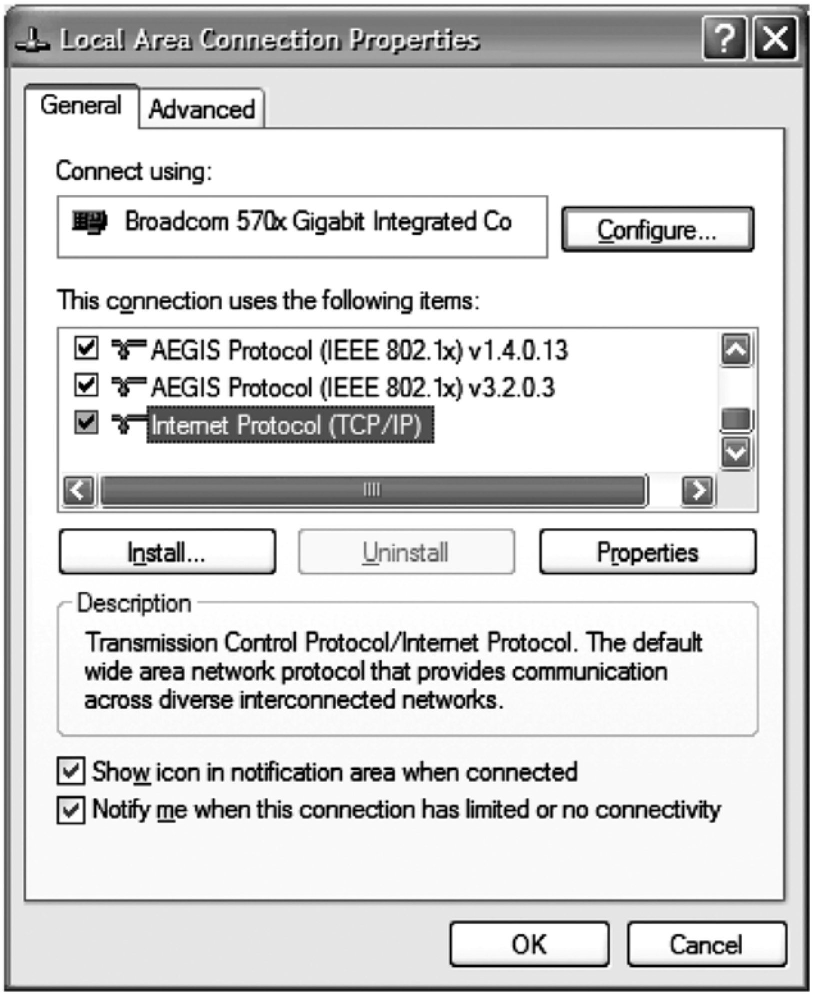



***Figure A-2. Local Area Connection Properties Screen***

In the General tab, scroll down the pane and Double Click on INTERNET PROTOCOL (TCP/IP). This will open the Internet Protocol (TCP/IP) Properties screen (Figure A-3).

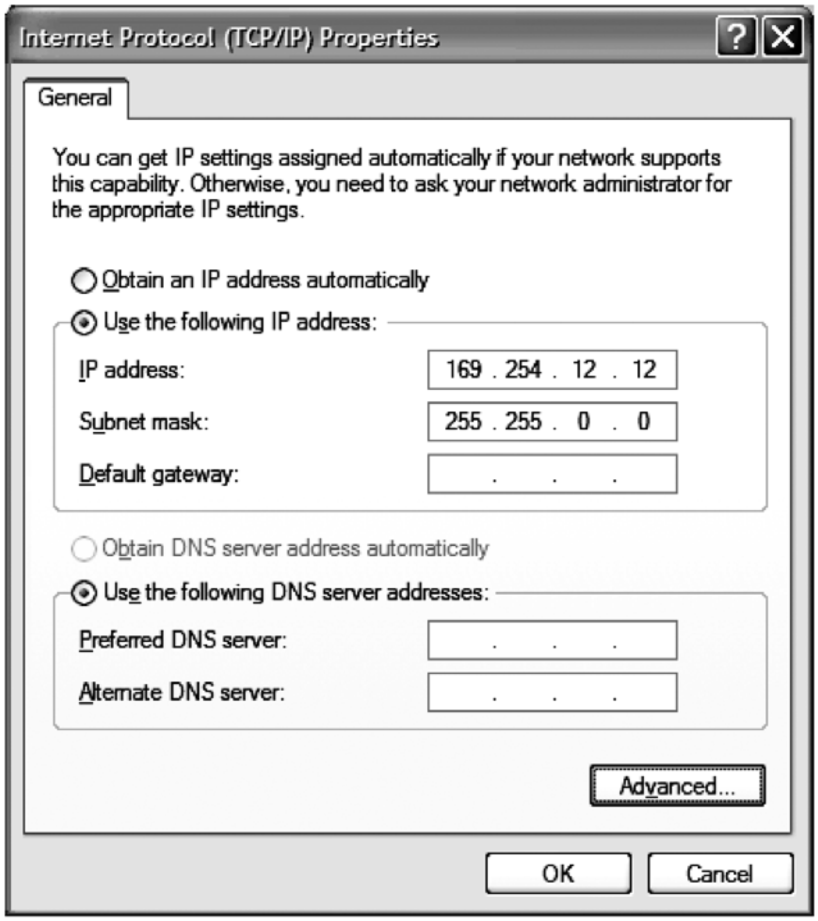



***Figure A-3. Internet Protocol (TCP/IP) Properties Screen***

Select "Use the following IP address:" and enter the numbers exactly as they appear in the Figure A-3. When done, dismiss all the open windows by selecting OK. The E-400 Series is now ready to be connected.

Once the DC connections to the E-400 Series have been verified, apply +48 VDC to the laser before proceeding with the next sections.

**Connection to the E-400 Series can still be obtained, even without the necessary permissions. Simply connect the Ethernet crossover cable as above and turn on the +48 VDC power supply. The operating system in the computer will attempt to obtain an IP address from the E-400 Series. Since the E-400 Series does not have a DHCP server, the computer will self assign an IP address (APIPA) that should be within the pool that includes the default E-400 Series IP address (169.254.x.x). This procedure can take a bit longer but a message will appear when the connection is ready with limited or no connectivity.**

## Testing the Connection Using PING

Start the Windows PING utility by selecting START->RUN…

Next, type CMD to bring up the Command Prompt.

Type *ping 169.254.12.13* and press ENTER.

The following screen (Figure A-4) should be displayed after a few moments.

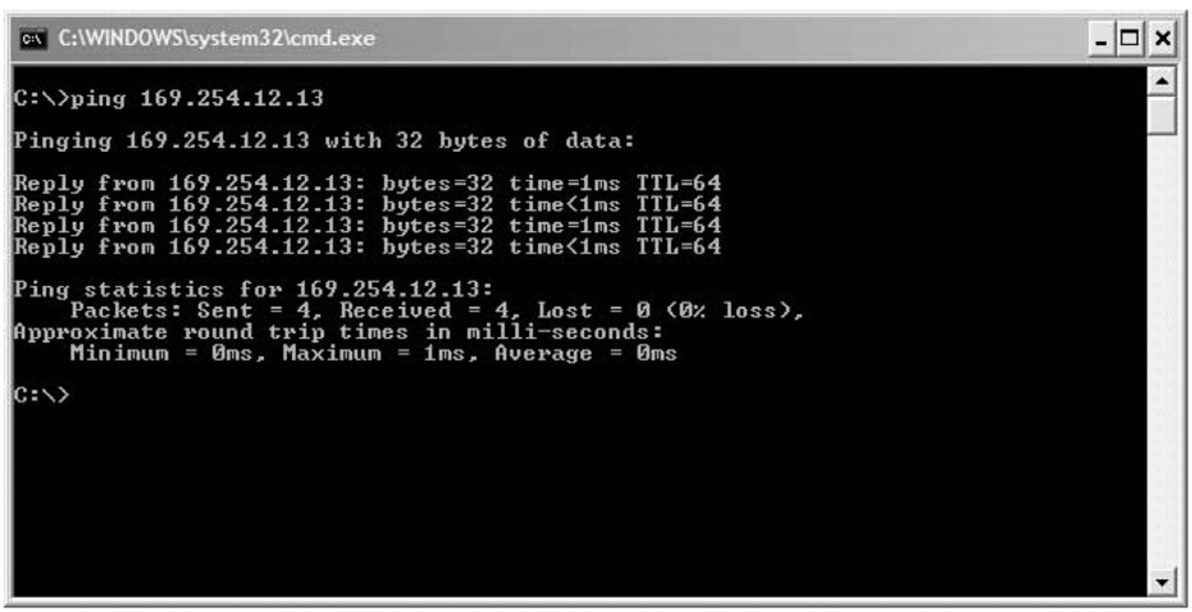



***Figure A-4. Ping Screen***

This IP address is the default address for the E-400 Series. The following sections will explain how this IP address can be changed and how connection to the LAN can be achieved. But first, the pages available to clients will be described.

## HTTP Information and Diagnostic Pages

### Home Page

Open the computers web browser (Microsoft Internet Explorer in this case) and type the following URL:

http://169.254.12.13

The following screen (Figure A-5) will be displayed:


***Figure A-5. Welcome Screen***

This is the home page for the E-400 Series Web Server. Navigation to all the other client services is available with links from here. The bottom third of the page has these links.

## System Info Page

This page (Figure A-6) provides general system data. In addition, there is a utility to change the IP address of the system. Coherent recommends that the system be first used with its default IP address.

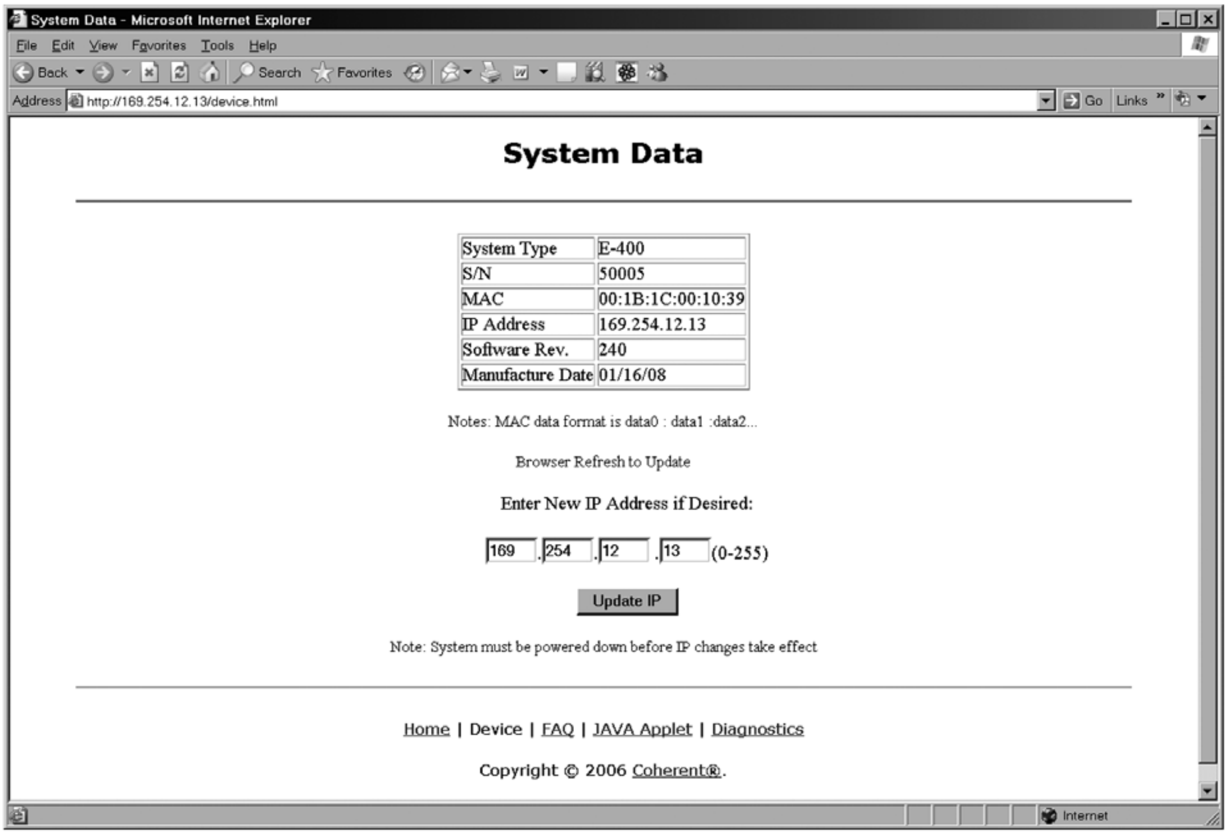



***Figure A-6. System Data Screen***

## Clock Diagnostics Page

System operation diagnostics are provided on this page (Figure A-7):

This screen logs the total system run time (+48 VDC ON) and the enabled run time (System Enable asserted). All the times described on this page now and in the future will be in the Days:Hours:Minutes:Seconds format. The system will also keep track of time that both the LASER and RF power module spend above the warning temperature. This along with a count of warning temperature threshold crossings will provide some insight into the usage of the DIAMOND E-400 Series system.

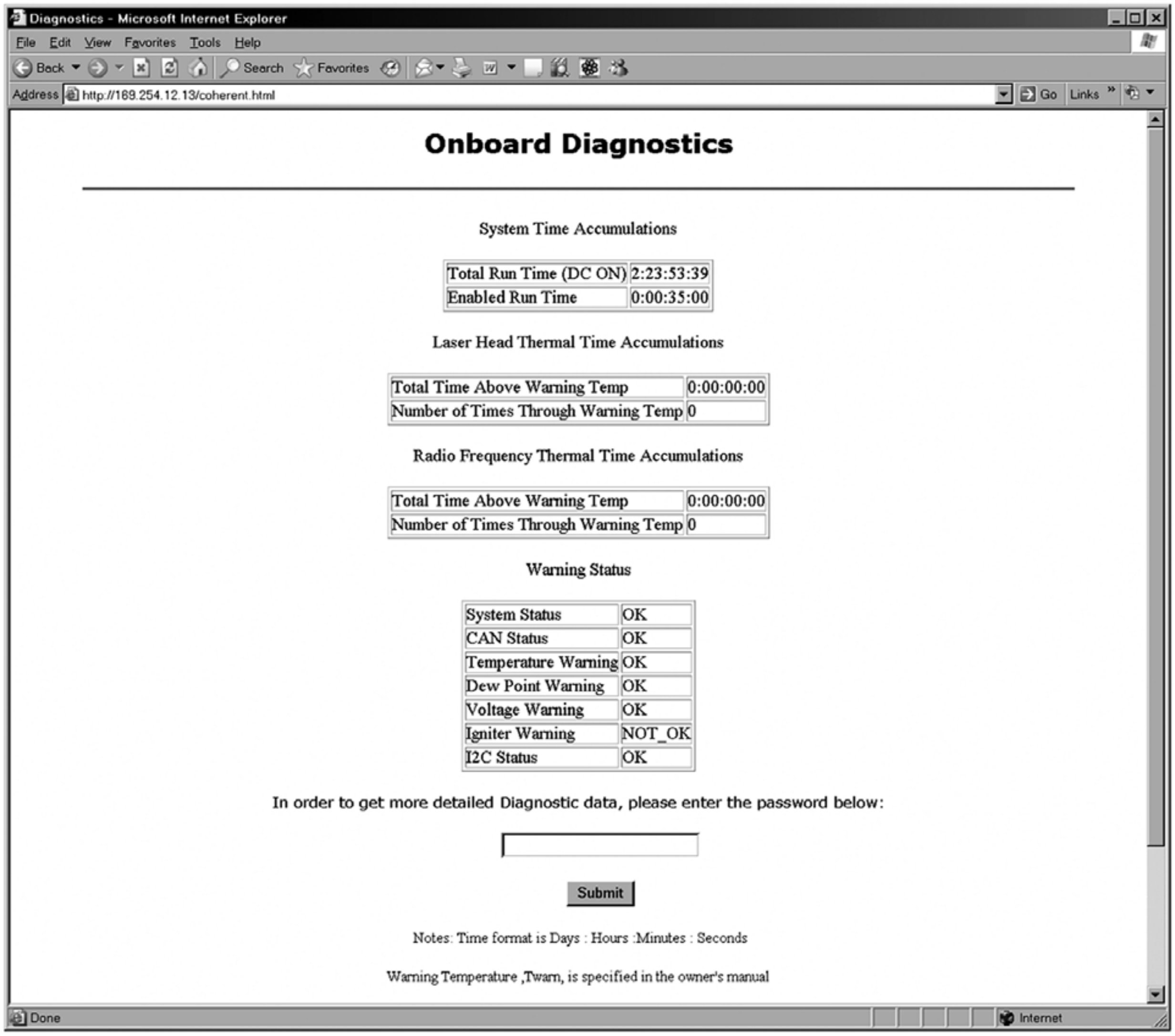



***Figure A-7. Onboard Diagnostics Screen***

The lower part of this page has System Warning and Fault information. The customer will have to navigate to this page in order to determine what condition is causing a System Warning. As can be seen in the Figure A-7, the system is operating with an Igniter Warning.

## FAQ

This page (not shown) will keep a list of Frequently Asked Questions for users of the E-400 Series system. In addition, the Coherent web site can be reached from any E-400 Series web page via a link at the bottom (Note: LAN connection is necessary for the link to work).

# Java Applet

## Java Runtime Configuration

Before using the JAVA applet, the JAVA runtime engine (JRE) must be installed on the client. A link to the download web page is provided on the E-400 Series home page. The system needs version 1.4.2 or later. Once JRE is downloaded and installed, disable the cache for the E-400 Series JAVA applet to run properly. This only needs to be done once. Again, launch the Windows Control Panel (START->CONTROL PANEL). Next, double click on Java to bring up the JAVA CONTROL PANEL (Figure A-8). The look of this panel has changed from version to version. Consult the documentation to find out how to disable the cache. In this version (1.5.0), on the GENERAL tab at the bottom of the page in the Temporary Internet Settings. Press the SETTINGS button:

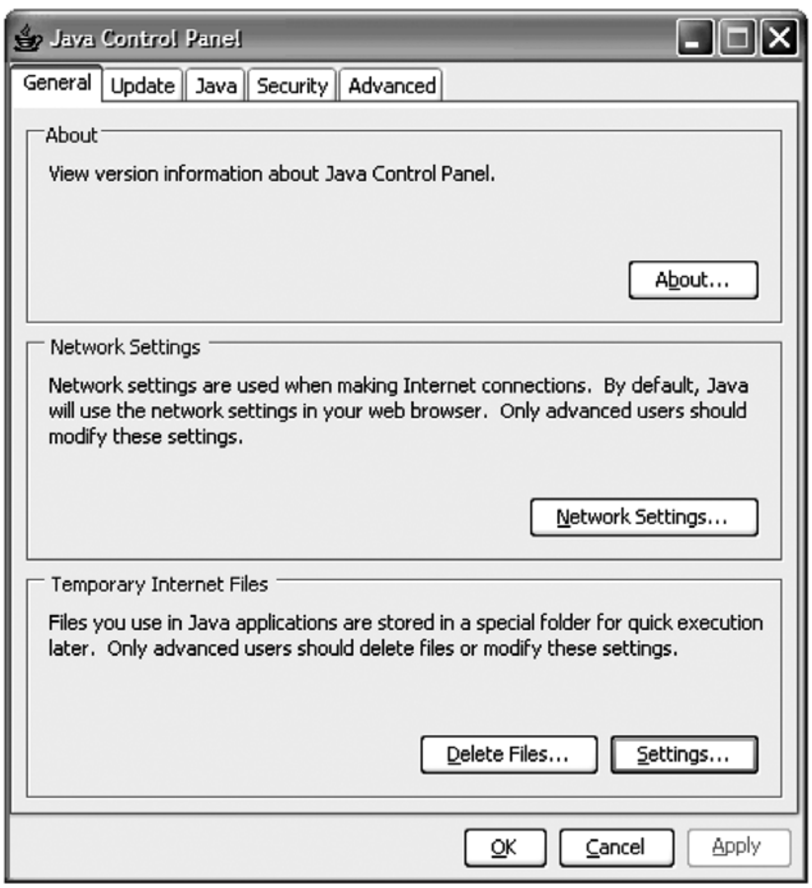



***Figure A-8. Java Control Panel Screen***

Next, press the VIEW APPLETS… button.

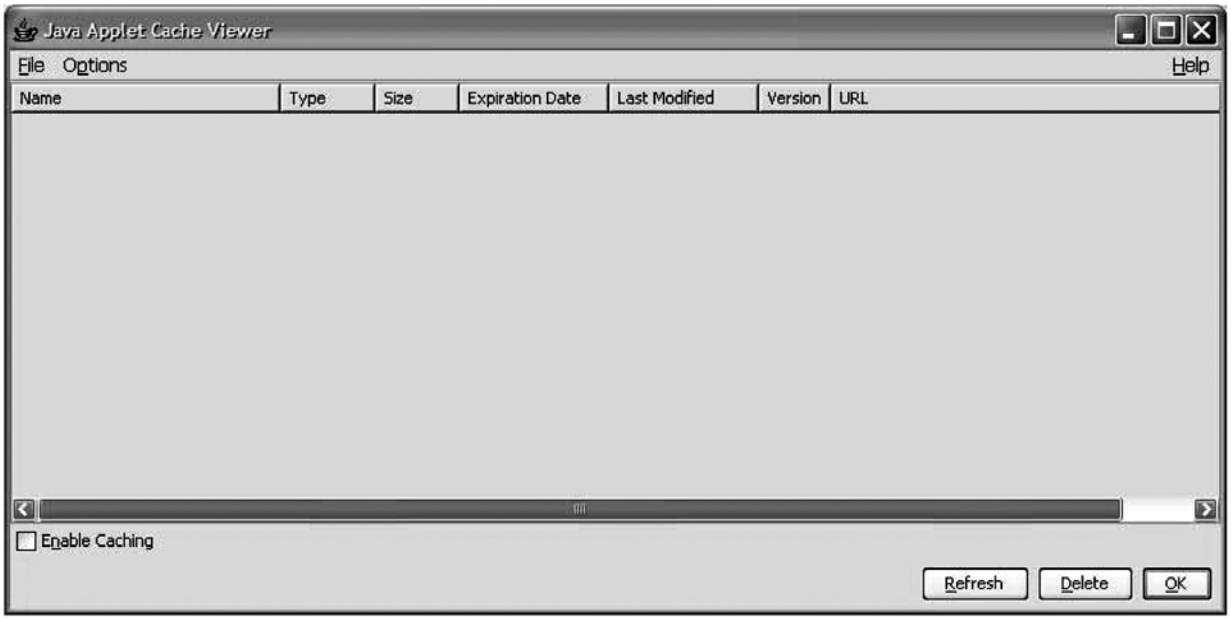



***Figure A-9. Java Applet Cache Viewer Screen***

In the bottom left corner (Figure A-9), uncheck ENABLE CACHING. Dismiss all opened windows by pressing OK.

Note that if there is a running instance of the web browser when doing the JAVA configuration, it must be closed before proceeding. In other words, close all instances of Internet Explorer before continuing with the JAVA applet.

## Opening a Socket

Start the Java Client after reopening a client connection to the E-400 Series. See the sections above if not already running an active client. After several seconds, the following screen (Figure A-10) will be displayed:

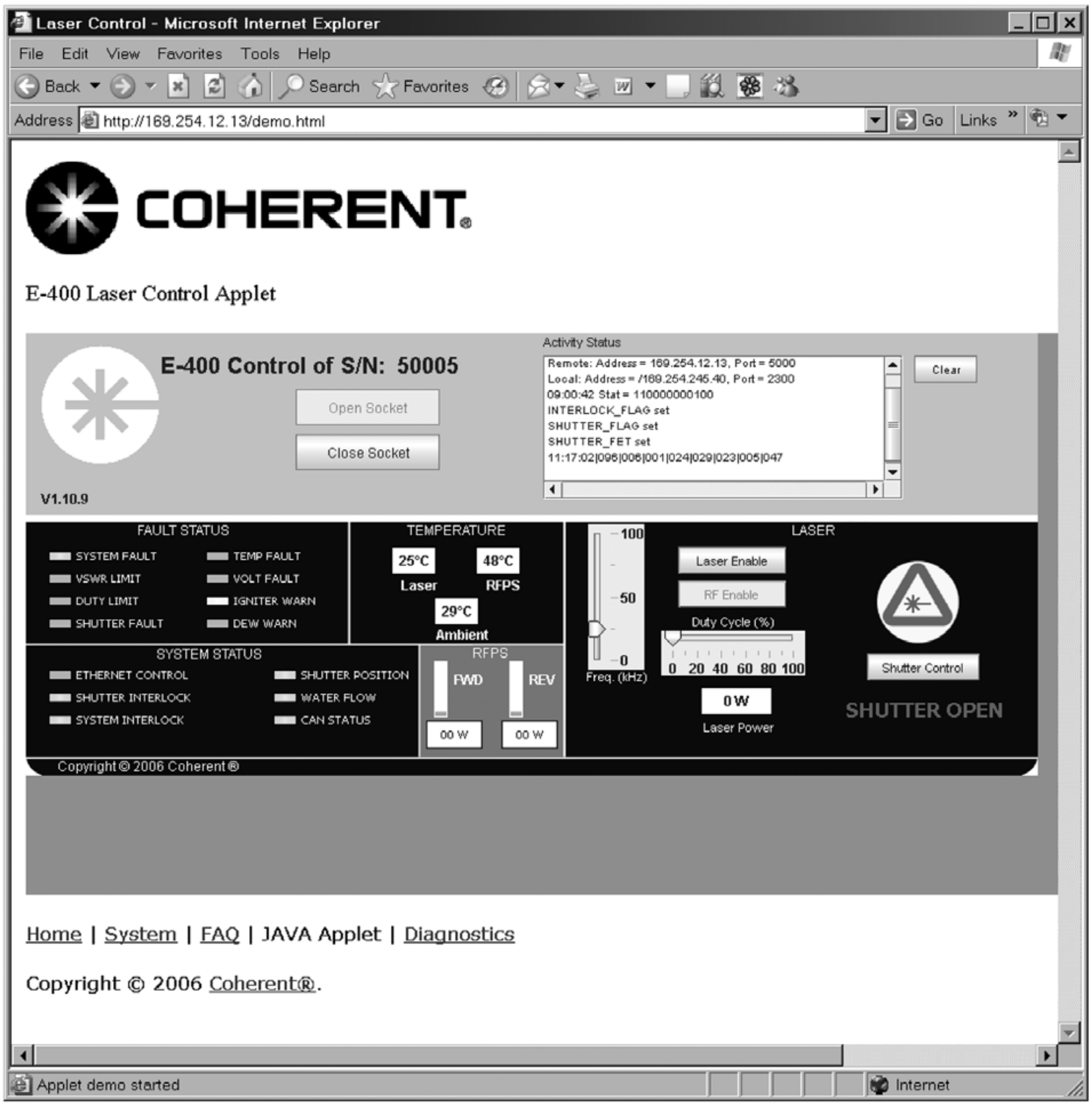



***Figure A-10. E-400 Laser Ethernet Control Applet***

To begin using this tool, click the OPEN SOCKET button to open a TCP connection to the E-400 Series system.

## Diagnostics Elements

The bottom left section is devoted to visual diagnostic indicators. Faults are kept apart from interlock and general system status indicators. Serious faults are indicated in RED and warnings are indicated in yellow. Temperature is indicated in the center of the applet. RF power is shown underneath the temperature. The activity window will track all faults and system messages with a timestamp.

## Control Elements

The right hand portion of the applet is devoted to controlling the E-400 Series. Note that control this way is only available if the Ethernet Control Input is asserted on the Extended I/O Connector (refer to “Section Four: Control Interfaces”). Shutter control is also available from this applet. To control the laser, press LASER ENABLE and then RF ENABLE. Slowly slide the DUTY CYCLE slider to the right and LASER POWER indicated in Watts should be seen.

# Extended Diagnostics Pages

Access to these pages is password protected. From any web page, press the Diagnostics link. At the bottom of this page (Figure A-11) enter the password in the text field provided and press the SUBMIT key. Access to the Extended Diagnostics pages is now possible.

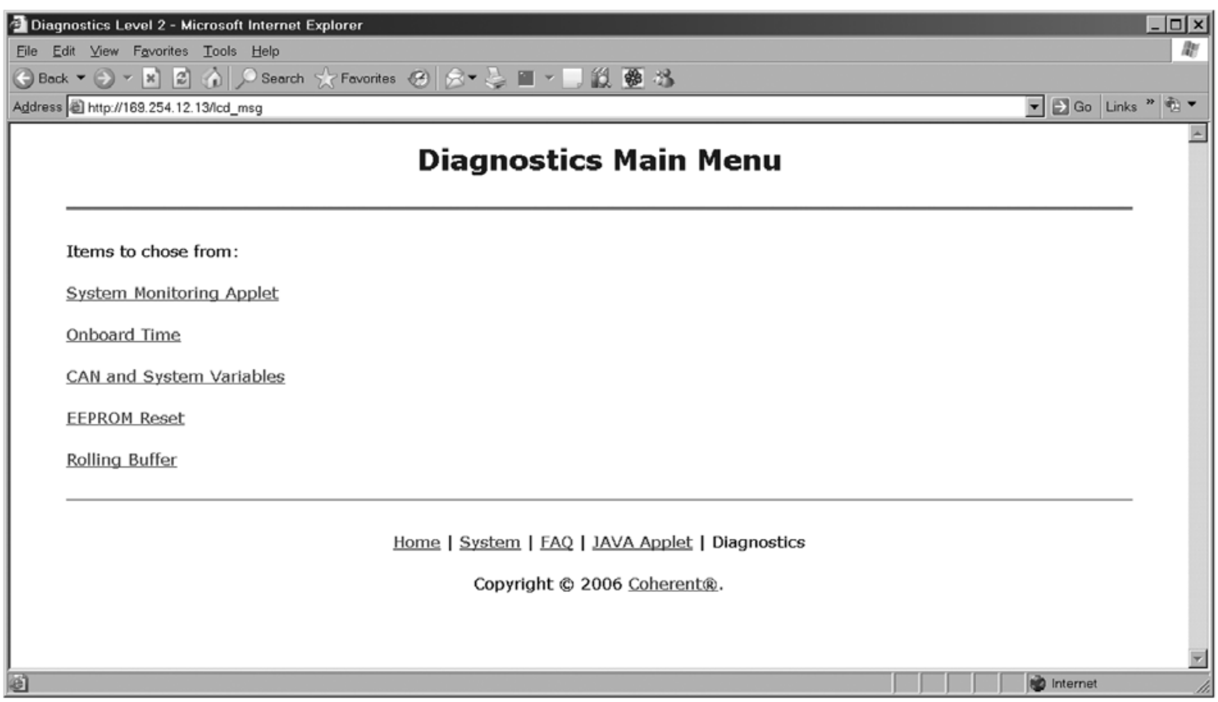



*Figure A-11. Diagnostics Main Menu*

## Onboard Time Page

This page (Figure A-12) reports the current time reported by the battery backed up onboard real time clock:

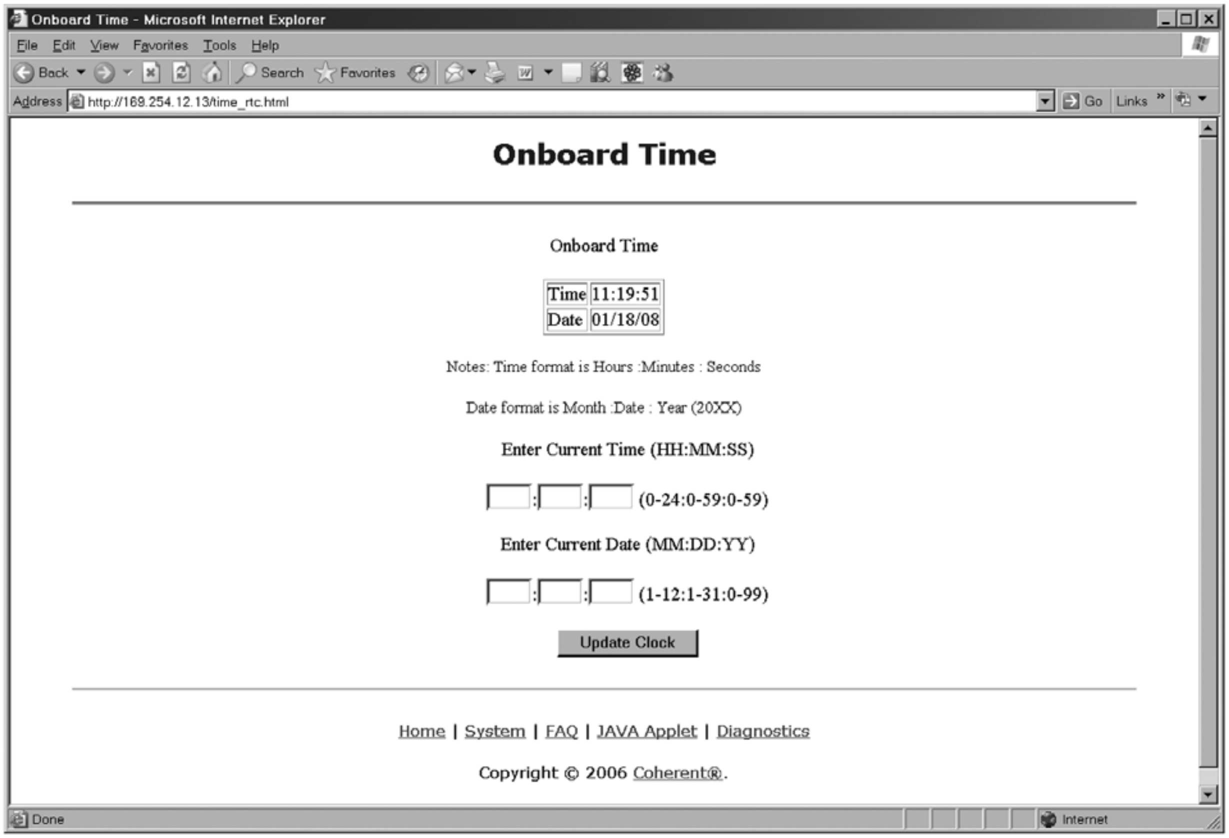



*Figure A-12. Onboard Time*

Provisions are also provided at the bottom of this page to reset the time and date. Please be very careful how the new time and date values are entered.

## CAN and System Variables

This page (Figure A-13) was developed for debugging the system during development. It may be replaced in the future.

## EEPROM Maintenance

Several non-volatile system parameters can be cleared from this web page (Figure A-13). To do so, select the appropriate section and click SUBMIT.

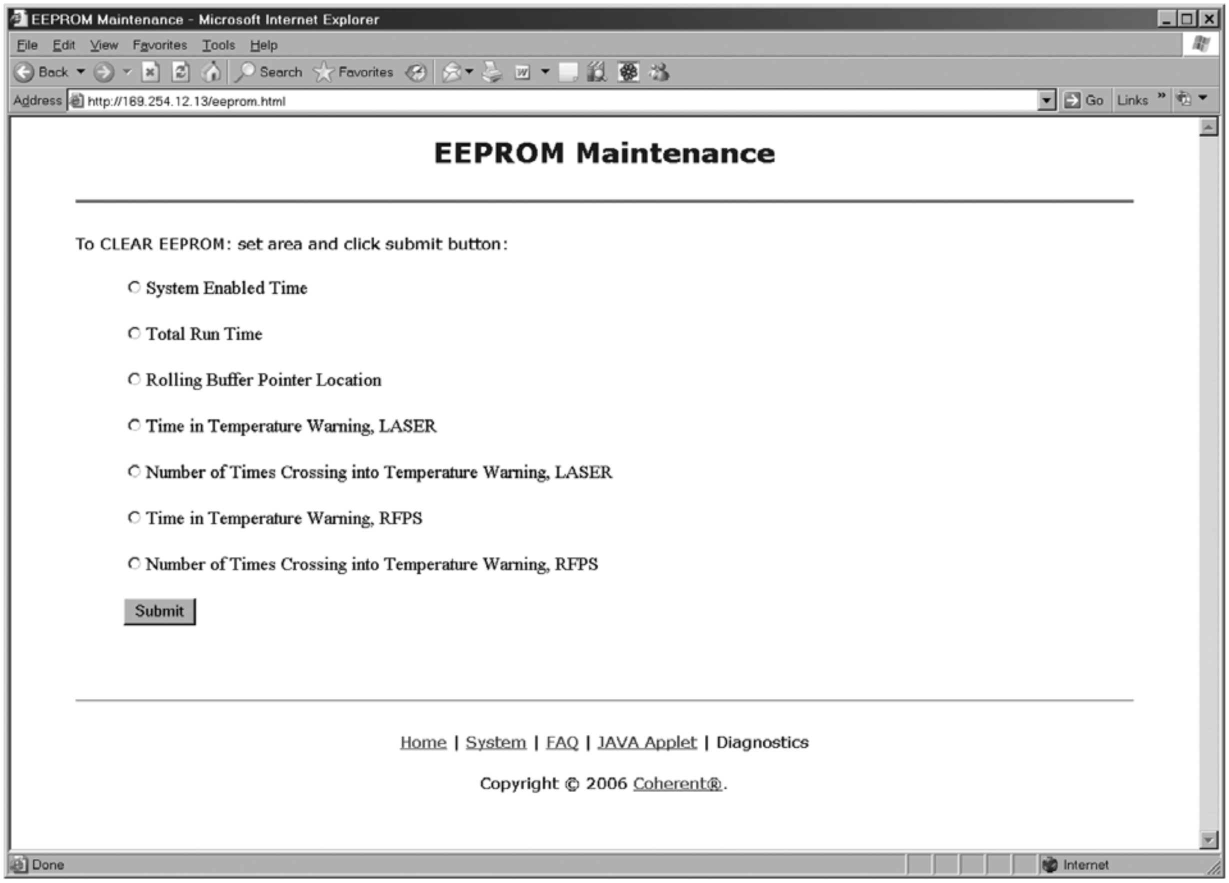



*Figure A-13. EEPROM Maintenance*

System Enabled Time as well as RF Power Module Time in Warning Temp is explained in the Diagnostics web page, above.

The Rolling Buffer Pointer Location is reserved for logging fault data to EEPROM. Since the log is a rolling buffer, the last used location is also saved to EEPROM. Use this option to clear the last location to the base location.

## Rolling Buffer

This web page (Figure A-14) provides a time-stamped log of system faults. Currently, the buffer is only eight entries deep. The ninth entry will overwrite the first and so on.

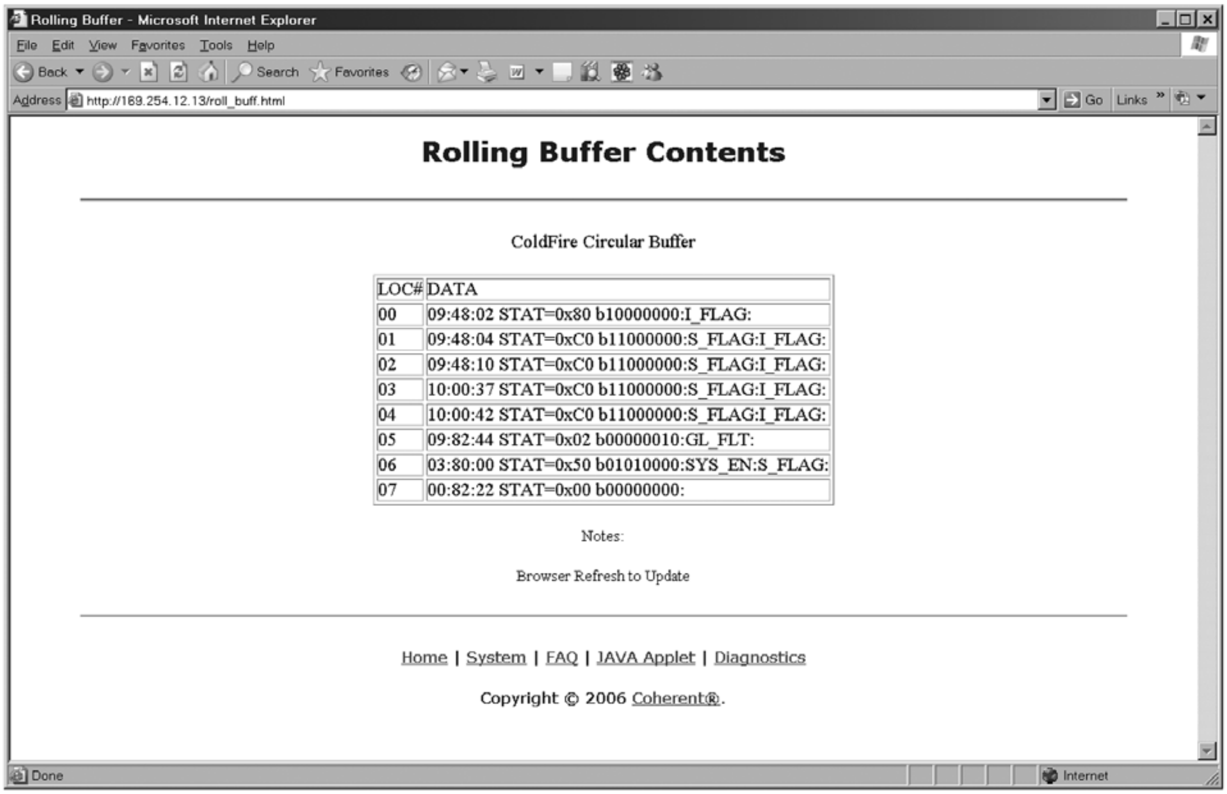



*Figure A-14. Rolling Buffer*

## System Monitoring Applet

This applet adds the ability to monitor system status more closely. It intercepts the CAN bus traffic internal to the E-400 Series and parses it into this display. Operation starts by opening a socket exactly as the previous applet, above. Fault status and Activity Log is also provided. Please note that the screenshot provided in Figure A-15 was taken during a test case condition and does not reflect the nominal values present in an actual system.

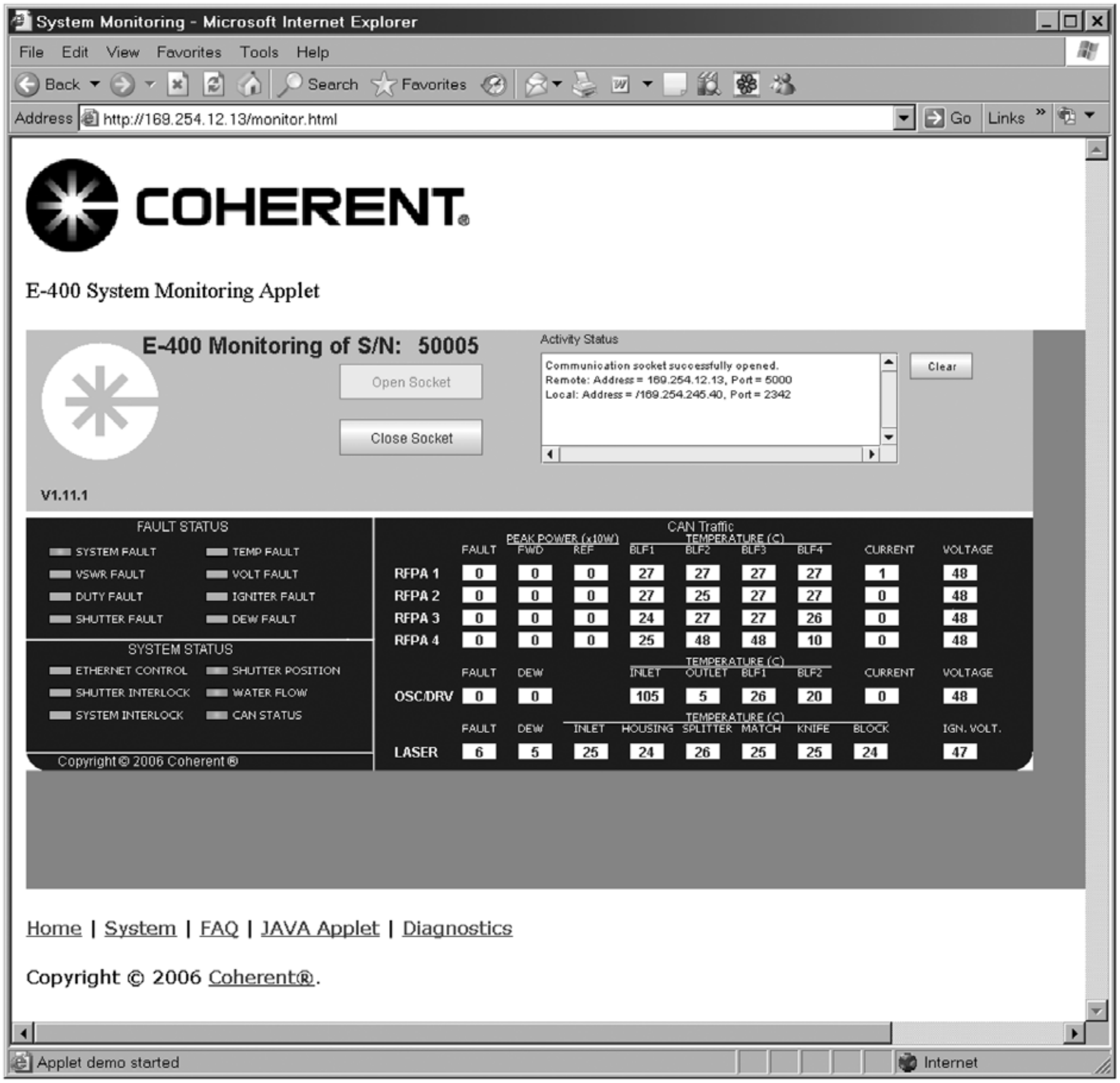



***Figure A-15. System Monitoring Applet for Standard E-400 Series***

## TCP Client Connections

In addition to the functionality introduced above, there are a few more options available to users. Since web pages and JAVA applets are suitable only for a 'human to machine' interface, Coherent has also provided some limited 'machine to machine' functionality. A user can use any TCP client software to open a TCP socket to the E-400 Series.

### Connection Requirements

Any TCP client software or firmware can communicate with the E-400 Series. However, only one socket to port 5000 is allowed at this time. Simply open a socket to the IP address of the E-400 Series using port 5000. When done, close this socket.

### API Available

Commands to the E-400 Series follow the standard 'GET' and 'SET' protocol. For example, to get the temperature of the LASER head the user or client software would type 'glt' and press return or concatenate the end of line character (\n\r). The E-400 Series would return the temperature in degrees Celsius. See end of document for command summary and structure. Some commands also require additional parameters to work properly. For instance, set shutter open also requires a '1' for true or a '0' for false. So, to open the shutter the user or client software would need to send 'sso 1\n\r'. 'grp' and 'gfp' optionally require additional parameters. Issuing 'gfp' without parameters will return total forward power in 10s of Watts. However, adding an integer from 1 to 5 (inclusive) will give the forward power of that particular RF power module in 10s of Watts.

## Using Pueblo TCP Client

A very easy to use TCP client is Pueblo. Pueblo is available from http://pueblo.sourceforge.net/pueblo/. Download and install the Pueblo application. Launch Pueblo, and using the QuickConnect feature, type in the IP and port of 5000 as in Figure A-16:

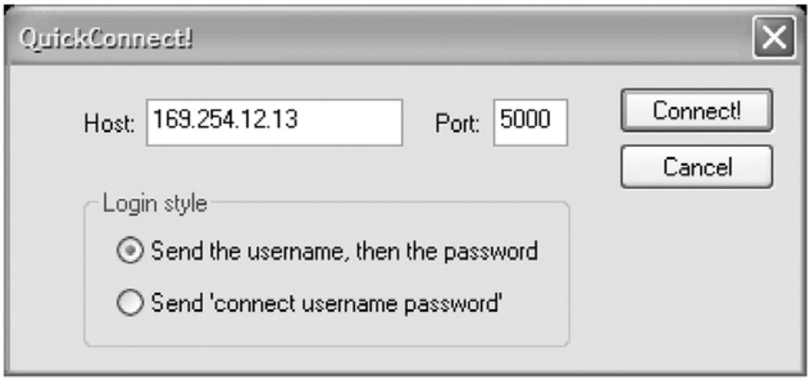



***Figure A-16. QuickConnect***

Type commands and receive responses directly as seen in Figure A-17.

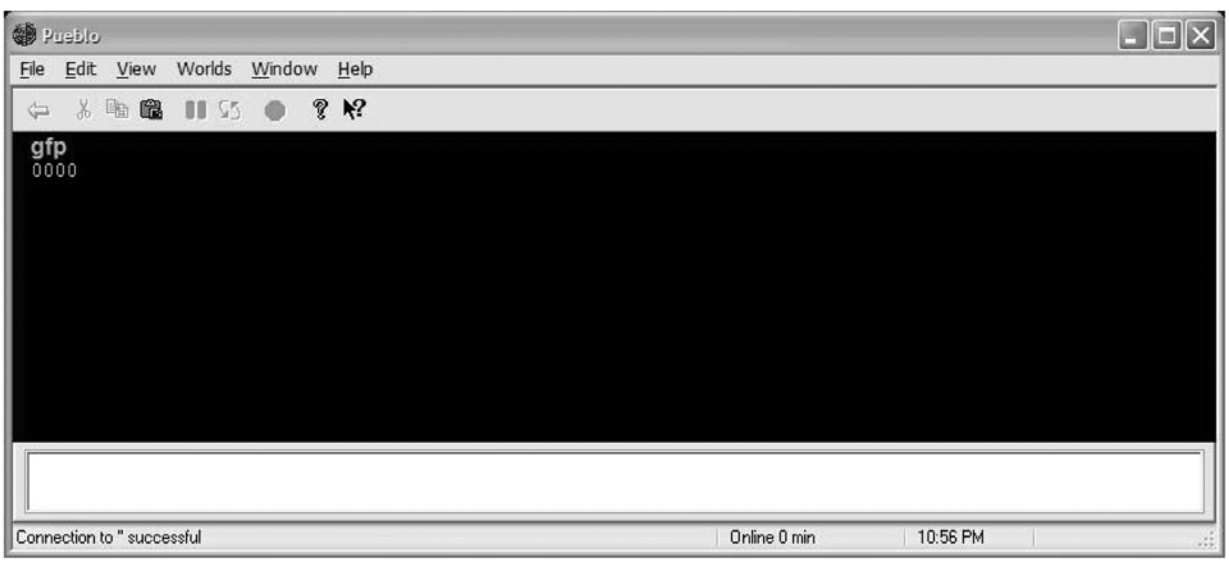



***Figure A-17. QuickConnect Response***

## Command Line Interface Details

*Table A-1. Get Commands (available at any time)*

| COMMAND | DEFINITION | PARAMETERS | RETURNS |
|---|---|---|---|
| grt | Get RF power module temperature | none | RF power module maximum temperature in degrees Celsius |
| glt | Get LASER temperature | none | Laser maximum temperature in degrees Celsius |
| gfp | Get forward power | none, 1-4 | RF power module peak forward power in 10s of watts. No parameters returns the total forward peak power. gfp 1 returns peak forward power for amp #1 in 10s of watts |
| grp | Get reflected power | none, 1-4 | RF power module peak reflected power in 10s of watts. No parameters returns the total reflected peak power. grp 1 returns peak reflected power for amp #1 in 10s of watts. |
| gms | Get modulation strength | none | Modulation on percentage in percent |
| gmd | Get modulation direction | none | 1 if RF power module is being modulated and 0 if the RF power module is not modulating |
| gsn | Get serial number | none | Serial number of system in decimal. This number is related to the MAC, see above. |
| glp | Get LASER power | none | LASER optical power in watts |
| gcs | Get CAN status | none | 1 if no CAN bus is detected and 0 if CAN is functioning normally |
| gso | Get shutter open | none | 1 if shutter is open and 0 if shutter is closed. |
| gsf | Get system frequency | none | Modulation frequency in kHz |

**Ethernet Control must be enabled via the Expanded Input Output Interface Connector for Set Commands to become effective.**

*Table A-2. Set Commands*

| COMMAND | DEFINITION & PURPOSE | PARAMETERS | RETURNS |
|---|---|---|---|
| sms | Set modulation strength<br><br>Sets modulation on percentage in percent. | integers (1-100), default is 1 | CRLF |
| smd | Set modulation direction<br><br>This command should be used to toggle the laser on and off | 1 to set modulation on and 0 to set modulation off | CRLF |
| sme | Set modulation enable<br><br>This command should be used to enable the system prior to operation | 1 to enable and 0 to disable | CRLF |
| sso | Set shutter open<br><br>This command is used to open and close the shutter | 1 to open and 0 to close | CRLF |
| ssf | Set system frequency<br><br>Sets modulation frequency in kHz | integers (1-100), default is 25 | CRLF |

*Table A-3. Special Commands (available at any time)*

| COMMAND | DEFINITION | PARAMETERS | RETURNS |
|---|---|---|---|
| log | start/stop transmission of log file data | none | A data stream from the system including fault status with timestamp and CAN traffic. |

Example sequence for turning on the DIAMOND E-400 Series via TCP:

1. Turn on power with Ethernet crossover cable connected.
2. Wait for the IP address assignment to occur.
3. Start a TCP Client.
4. Open socket.
5. Type 'sme 1' to enable the system.
6. Type 'ssf x' to set a modulation frequency (replace x with desired the desired frequency in kHz).
7. Type 'sms x' to set the modulation strength (replace x with the desired on percentage).
8. Check that safe operation of the LASER is possible!
9. Type 'smd 1' to turn on the LASER.
10. Verify the LASER is operating by typing 'glp'.

## Generating a Log File

In order to retrieve the log file from a running E-400 Series system, use a TCP client software that allows buffering. For demonstration purposes in this manual the Pueblo/UE will be used for this example and is available at: [http://pueblo.sourceforge.net/pueblo/](http://pueblo.sourceforge.net/pueblo/).

To generate a log file using Pueblo, perform the following steps:

1. Find the IP address of the unit to be logged (default laser IP address is *169.254.12.13*).
2. Connect a PC with the Pueblo application to the laser.
3. Configure the PC network adapter card to use static IP address 169.254.12.12, with subnet mask 255.255.0.0.
4. Launch the Pueblo application.
5. From the Worlds tab, select QuickConnect. Enter the laser IP address and port 5000. See Figure A-16. The port used to open the TCP socket is 5000; only one TCP port can be opened at one time. Press "Connect."
6. From the Pueblo command line, select File->Log to a File. Click on "Log to a File" and note a check mark at this line.
7. A new "Save As" dialog box will open. Choose an appropriate path/folder for the log file, then create a file name using the laser serial number and date (serialnumber_DDMMYY). Leave the extension .txt and press "Save".

8. From the Pueblo window, type LOG (or log, case does not matter) followed by a return to start the logging function. The logging function will begin and the following data will appear approximately once a second (example data shown).

   ```
   225421192008
   096|000|000|000|001|000|000|021
   032|000|000|005|105|019|000|048
   065|000|000|000|000|021|000|048
   066|000|000|000|000|021|000|048
   067|000|000|000|000|021|000|048
   068|000|000|000|000|021|001|049
   069|000|000|000|000|021|000|048
   096|000|001|021|024|030|006|047
   032|000|000|005|105|019|000|048
   065|000|000|000|000|021|000|048
   066|000|000|000|000|021|000|048
   067|000|000|000|000|021|000|048
   068|000|000|000|000|021|001|049
   069|000|000|000|000|021|000|048
   096|000|002|020|021|020|019|021
   ```

9. Allow approximately 15 minutes worth of data to be logged. During the log time, command the laser to perform a sequence that is causing a problem, generates a fault or where performance is in question.

10. At the end of the logging period, type LOG (or log), followed by a return to stop the logging function.

11. From the Pueblo command line, select File->Log to a File and note the check mark should disappear. This will "write" the logged data to the file *serialnumber_DDMMYY.txt*.

## Interpreting the Raw Data from an E-400 Series Log File

Please refer to the CD that was supplied with the laser system and locate the E-Diagnostic software on the CD for assistance in interpreting the laser log file. The following section details methods to obtain the log file and save as a .txt file, or using the software, how to stream the data directly into the diagnostics software.

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***NOTICE!***
**Fully review the E-Diagnostics User Guide located on the CD supplied with the laser system prior to using the E-Diagnostics software.**

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The CPLD Time Stamp and CAN Nodes (Raw Data) are two types of data that are created by the CPLD (Complex Programmable Logic Device). They are recorded to the Log File and need to be understood as a means to interpret the log file. The following is an example of how data appears in the log file:

| | |
|---|---|
| (Command, start log) | log |
| 1) Time stamp | 225421192008 |
| 2) CAN Nodes (Raw Data) | 067\|000\|000\|208\|000\|042\|035\|049 |
| | 068\|000\|000\|214\|000\|042\|039\|049 |
| | 096\|000\|000\|002\|089\|000\|000\|031 |
| | 032\|000\|001\|033\|039\|000\|000\|010 |
| | 065\|000\|001\|037\|040\|039\|038\|043 |
| | 066\|000\|001\|035\|042\|038\|037\|031 |
| | 067\|000\|001\|038\|041\|043\|038\|035 |
| | 068\|000\|001\|040\|042\|043\|039\|039 |

## 1) CPLD Time Stamp

The first is a series or group of numbers that is 12 digits long. A typical example might be 225421192008. This data breaks down as follows:

**First six digits 225421**

This is a simple representation of the time. It is represented as SSMMHH and is reported in decimal but must be converted to hex to obtain the TIME information in true 24 hour time notation.

In base 10, decimal, number structure is 10’s and units, so 22 is 2 “10's” and 2 “units”, a familiar format. To encode this in hexadecimal, which is base 16, numbers are represented as “16's” and “units”. To encode 22, we need 1 “16” and 6 “units”. Following this encoding logic:

22dec = 16 hex (Hex code 0x16)
54dec = 36 hex (Hex code 0x36)
21dec = 15 hex (Hex Code 0x15)

225421 recodes to 163615 in format SSMMHH. In reversing this, real time in 24 hour notation is obtained as 15:36:16 (or 3:36:16 pm).

**Next three digits 192**

This is a decimal representation of the first CPLD status byte, shown in Table A-4 on page A-27.

**Next three digits 008**

This is a decimal representation of the second CPLD status byte, also shown in Table A-4 on page A-27.

Table A-4 on page A-27 shows how the code is generated from the bit data and will assist in interpreting the bit wise representation of the data. For this example, 192 is reporting a high on the “Shutter Interlock Flag” status (Bit 128) on the first byte table as well as an “Interlock Flag” status (Bit 64), meaning that the shutter is closed. Bit 64 and Bit 128 summed give the resultant code 192. The second batch of digits, 008 is reporting a “Shutter Position” as a high status meaning also that the shutter is closed. The above codes are recorded only when there is a change in CPLD status bytes. They are not recorded as often as the second type of log entry, which are referred to as CAN Node Addresses.

## 2) CAN Nodes (Raw Data)

CAN (Controller Area Network) messages represent the data received from the various CAN nodes. In total there are 7 CAN node addresses. Six of these Can Node Addresses refer to data from the RF power module used on the laser. The remaining CAN Node Address refers to data from the laser head.

## RF Power Module CAN Nodes

| CAN Node Address | Description |
|---|---|
| 032 = OSC/DRV | (Oscillator/Driver circuitry) |
| 065 = RFPA1 | (RF Power Amplifier 1) |
| 066 = RFPA2 | (RF Power Amplifier 2) |
| 067 = RFPA3 | (RF Power Amplifier 3) |
| 068 = RFPA4 | (RF Power Amplifier 4) |
| 069 = RFPA5 | (RF Power Amplifier 5) |

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**The CPLD can automatically detect and report data from the number of RFPA's actually in use on the laser system. The number of RFPA stages used however, may vary with laser model**

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## Laser Head CAN Nodes

096 = LASER HEAD (Laser Head Fault)

Each of these CAN Node Addresses have a defined number of "data pages". A data page is a selection of data reported from areas of the RF power module or laser head to the logfile. The origin of this data may be from temperature sensors, switches, voltage sensors or other similar devices.

| CAN Node Address | Description | No. of Data Pages |
|---|---|---|
| 032 = OSC/DRV | (Oscillator/Driver circuitry) | 2 |
| 065 = RFPA1 | (RF Power Amplifier 1) | 2 |
| 066 = RFPA2 | (RF Power Amplifier 2) | 2 |
| 067 = RFPA3 | (RF Power Amplifier 3) | 2 |
| 068 = RFPA4 | (RF Power Amplifier 4) | 2 |
| 069 = RFPA5 | (RF Power Amplifier 5) | 2 |
| 096 = LASER | (Laser Head Fault) | 3 |

***Table A-4. CPLD Status Byte Codes***

| RTIO_ENABLE_STATUS (1ST BYTE) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **INTERLOCK FLAG** | **SHUTTER INTERLOCK FLAG** | **SYSTEM FAULT** | **SYSTEM ENABLE** | **ETHERNET CONTROL** | **TEMPERATURE FAULT** | **GENERAL FAULT** | **SHUTTER FAULT** | **DECIMAL OUTPUT** | **HEX OUTPUT** |
| Bit 128 | Bit 64 | Bit 32 | Bit 16 | Bit 8 | Bit 4 | Bit 2 | Bit 1 | | |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 16 | 0x10 |
| | | | | | | | | | |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 128 | 0x80 |
| 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 144 | 0x90 |
| 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 176 | 0xB0 |
| 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 178 | 0xB2 |
| | | | | | | | | | |
| 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 192 | 0xC0 |
| 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 194 | 0xC2 |
| 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 200 | 0xC8 |
| 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 208 | 0xD0 |
| | | | | | | | | | |
| 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 240 | 0xF0 |
| 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 241 | 0xF1 |
| 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 242 | 0xF2 |
| | | | | | | | | | |
| **RTIO_CPLD_STATUS (2ND BYTE, MODULATING FAULTS)** | | | | | | | | | |
| **NOT USED** | **NOT USED** | **NOT USED** | **NOT USED** | **SHUTTER POSITION*** | **SHUTTER COMMAND**** | **DUTY CYCLE** | **VSWR** | **DECIMAL OUTPUT** | **HEX OUTPUT** |
| Bit 128 | Bit 64 | Bit 32 | Bit 16 | Bit 8 | Bit 4 | Bit 2 | Bit 1 | | |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0x01 |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 0x02 |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 3 | 0x03 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 4 | 0x04 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 5 | 0x05 |
| | | | | | | | | | |
| 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 7 | 0x07 |
| 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 8 | 0x08 |
| 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 9 | 0x09 |
| *High (1) is closed, Low is opening, **High (1) is commanding to open | | | | | | | | | |

When creating a log file from an E-Series laser, the CAN Node data are recorded in sequence at 1 second intervals, and presented in the log record. Column headings for this data are:

CAN Node Address|Fault Code|Data Page|Data 3|Data 4|
Data 5|Data 6|Data 7

| Data Displayed | Comments |
|---|---|
| 032\|000\|000\|024\|025\|025\|000\|048 | OSC/DRV, Data Page 0 |
| 065\|000\|000\|000\|000\|025\|000\|049 | RFPA1, Data Page 0 |
| 066\|000\|000\|000\|000\|025\|000\|048 | RFPA2, Data Page 0 |
| 067\|000\|000\|000\|000\|025\|001\|049 | RFPA3, Data Page 0 |
| 068\|000\|000\|000\|000\|025\|001\|048 | RFPA4, Data Page 0 |
| 096\|000\|000\|000\|000\|000\|000\|024 | LASER HEAD, Data Page 0 |
| 032\|000\|001\|025\|025\|000\|000\|017 | OSC/DRV, Data Page 1 |
| 065\|000\|001\|025\|024\|024\|024\|011 | RFPA1, Data Page 1 |
| 066\|000\|001\|025\|024\|025\|025\|013 | RFPA2, Data Page 1 |
| 067\|000\|001\|025\|025\|024\|024\|015 | RFPA3, Data Page 1 |
| 068\|000\|001\|025\|025\|025\|025\|017 | RFPA4, Data Page 1 |
| 096\|000\|001\|023\|032\|003\|000\|047 | LASER HEAD, Data Page 1 |
| 032\|000\|000\|024\|025\|026\|004\|048 | OSC/DRV, Data Page 0 |
| 065\|000\|000\|211\|009\|027\|017\|048 | RFPA1, Data Page 0 |
| 066\|000\|000\|209\|008\|026\|015\|048 | RFPA2, Data Page 0 |
| 067\|000\|000\|213\|010\|027\|016\|048 | RFPA3, Data Page 0 |
| 068\|000\|000\|218\|009\|027\|017\|048 | RFPA4, Data Page 0 |
| 096\|000\|002\|024\|023\|024\|024\|024 | LASER HEAD, Data Page 2 |

The above example demonstrates a complete set of data in that both OSC/DRV pages 0 and 1 have been displayed, both pages 0 and 1 for the RFPA1 thru RFPA4 data sets have been displayed and all three pages of LASER data, 0, 1 and 2 have been displayed. Data will continue to be logged and recorded in this format until the logging is halted.

Once logging of the data has concluded, interpretation of the data can start. There are several tables within this section that will be referred to, which will assist in data interpretation. The following list of CAN Data Page contents describes in greater detail what the individual data outputs represent.

Page intentionally left blank.

## CAN Data Page Contents

| CAN Node 065 thru 069 RFPA 1 thru 5 |
|---|
| Data page 0<br>Data 2 - Fault Code - See Table A-6<br>Data 3 - Peak Forward Power in 10's of watts<br>Data 4 - Peak Reflected Power in 10's of watts<br>Data 5 - Highest Temperature on Head Assembly °C<br>Data 6 - RFPA DC Current Amps<br>Data 7 - Vdd DC Voltage Volts |

| CAN Node 065 thru 069 RFPA 1 thru 5 |
|---|
| Data page 1<br>Data 2 - Fault Code - See Table A-6<br>Data 3 - RF Transistor stage 1 Temperature °C<br>Data 4 - RF Transistor stage 2 Temperature °C<br>Data 5 - RF Transistor stage 3 Temperature °C<br>Data 6 - RF Transistor stage 4 Temperature °C<br>Data 7 - RFPA DC Current Amps |

| CAN Node 032 OSC/DRV |
|---|
| Data page 0<br>Data 2 - Fault Code - See Table A-6<br>Data 3 - Inlet Water Temperature °C<br>Data 4 - Outlet Water Temperature °C<br>Data 5 - Highest Temperature °C<br>Data 6 - DC Current Amps<br>Data 7 - Vdd Voltage Volts |

| CAN Node 032 OSC/DRV |
|---|
| Data page 1<br>Data 2 - Fault Code - See Table A-6<br>Data 3 - Transistor 1 Temperature °C<br>Data 4 - Transistor 2 Temperature °C<br>Data 5 - Temperature 3, °C<br>Data 6 - Temperature 4, °C<br>Data 7 - Dew Point |

CAN Node 096 LASER HEAD

Data page 0
Data 2 - Fault Code - See Table A-6
Data 3 - Optical Power High Byte (Multiply by 256)
Data 4 - Optical Power Low Byte (add to data 3 for real power output in watts)
Data 5 - Boolean fault 0, “Any High output = fault condition” “Low output = safe”

| | |
|---|---|
| Bit 0 - Flow | Decimal 1 |
| Bit 1 - 48V monitor, faults at <42V or >53V | Decimal 2 |
| Bit 2 - not used (Igniter on LEGACY units) | Decimal 4 |
| Bit 3 - 5V Monitor, faults at <4.75V or >5.25V | Decimal 8 |
| Bit 4 - Dew Point, faults when Dew Point <Ambient Temp | Decimal 16 |
| Bit 5 - Spare | |
| Bit 6 - Spare | |
| Bit 7 - Spare | |

Data 6 - Boolean Fault 0, “Any High output = fault condition” “Low output = safe”

| | |
|---|---|
| Bit 0 - Thermistor 1 Fault when T<10°C or T>50°C | Decimal 1 |
| Bit 1 - Thermistor 2 Fault when T<10°C or T>50°C | Decimal 2 |
| Bit 2 - Thermistor 3 Fault when T<10°C or T>50°C | Decimal 4 |
| Bit 3 - Thermistor 4 Fault when T<10°C or T>50°C | Decimal 8 |
| Bit 4 - Thermistor 5 Fault when T<10°C or T>50°C | Decimal 16 |
| Bit 5 - Thermistor 6 Fault when T<10°C or T>50°C | Decimal 32 |
| Bit 6 - Spare, set to 0 | |
| Bit 7 - Spare, set to 0 | |

Data 7 - Highest Temperature from all Temperature Nodes

The number reported in the log file in the Data 5 and Data 6 record is based on the status of the “Bit” output listed above and whether it is a low or high. The number is a decimal number which represents which bit status lines are high. The data is presented as a 3 digit decimal number that can be decoded to find which of the output Bits are active. Binary allows us to encode numbers using only 1’s and 0’, or lows and highs. Table A-5 provides an example of this encoding method.

***Table A-5. Binary Encoding Example***

| | | | | | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Hundreds | Tens | Units | | 32’s | 16’s | 8’s | 4’s | 2’s | 1’s | |
| Decimal Number | 0 | 1 | 2 | Binary Number | 0 | 0 | 1 | 1 | 0 | 0 | Example 1 |
| | 0 | 4 | 6 | | 1 | 0 | 1 | 1 | 1 | 0 | Example 2 |

Using the above method in Example 1, it can be decoded that if in the Data 6 output record the number 012 appears, then Bit 2, (decimal 4) and Bit 3, (decimal 8) must be high, and have been summed together to represent the number 012. This also shows that Bit 2, Thermistor 3 is in fault condition as well as Bit 3, Thermistor 4.

Example 2 Decimal 46, tells us that Bit 5, Bit 3, Bit 2 and Bit 1 are active (summing 32+8+4+2 = 46) also indicating thermistors 6, 4, 3, and 2 are in fault condition. The same methodology can be applied to the Data 5 record. For example if Data 5 is 018, it would be indicating that we simultaneously have a 48V supply out of specified range that is <42V or >53V, and that also the Dew Point detector has detected that the dew point is less than Ambient temperature.

CAN Node 096 LASER HEAD

data page 1
Data 2 - Fault Code - See Table A5
Data 3 - Thermistor 6 - °C
Data 4 - Ambient Temperature - °C
Data 5 - Humidity
Data 6 - Dew Point
Data 7 - Not Used

CAN Node 96 LASER HEAD

data page 2
Data 2 - Fault Code - See Table A5
Data 3 - Thermistor 1 - °C
Data 4 - Thermistor 2 - °C
Data 5 - Thermistor 3 - °C
Data 6 - Thermistor 4 - °C
Data 7 - Thermistor 5 - °C

***Table A-6. CAN FAULT CODES***

| NAME | CODE (HEX - $XX) | DESCRIPTION | DECIMAL |
|---|---|---|---|
| No Fault | 0 | No Faults Detected - Reset Faults State | 000 |
| **NODE FAULTS (0X01-0X7F)** | | | |
| RF power module SWR | 0x01 | RF SWR exceeds maximum | 001 |
| Shutter Interlock | 0x02 | Shutter Interlock Open | 002 |
| Shutter Transition | 0x03 | Shutter Transition Failure | 003 |
| Node Temperature | 0x04 | Node Temperature Out of Range | 004 |
| Node Dew Point | 0x05 | Node Dew Point Out of Range | 005 |
| Igniter | 0x06 | Igniter Failure | 006 |
| 48V Power Supply | 0x07 | 48V DCPS Out of Range | 007 |
| 5V Power Supply | 0x08 | 5V DCPS Out of Range | 008 |
| I2C Communication | 0x09 | I2C Communication Failure | 009 |
| Microcomputer EEPROM | 0x0A | Microcomputer EEPROM Failure | 010 |
| Microcomputer RAM | 0x0B | Microcomputer RAM Failure | 011 |
| Microcomputer Memory | 0x0C | Microcomputer Checksum Failure | 012 |
| Microcomputer ADC | 0x0D | Microcomputer ADC Failure | 013 |
| Flow | 0x0E | Coolant Flow Failure | 014 |
| 48VDC Supply Current | 0x0F | 48VDC Supply Current Fault | 015 |
| **COMMUNICATION AND MESSAGE FAULTS** | | | |
| NFOR RS-232 noise, framing, overrun error | 0x80 | Serial Comm Character Reception Fault | 128 |
| RS-232 Time Out | 0x81 | Serial Comm Message Time-out | 129 |
| Bad RS-232 Header | 0x82 | Bad Serial Comm Message Header Character | 130 |
| Bad RS-232 Footer | 0x83 | Bad Serial Comm Message Footer Character | 131 |
| Bad Checksum | 0x84 | Bad Serial Comm Message Checksum | 132 |
| Command Sequence | 0x85 | Improper Command Sequence | 133 |
| Bad Command | 0x86 | Illegal or Invalid Node Command | 134 |
| Command Parameter | 0x87 | Remote Command Parameter Invalid | 135 |
| Bad Message | 0x88 | Illegal or Invalid Node Message | 136 |
| Node Reset Completed | 0x89 | Node has completed a local reset | |

Now to analyze some real data from an E-Series laser data log file. To make this easier to understand, only the LASER NODE 96 data page "0" information has been extracted from a real log file. Note that a temperature change over a time period will be observed.

| Data | Comment |
|---|---|
| 658520208008<br>096\|000\|000\|002\|089\|000\|000\|031 | Time 658520 = 14:55:41<br>Power = 601W, Highest Temp = 31C |
| (Power = Data 3 times 256 plus data 4, Highest Temp = actual degrees C, data 7) | |
| 096\|000\|000\|002\|100\|000\|000\|034<br>096\|000\|000\|002\|092\|000\|000\|036<br>096\|000\|000\|002\|086\|000\|000\|038<br>096\|000\|000\|002\|100\|000\|000\|040<br>096\|000\|000\|002\|073\|000\|000\|041<br>096\|000\|000\|002\|086\|000\|000\|042<br>096\|000\|000\|002\|097\|000\|000\|043<br>096\|000\|000\|002\|073\|000\|000\|044<br>096\|000\|000\|002\|055\|000\|000\|044<br>096\|004\|000\|002\|057\|000\|012\|045<br>↑ ↑ ↑ | Power = 612W, Highest Temp = 34C<br>Power = 604W, Highest Temp = 36C<br>Power = 598W, Highest Temp = 38C<br>Power = 612W, Highest Temp = 40C<br>Power = 585W, Highest Temp = 41C<br>Power = 598W, Highest Temp = 42C<br>Power = 609W, Highest Temp = 43C<br>Power = 585W, Highest Temp = 44C<br>Power = 567W, Highest Temp = 44C<br>Power = 569W, Highest Temp = 45C |
| 004, Failure Code from Table A5 = Node Temperature out of Range<br>012, Boolean Fault, sum of Bit 2 (4) and Bit 3 (8) = 012<br>045, Highest Temp Recorded in degrees C | |

This was real data from a laser that had adequate water FLOW but a water source that was unable to maintain temperature which led to a laser over-temperature warning. This is detected and is evident in the last line of data.

096 = CAN Node Address LASER
004 = Fault Code 004
000 = Laser Data Page 0
002 = Optical Power (multiply by 256)
057 = Optical Power (add to above line for total power)
000 = Boolean Fault
012 = Boolean Fault
(Output is Binary 8 and Binary 4 summed to 12)
045 = Highest Temperature reached

The 012 Boolean Fault indicates, as mentioned earlier, that output 8 and 4 are active indicating Thermistor 2 and 3 have reached the warning temperature. The individual outputs for these Thermistors are on CAN Node 96, data page 2. To confirm, the output of Data page 2 for the above example, was as follows:

096|004|002|020|020|045|045|023

Interpret the above data page output as follows:

096 = CAN Node Address LASER
004 = Fault Code 004
002 = Laser Data Page 2
020= Thermistor 0 temperature in °C
020 = Thermistor 1 temperature in °C
045 = Thermistor 2 temperature in °C
045 = Thermistor 3 temperature in °C
023 = Thermistor 4 temperature in °C

A further example of data interpretation from a log file is given below:

| CAN Node | \|Fault | \|Data Page | \|Data 3 | \|Data 4 | \|Data 5 | \|Data 6 | \|Data7 |
|---|---|---|---|---|---|---|---|
| 067 | \|000 | \|000 | \|000 | \|000 | \|023 | \|000 | \|048 |
| 068 | \|000 | \|000 | \|000 | \|000 | \|023 | \|002 | \|048 |
| 096 | \|004 | \|000 | \|000 | \|121 | \|000 | \|032 | \|026 |
| | ↑ | | | ↑ | | ↑ | |

Node 96, Data Page 000, laser head has a temperature fault 004
Data 4 is reporting 121 watts of optical power
Data 6 is indicating 32, showing a problem at Bit 5, Thermistor 6

| CAN Node | \|Fault | \|Data Page | \|Data 3 | \|Data 4 | \|Data 5 | \|Data 6 | \|Data7 |
|---|---|---|---|---|---|---|---|
| 032 | \|000 | \|001 | \|023 | \|023 | \|027 | \|000 | \|000 |
| 065 | \|000 | \|001 | \|023 | \|023 | \|023 | \|023 | \|000 |
| 066 | \|000 | \|001 | \|023 | \|023 | \|023 | \|023 | \|001 |
| 067 | \|000 | \|001 | \|023 | \|023 | \|023 | \|022 | \|000 |
| 068 | \|000 | \|001 | \|023 | \|023 | \|023 | \|023 | \|002 |
| 096 | \|004 | \|001 | \|002 | \|029 | \|020 | \|003 | \|045 |
| | ↑ | | ↑ | | | | |

Node 96, Data Page 001, laser head has a temperature fault 004
Data 3 is reporting 2 degrees at Thermistor 6, clearly a problem

The above data was taken from a log file of a laser with a shorted Thermistor 6.

In the above case, CAN Node 96 (Laser Head) shows on data page 000 that there is a temperature problem (Fault Code 004), and where the problem is located (Thermistor 6).

This is then followed up with the output from CAN Node 96 data page 001 which repeats the temperature warning (Fault Code 004) and allows the Thermistor output at Data 3 at 002 which is outside the limits of T<10°C or T>50°C to be seen.

# Appendix B: Fault Matrix

## Fault Matrix

*Table B-1. Fault Matrix*

| Fault Name | Class | Monitored By | Implementation | CAN Fault Code | System Fault | Additional Pin Signals |
|---|---|---|---|---|---|---|
| VSWR | Disruptive | RFPA | VSWR > 3.1 AND Duty Cycle > 10% | 0x01 | N | VSWR Limit |
| Duty Cycle | Disruptive | CONTROL | Duty Cycle > 60% | n/a | N | Duty Cycle Limit |
| Maximum Pulse Width | Disruptive | CONTROL | Pulse Width > 1ms | n/a | N | Duty Cycle Limit |
| Temperature Limit | Latching | RFPA | 2°C > T > 80°C | 0x04 | Y | Over Temperature Fault |
| Temperature Limit | Latching | OSC/DRV | 2°C > T > 80°C | 0x04 | Y | Over Temperature Fault |
| Temperature Limit | Latching | LASER | 10°C > T > 50°C | 0x04 | Y | Over Temperature Fault |
| Shutter Fault | Latching | CONTROL | (Shutter Cmd False AND Shutter Open (>210ms) OR (Shutter Not Open AND Shutter Not Closed (>210ms)) | n/a | Y | Shutter Fault |
| Water Flow (Legacy) | Latching | LASER | Flow < 1gpm | 0x0E | Y | Flow Fault |
| Igniter Warning (Legacy) | Non Latching | LASER | Igniter Current < 80mA OR Igniter Current > 200mA (during system init and after) | 0x06 | N | System Warning |
| +48V Voltage Limit | Terminal | RFPA | 43 VDC > VDC > 53 VDC | 0x07 | Y | N |
| +48V Voltage Limit | Terminal | OSC/DRV | 43 VDC > VDC > 53 VDC | 0x07 | Y | N |

**Table B-1. Fault Matrix (Continued)**

| FAULT NAME | CLASS | MONITORED BY | IMPLEMENTATION | CAN FAULT CODE | SYSTEM FAULT | ADDITIONAL PIN SIGNALS |
|---|---|---|---|---|---|---|
| +48V Voltage Limit | Terminal | LASER | 43 VDC > VDC > 53 VDC | 0x07 | Y | N |
| Node Reset (soft reset) | Non Latching | ALL | Skip Init Sections dealing with CAN discovery | n/a | N | N |
| CAN Communica-tion | Terminal | ALL | No report during discovery OR persis-tent loss of Comm to a particular node (No response after Node Reset Command) | n/a | Y | N |
| Node Initialization Error (Silicon Check, Vref check, etc) | Terminal | ALL | determined prior to CAN discovery phase | various (0x0A - 0x0D) | Y | N |

# APPENDIX C: E-400CL2

## Introduction

The E-400CL2 laser is equipped with closed loop power control. This appendix should be used along with other parts of the E-400 Operator's Manual as it includes only the supplemental information for using the closed loop control capability. The purpose of the closed loop control is to control the laser output power stability and to control the laser's transient response when the power set point is changed by the operator. It is disabled when DC power is first applied to the laser head. From power up, an E-400CL2 laser is compatible with the E-400 in that the MODULATION input on the Real Time I/O Connector is active. To enable and use closed loop power control, a serial interface command must be received by the laser. Either RS-232 or RS-422 serial interfaces can be connected to the laser using pins on the DCPS/Aux I/O Connector that are not used by E-400 lasers. Note that both RS-232 and RS-422 should not be connected at the same time because they are hardwired to the same internal port.

## Power Control Loop Overview

A PID servo loop is used to control average laser output power and step response. The set point is defined either by a serial command or by an analog voltage signal after the analog input has been enabled by a serial command. The feedback to the control loop comes from an internal laser power detector assembly. See Figure C-1.

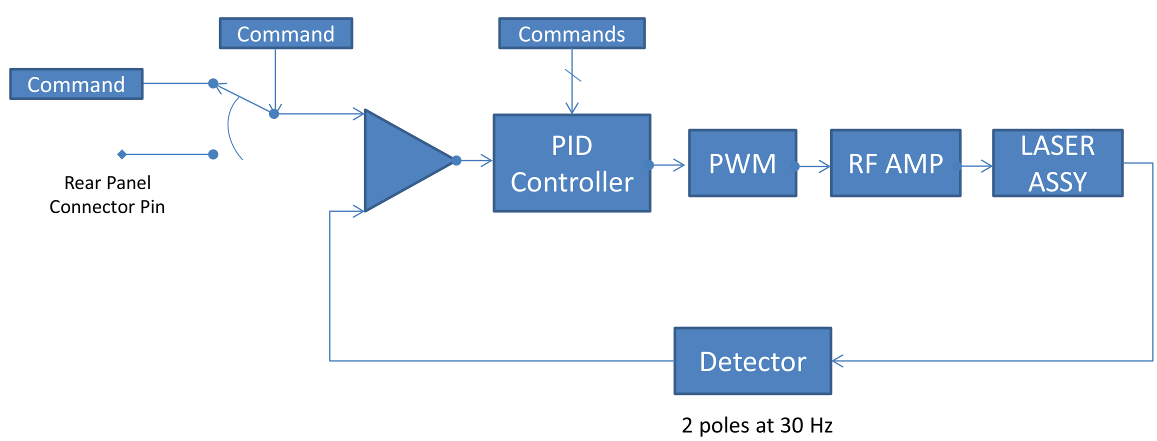


*Figure C-1. Control Loop Block Diagram*

## Accessories

For convenience only, the CL Communications Adapter (Figure C-2) is included for rapid prototyping of closed loop control. This adapter is not intended for any other use. It is not intended for uses requiring regulated electro-magnetic compliance. Connections for prototyping RS-422 interfaces and analog input power level control are identified in print on the printed circuit board. The pin designations for the 15 pin connector are the same as the DCPS/AUXILIARY I/O Connector on the E-400CL2 laser as shown in Figure C-3.

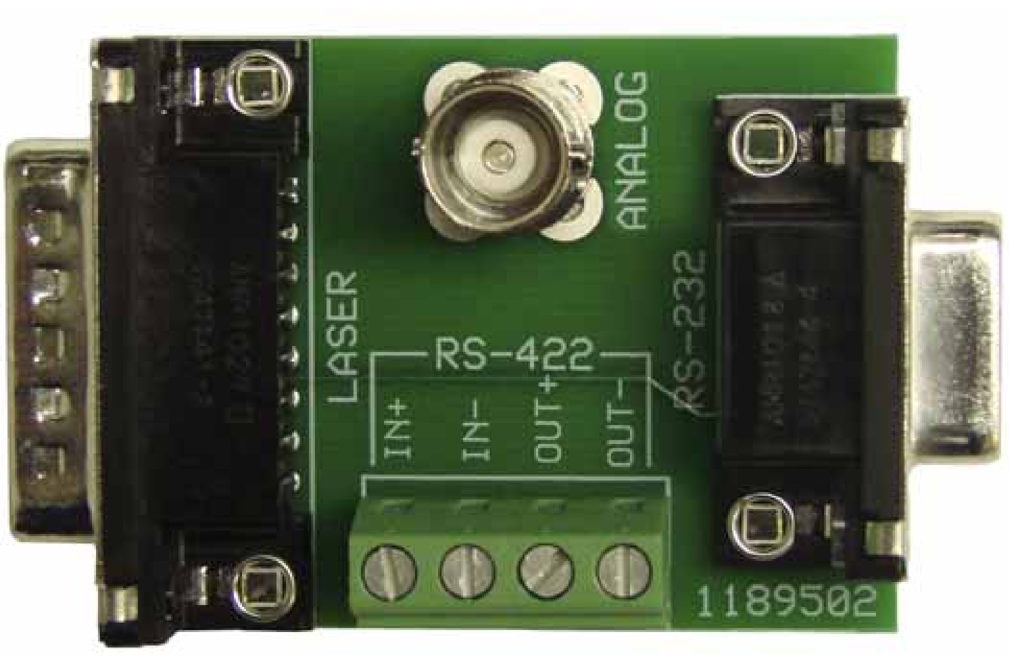


***Figure C-2. CL Communications Adapter Connector Signals***
***Coherent Part Number 1189502***

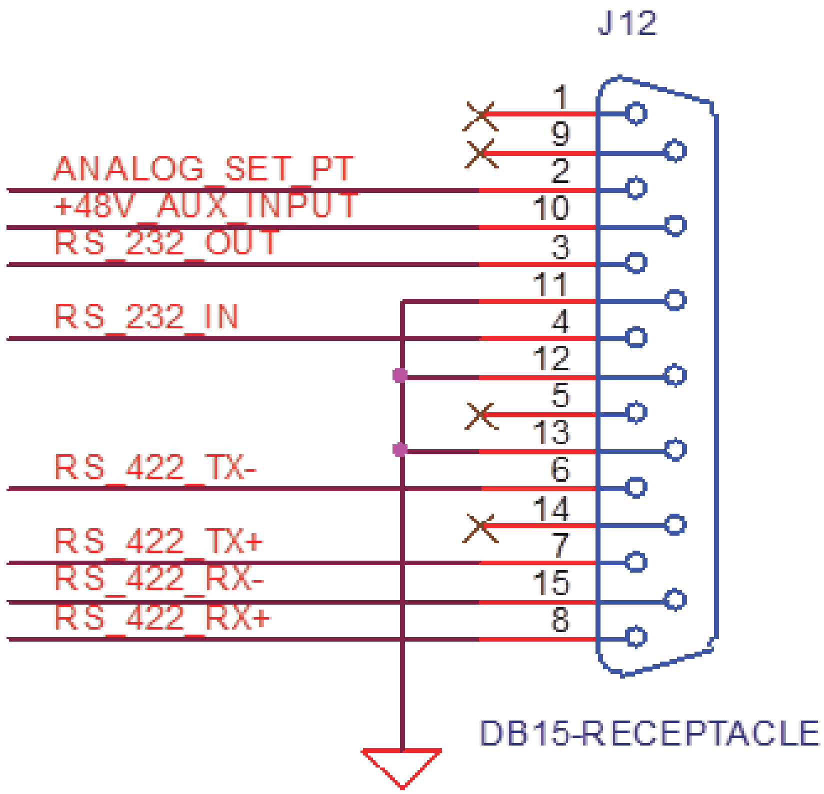


*Figure C-3. Communications Adapter Connector Signals*

*Table C-1. Communications Adapter Connector Signals Pin Descriptions*

| PINS | DESCRIPTION |
|---|---|
| 1, 5, 9, 14 | Reserved; do not connect. |
| 2 | Analog power set point input. Range 0-4 VDC; scale factor 5 mV/W. |
| 3 | RS-232 output. |
| 4 | RS-232 input. |
| 6 | RS-422- output. |
| 7 | RS-422+ output. |
| 8 | RS-422+ input. |
| 10 | Optional + 48 VDC input to allow operation of control circuitry when main laser DC power supply is not enabled. Not used in normal operation. |
| 11, 12, 13 | System ground. Used as Common for all control functions. |
| 15 | RS-422- input. |

# *Closed Loop Control*

## Serial Interface

All communications with the laser are through an asynchronous serial link, which can be either 2-wire RS-232 or 4-wire RS-422. Both links are always enabled, but should not be used simultaneously.

All commands to and responses from the laser consist of ASCII strings. These can be sent and received through a standard terminal emulator, such as HyperTerminal, or by computer application/serial driver software. The remainder of this section is necessary programmer reference and end user information that should be understood in its entirety for successful implementation of E-400CL2 computerized control.

### Serial Port Configuration

The serial port should be configured as follows:

19200 bits per second

data bits: 8

parity: none

stop bits: 1

flow control: none

### Power Up Behavior

Closed loop control is disabled when DC power is first applied to the laser head. From power up, an E-400CL2 laser is compatible with the E-400 in that the MODULATION input on the Real Time I/O Connector is active. To enable and use closed loop power control, a serial interface command must be received by the laser. The closed loop microcontroller signals it is ready by annunciating its firmware version number on the serial interface.

### Command Echo and Command Processing Time

The E-400CL2 echoes all characters back to the sender.

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**Due to limitations in the processing speed of the CL2 microcontroller, strings of ASCII characters should not be transmitted back-to-back, as this may result in the loss of some characters. Coherent recommends that a minimum 20 milliseconds delay be inserted between the characters.**

---

### Loop Fault Message

When the closed loop function is active, but an internal loop error signal goes true, the character string "Loop Fault" is transmitted and laser output power is internally set to zero. The serial interface should be continuously monitored for occurrence of this string. Instructions for troubleshooting root cause of this message are given in the "Troubleshooting" on page C-12.

### Max Set Point Message

When a set point greater than 400 W is requested, the E-400CL2 responds with a message indicating it is out of range and output power is unchanged.

### Analog Control Input

When enabled by the PA command over the serial interface, the laser follows the analog set point input signal on pin 2 of the DCPS/AUXILIARY I/O Connector. The scale factor for this input is 5 mV/W. The input impedance is 1 KΩ.

## Internal Power Detector

### Analog Output Signals

Power monitor signals are available on the Extended I/O Connector. The voltage of these signals is proportional to the laser output power. Pin 21 has higher bandwidth than Pin 11. Pin 21 is used for measuring step response and Pin 11 is used for measuring stability. A 1 kHz or lower low pass filter and/or averaging is recommended for noise rejection when these output pins are used. See Table C-2.

***Table C-2. Analog Output Signal Description***

| PIN | SIGNAL DESCRIPTION |
|---|---|
| 11 | 5 mV/Watt, nominal |
| 21 | 1.5 mV/Watt, nominal |

## Serial Interface Command Set

Table C-3 summarizes the E-400CL2 laser command set. Alpha characters are not case-sensitive. All commands must be followed by Enter.

***Table C-3. E400CL2 Laser Command Set***

| COMMAND | OPERAND | DESCRIPTION | EXAMPLE |
|---|---|---|---|
| CAL | none | Calibrate; see description below | CAL |
| CF | none | Clear Loop Fault | CF |
| CL | none | Closed Loop mode select | CL |
| D | none | Print Duty cycle | D |
| D | 0.1-60 | Duty cycle entered in % | D45.2 |
| E | 1 or 0 | Enable (E1) or disable (E0) closed loop operation | E1 |
| F | 1-200 | Enter Frequency set point in KHz | F150 |
| F | none | Frequency print | F |
| K | none | Print PID coefficients | K |
| KD | 1-100 | Differential gain coefficient enter | KD1 |
| KI | 1-100 | Integral gain coefficient enter | KI13 |
| KP | 1-100 | Proportional gain coefficient enter | KP3 |
| KT | 1-255 | Differential Time constant enter | KT64 |
| OL | none | Open Loop mode select | OL |
| P | 1-500 | Enter Power set point in Watts | P225 |
| P | none | Print Power | P |
| PA | none | Enable Power Analog input mode | PA |
| R | 0.001-37.999 | Enter detector Responsivity in mV/W | R4.65 |
| R | none | Responsivity print | R |
| RST | none | Closed loop microcontroller returns to power up state, annunciates its firmware version number | RST |
| T | none | prints the current temperature of the detector | T |
| TC | 1 or 0 | Enable (TC1) or disable (TC0) Temperature Compensation | TC1; TC0 |
| TC. | none | Print Temperature Compensation coefficient | TC. |
| TC. | 1-999 | Temperature Compensation coefficient enter | TC.301 |

***Table C-3. E400CL2 Laser Command Set***

| COMMAND | OPERAND | DESCRIPTION | EXAMPLE |
|---|---|---|---|
| UL | none | Unlock to change reference temperature or PID coefficients | UL |
| VT | none | Automatically calibrate Detector Output 1 and 2 | VT |
| V1+, V1- | none or 1--999 | Increment (+) or decrement (-) Detector Output 1 (pin 21 of Extended I/O) | V1+; V1-55 |
| V1S | none | Save scale setting for Detector Output 1 | V1S |
| V2+, V2- | none or 1--999 | Increment (+) or decrement (-) Detector Output 2 (pin 11 of Extended I/O) | V2+; V2+125 |
| V2S | none | Save scale setting for Detector Output 1 | V2S |

**Calibrate (CAL):**

The internal power detector has a very small temperature coefficient of about 0.25% / C. For extreme stability control requirements, the E-400CL2 has a temperature compensation function. The CAL command saves the current detector temperature as the reference temperature for temperature compensation. Before executing the CAL command, the laser should be enabled and running for 5 minutes at the typical operating power level (such as 400 W).

**Clear Fault (CF):**

Under some operating conditions, the P-I-D integrator may overflow and trigger a loop fault. When this happens, the laser disables the output and sends a fault message to the user. To resume operation, the user must execute a CF instruction to clear the fault condition then re-enable output using E1.

**Closed Loop (CL):**

Executing the CL command puts the system into the Closed Loop mode of operation if it is in the Open Loop mode. If the system is already in Closed Loop mode when the command is executed, the command has no effect. In Closed Loop mode, the user inputs a target power level and the laser adjusts the duty cycle to achieve that power level using feedback from the internal power sensor. The Closed Loop mode is the default mode for the system.

**Duty Cycle (D):**

The Duty Cycle command allows the user to enter an operating duty cycle for the laser when the system is in Open Loop mode. See "Open Loop (OL):" on page C-9 for a description of the Open Loop mode. The range is 0.1% up to the system's maximum operating duty cycle (for example, 60% for the E-400CL2) in 0.1% steps. For example, the command D43.9 will cause the laser to operate at 43.9% duty cycle. The command D (with no operand) causes the laser to return the current duty cycle.

**Enable (E):**

When the laser system is first powered up, closed loop control is not enabled. The laser is in its normal operating mode which is compatible with E-400 and other E-series lasers. In this mode, laser output is controlled by a user supplied modulation signal. If operation in this mode is required, a Modulation signal must be is applied to the Modulation input on the REAL_TIME_I/O connector. To enable closed loop control, send command E1. To return to normal mode, send command E0. Note: if a modulation signal is present at the modulation input on the REAL_TIME_I/O connector when the E0 command is sent, the laser will immediately output power accordingly.

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**CAUTION!**
**Exercise caution to protect against specular reflections since all reflections at the E-400 Series wavelength are invisible. These reflections, while weaker than the main beam, may be sufficiently intense to cause eye damage.**

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**Frequency (F):**

The Frequency command allows the user to enter an operating frequency for the laser when the system is in Open Loop or Closed Loop mode. The range is 1 kHz to 200 kHz with a resolution of 0.1 kHz (100 Hz), although the system is not able to achieve this level of resolution at the high end of the range. For example, the command F4.7 will cause the laser to operate at 4.7 kHz. However, the command F199.2 will cause the laser to operate at 199 kHz because this is the closest that the Pulse Width Modulator is able to approximate 199.2 kHz using its internal 40 MHz clock. Specifying a frequency higher than 200 KHz will return an error message and the frequency will be unchanged. Any changes made using this command are also saved to non-volatile memory and the new value will be recalled upon system power-up. The command F (with no operand) causes the laser to print the current frequency.

**P-I-D Coefficients (K):**

The UL command must be executed prior to executing any of the K commands. The K commands allow the user to change the gain coefficients of the P-I-D (proportional-integral-differential) loop. There are four constants which may be changed: KD (loop Differential gain), KI (loop integral gain), KP (loop proportional gain), and KT (loop differential time constant). All of these have a range of 0-100, except for KT which has a range of 0-255. Any changes made using these commands are saved to non-volatile memory and the new values will be recalled on system power-up. The command K (with no operand) causes the laser to return the current value of all of the K constants.

**Open Loop (OL):**

Executing the OL command puts the system into the Open Loop mode of operation if it is in the Closed Loop mode. In the Open Loop mode, the laser ignores the P command value and does not directly control power. Power is controlled by the D command value in Open Loop mode. If the system is already in Open Loop mode when the command is executed, the command has no effect. Open Loop mode allows the user to run the laser at a fixed frequency and duty cycle without needing an external MODULATION signal.

**Power (P):**

The laser power is defined either by sending a serial command or by applying an analog voltage to pin 2 of the DCPS/AUXILIARY_I/O connector. The power is specified in 1 W steps from 1 W to 500 W. For example, the command P175 will set the laser output to 175 W. Specifying a power greater than 500 W will return an error message and the power will be unchanged. The command PA will cause the laser to switch to Analog Input mode. The laser output power will track the analog input voltage with a scale factor of 5 mV/W (or 0.2 W/mV). For example, an input voltage of 500 mV will result in an output of 100 W. The set point is limited to 500 W. However applying a voltage higher than 2.5 V (2500 mV) will cause the laser to put out 500 W if it can. The laser will remember whether it was last run in Analog input or Command input mode, even if the DC power supply is turned off. To return from Analog input mode to Command input mode, simply send a new numerical power command, for example, P75. If the laser is in Command input mode (that is, expecting a numerical set point), the power defaults to 10 W when the system is powered up. The Command P (with no operand) causes the laser to return the set point power, whether the laser is running in Analog input or Command input mode.

**Responsivity (R):**

The responsivity describes the gain of the preamp used to amplify the signal from the optical power sensor inside the laser. It is set at the factory for proper operation of the system, but because of aging of the detector and optical components in the laser system, it may change with time. The command R (with no operand) causes the current value of the responsivity to be returned by the laser. It is nominally 5.0 mV/W. The command R followed by a number between 0.001 and 37.999 will change the responsivity value stored in the laser. Making the R value smaller will decrease the laser output, and making the R value larger will increase the laser output (assuming a constant power input command). Entering an R value larger than 37.999 will cause the laser to return an error message and the R value will be unchanged.

**Reset (RST):**

This command causes the loop microcontroller to return to the power up state. Response is the same as power up. The loop micro-controller version number is annunciated over the serial interface.

**Temperature Compensation (TC):**

The Temperature Compensation algorithm uses the output of a temperature sensor mounted on the detector assembly to apply a linear correction to the detector responsivity. The command TC1 turns the temperature compensation on and the command TC0 turns it off. The system will "remember" which of these commands was last executed, so it is not necessary to execute one of these commands every time the system is initialized. The temperature compensation coefficient has units of % change/deg. C, and can be changed by executing the command TC.xxx, where xxx is a number between 001 and 999. The command TC. (with no operand) causes the laser to return the current value of the temperature compensation coefficient.

**Unlock (UL):**

The UL command must be executed before executing the CAL command or any of the K commands. The laser will remain unlocked until DC power is cycled off and then back on.

**VT:**

This command will cause the laser to automatically adjust the voltage gain (scale factor) of the internal detector analog output pins. It is equivalent to doing a single point scale calibration procedure at the power level currently being output by the laser at the time the VT command is received.

**Voltage (V):**

These commands are legacy commands for earlier versions. For newer versions the automated scaling command, VT is recommended. The voltage commands are for adjusting the voltage gain (scale factor) of the two internal detector analog output pins. Output 1 is pin 21 of the Extended I/O connector and Output 2 is pin 11 of the same connector. The scale factor of Output 1 is set at the factory for 1.5 mV/W and Output 2 is set for 5 mV/W. The commands V1+ and V1- are used for respectively increasing or decreasing the scale factor of Output 1, and the commands V2+ and V2- are for adjusting the scale factor of Output 2. These commands act on the settings for a 2-channel, 1024-step digital potentiometer. If the command is entered without an operand (for example, V1+ or V2-), the potentiometer setting is changed by one step. If the command is accompanied by a number from 1-999 (for example, V2+153), the pot is changed by the specified number of steps. If the pot reaches its limit, further increases (or decreases) will have no effect on the output voltage, although no error message will be returned. In order to save any changes to non-volatile memory, it is necessary to execute the command V1S (for Output 1) or V2S (for Output 2).

## Laser Set Up and Quick Start

The basic set-up of the E-400CL laser with closed loop control is the same as a standard E-400 laser (see Table 1-2 on page 1-10 for DC power and coolant requirements). In addition to these basics, it is necessary to satisfy the System Enable, the System Interlock, and the Shutter Interlock in order to operate the laser system, either in open loop or closed loop mode.

**System Enable:**

The System Enable is pin 3 on the REAL TIME I/O connector. This pin must either be driven by a logic low signal (0 V), or connected to system ground (pins 14, 15, and 16 of the REAL TIME I/O connector) in order to enable laser output. Driving this pin to logic high (5 V), or disconnecting it from system ground, will cause the laser output to be disabled.

**System Interlock:**

The System Interlock requires a low-resistance connection between pins 24 and 12 of the EXTENDED I/O connector. If the Interlock is opened up while the laser is running in closed-loop mode, the laser output will be disabled. Closing the Interlock again will cause the laser to resume operation at its previous power level.

**Shutter Interlock:**

The Shutter Interlock requires a low-resistance connection between pins 25 and 13 of the EXTENDED I/O connector. If this interlock is not satisfied, the system will not allow the shutter to be opened.

### Quick Startup Steps

1. Connect a serial interface cable and set up a terminal emulator program using "Serial Port Configuration" on page C-4.
2. Turn on laser coolant flow.
3. Turn on DC power supply. Within a few seconds, a start-up message on the computer will be seen that annunciates the loop controller's firmware revision number.
4. Close interlocks and set the System Enable input low.
5. Open the shutter. Make sure beam path is unobstructed and terminated at a suitable beam stop.
6. Enter the desired power level. For example, type P100 [enter] for 100 watts.
7. Enter desired modulation frequency. For example, F75 [enter] will make the modulation frequency 75 KHz.
8. Send command E1 [enter]. Laser output will be turned on.
9. To disable laser output, send command E0 [enter] (while not applying external modulation) or bring System Enable high or open the System Interlock.

## *Troubleshooting*

### Loop Fault Error

**Confirm Internal Detector Operation:**

1. Operate the laser in open loop mode (see "Open Loop (OL):" on page C-9 and "Duty Cycle (D):" on page C-8 for command descriptions).
2. Measure one of the Analog Outputs with a voltmeter.
3. Nominal operation of the internal power detector is confirmed if the output voltage is within expected range and it changes when the laser duty cycle is changed. If practical, compare voltage to expected value using a power meter to measure actual output power.

**Confirm Loop Coefficient Values:**

1. Send UL Command
2. Send K Command
3. Confirm K values. Typical values are: KP=3; KI=13; KD=1;KT=64.
4. If one or more K values is much different than the typical value, then change it to typical value and retry closed loop mode.

## *Calibration and Adjustment Calibration Procedures*

### Output Power Calibration

**Recommended Interval:**

The E-400CL2 is intended for use in material processing applications. Process quality control procedures, such as control chart methods, are the best indicator of lower level maintenance requirements such, as E-400CL2 power control calibration. In the absence of established control chart procedures, a calibration interval of 12 months is recommended.

**Equipment required:**

Coherent LM-1000 or Equivalent Power Meter

**Procedure:**

1. Align Power Meter with E-400CL2 output beam.
2. Set E-400CL2 output power to 350 W using the P command.
3. Wait 5 minutes for optimum stabilization.
4. Read E-400CL2 responsivity value using the R command.
5. Record power meter reading Rp.
6. Calculate the new responsivity value = $Rnew = Rold * \frac{350}{Rp}$
7. Download the new responsivity using the R command. Wait 1 second.

8. Send the VT command to adjust the analog output scaling factors.

## Adjusting Power Step Response

**Recommended Interval:**

None

**Equipment required:**

2 Channel Oscilloscope

Low Pass Filter 50 Hz < cutoff frequency < 1 KHz

**Function Generator:**

1 Hz square wave Low level = 0V, high level = 1V

**Procedure:**

1. Apply the Function Generator to the Analog Set Point Input and CH1 of the Oscilloscope.
2. Attach CH2 of the Oscilloscope to pin 21 of the Extended I/O Connector.
3. Enable the Analog Set Point Input using the PA command.
4. Adjust KP or KI to achieve the desired trade off between settling time and overshoot.
5. Refer to Figure C-4 and Figure C-5. These illustrate typical results.
6. Send the UL, then the K command.
7. Write down the response (K values).
8. Change K values as desired using the K command.
9. Cycle laser power to terminate the unlocked state.

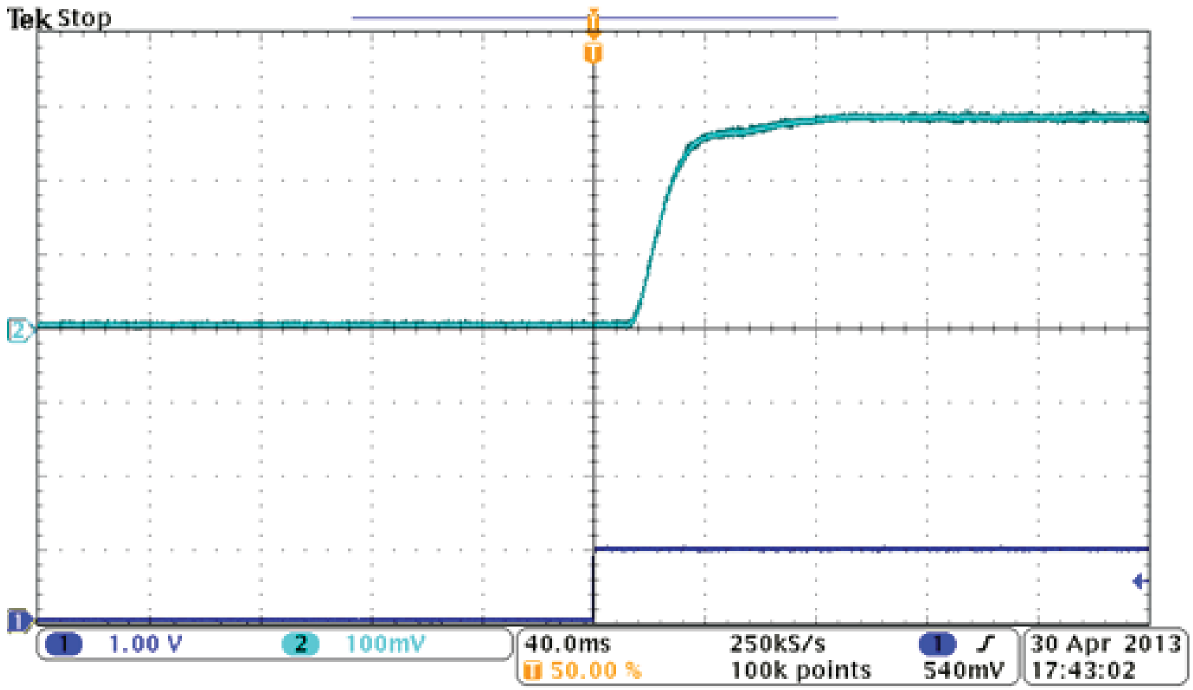



*Figure C-4. Step Response with KP = 3; KI = 13; KD=1; KT=64*

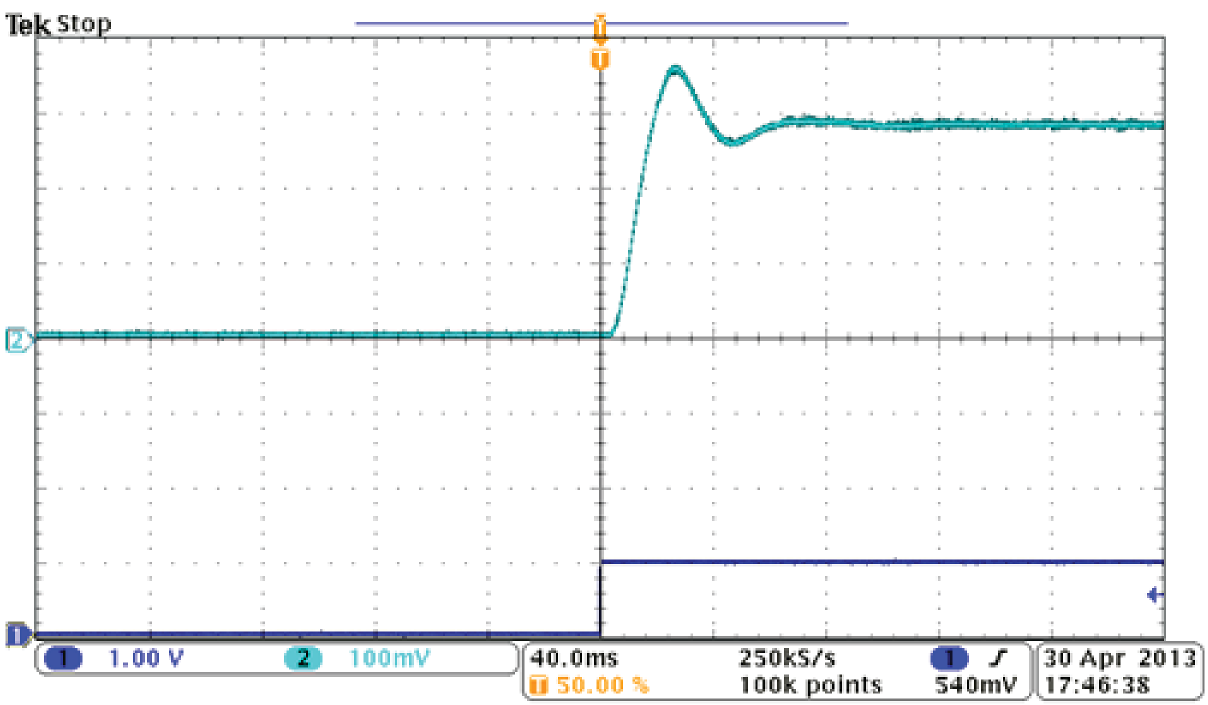



*Figure C-5. Step Response with KP = 3; KI = 20; KD =1; KT=64*

# APPENDIX D: E-400iCL

## *Introduction*

The E-400iCL laser is equipped with closed loop power control. This appendix should be used along with other parts of the E-400 Operator's Manual as it includes only the supplemental information for using the closed loop control capability. The purpose of the closed loop control is to control the laser output power stability and to control the laser's transient response when the power set point is changed by the operator. It is disabled when DC power is first applied to the laser head. From power up, an E-400iCL laser is compatible with the E-400i in that the MODULATION input on the Real Time I/O Connector is active. To enable and use closed loop power control, a serial interface command must be received by the laser. Either RS-232 or RS-422 serial interfaces can be connected to the laser using pins on the DCPS/Aux I/O Connector that are not used by E-400i lasers. Note that both RS-232 and RS-422 should not be connected at the same time because they are hardwired to the same internal port.

## *Power Control Loop Overview*

A PID servo loop is used to control average laser output power and step response. The set point is either a serial command or by an analog set point signal when the analog input is enabled by a serial command. The feedback to the control loop comes from an internal laser power detector assembly. See Figure D-1.

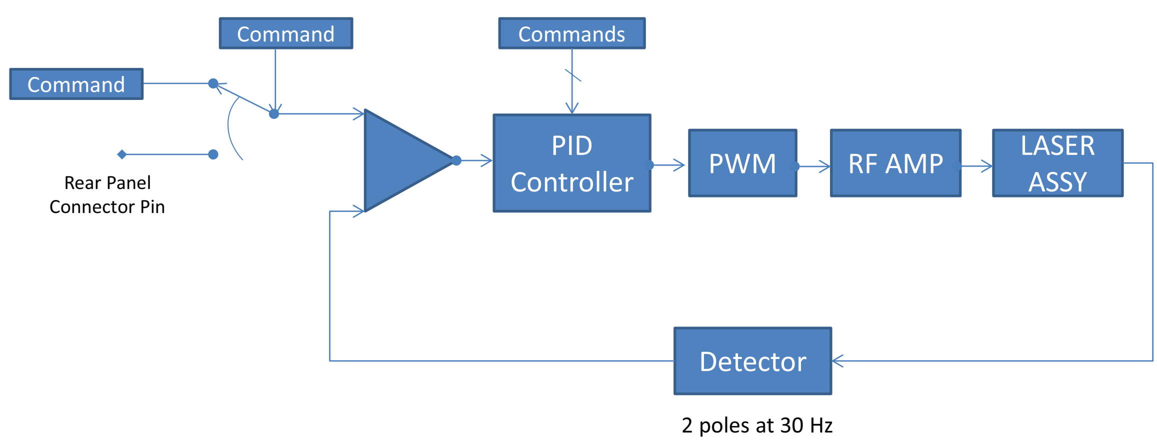



***Figure D-1. Control Loop Block Diagram***

## Accessories

For convenience only, the CL Communications Adapter (Figure D-2) is included for rapid prototyping of closed loop control. This adapter is not intended for any other use. It is not intended for uses requiring regulated electro-magnetic compliance. Connections for prototyping RS-422 interfaces and analog input power level control are identified in print on the printed circuit board. The pin designations for the 15 pin connector are the same as the DCPS/AUXILIARY I/O Connector on the E-400iCL laser as shown in Figure D-3.

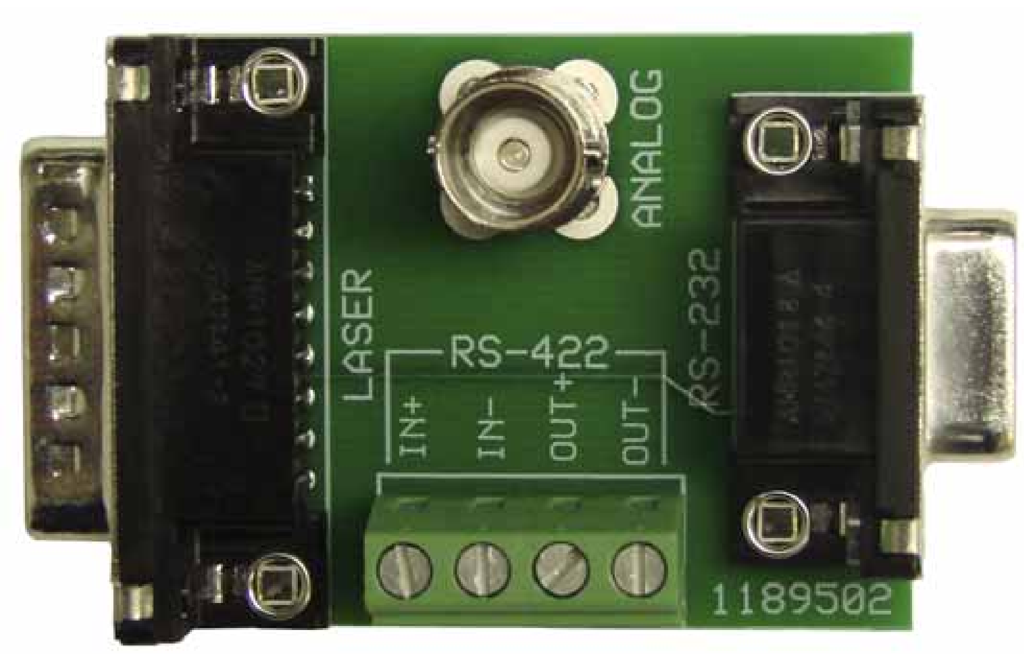



***Figure D-2. CL Communications Adapter Connector Signals***
***Coherent Part Number 1189502***

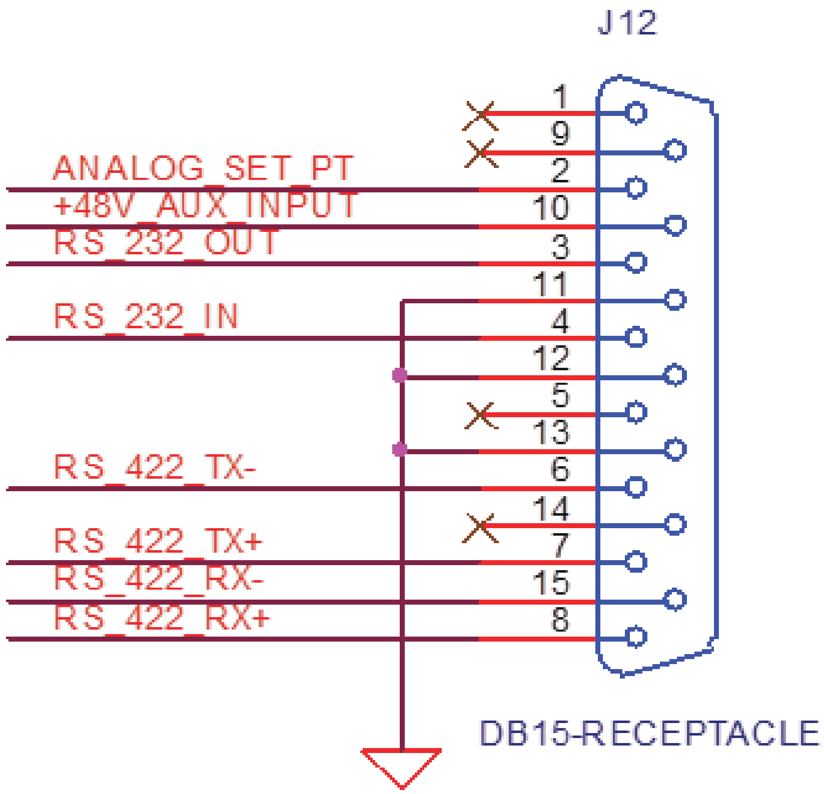



*Figure D-3. Communications Adapter Connector Signals*

*Table D-1. Communications Adapter Connector Signals Pin Descriptions*

| PINS | DESCRIPTION |
|---|---|
| 1, 5, 9, 14 | Reserved; do not connect. |
| 2 | Analog power set point input. Range 0-4 VDC; scale factor 5 mV/W. |
| 3 | RS-232 output. |
| 4 | RS-232 input. |
| 6 | RS-422- output. |
| 7 | RS-422+ output. |
| 8 | RS-422+ input. |
| 10 | Optional + 48 VDC input to allow operation of control circuitry when main laser DC power supply is not enabled. Not used in normal operation. |
| 11, 12, 13 | System ground. Used as Common for all control functions. |
| 15 | RS-422- input. |

# Closed Loop Control

## Serial Interface

All communications with the laser are through an asynchronous serial link, which can be either 2-wire RS-232 or 4-wire RS-422. Both links are always enabled, but should not be used simultaneously.

All commands to and responses from the laser consist of ASCII strings. These can be sent and received through a standard terminal emulator, such as HyperTerminal or by computer application/serial driver software. The remainder of this section is necessary programmer reference and end user information that should be understood in its entirety for successful implementation of E-400iCL computerized control.

### Serial Port Configuration

The serial port should be configured as follows:

19200 bits per second

data bits: 8

parity: none

stop bits: 1

flow control: none

### Power Up Behavior

Closed loop control is disabled when DC power is first applied to the laser head. From power up, an E-400iCL laser is compatible with the E-400i in that the MODULATION input on the Real Time I/O Connector is active. To enable and use closed loop power control, a serial interface command must be received by the laser. The closed loop microcontroller signals it is ready by annunciating its firmware version number on the serial interface.

### Command Echo and Command Processing Time

The E-400iCL echoes all characters back to the sender.

---

**Due to limitations in the processing speed of the CL microcontroller, strings of ASCII characters should not be transmitted back-to-back, as this may result in the loss of some characters. Coherent recommends that a minimum 20 milliseconds delay be inserted between the characters.**

---

### Loop Fault Message

When the closed loop function is active, but an internal loop error signal goes true, the character string “Loop Fault” is transmitted and laser output power is internally set zero. The serial interface should be continuously monitored for occurrence of this string. Instructions for troubleshooting root cause of this message are given in “Trouble-shooting” on page D-12.

### Max Set Point Message

When a set point greater than 350 W is requested the E-400iCL responds with a message indicating it is out of range and output power is unchanged.

### Analog Control Input

When enabled by the PA command over the serial interface, the laser follows the analog set point input signal on pin 2 of the DCPS/AUXILIARY I/O Connector. The scale factor for this input is 5 mV/W. The input impedance is a low pass filter with 1 k series resistor followed by a 0.01 µF capacitor to circuit ground.

## Internal Power Detector

### Analog Output Signals

Power monitor signals are available on the Extended I/O Connector. The voltage of these signals is proportional to the laser output power. Pin 21 has higher bandwidth than Pin 11. Pin 21 is used for measuring step response and Pin 11 is used for measuring stability. A 1 kHz or lower low pass filter and/or averaging is recommended for noise rejection when these output pins are used. See Table D-2.

***Table D-2. Analog Output Signal Description***

| PIN | SIGNAL DESCRIPTION |
|---|---|
| 11 | 5 mV/Watt, nominal |
| 21 | 1.5 mV/Watt, nominal |

## Serial Interface Command Set

Table D-3 summarizes the E-400iCL laser command set. Alpha characters are not case-sensitive. All commands must be followed by Enter.

***Table D-3. E400iCL Laser Command Set***

| COMMAND | OPERAND | DESCRIPTION | EXAMPLE |
|---|---|---|---|
| CF | none | Clear Loop Fault | CF |
| CL | none | Closed Loop mode select | CL |
| D | none | Print Duty cycle | D |
| D | 0.1-60 | Duty cycle entered in % | D45.2 |
| E | 1 or 0 | Enable (E1) or disable (E0) closed loop operation | E1 |
| F | 1-200 | Enter Frequency set point in KHz | F150 |
| F | none | Frequency print | F |
| K | none | Print PID coefficients | K |
| KD | 1-100 | Differential gain coefficient enter | KD1 |
| KI | 1-100 | Integral gain coefficient enter | KI13 |
| KP | 1-100 | Proportional gain coefficient enter | KP3 |
| KT | 1-255 | Differential Time constant enter | KT64 |
| OL | none | Open Loop mode select | OL |
| P | 1-500 | Enter Power set point in Watts | P225 |
| P | none | Print Power | P |
| PA | none | Enable Power Analog input mode | PA |
| R | 0.001-37.999 | Enter detector Responsivity in mV/W | R4.65 |
| R | none | Responsivity print | R |
| RST | none | Closed loop microcontroller returns to power up state, annunciates its firmware version number | RST |
| T | none | prints the current temperature of the detector | T |
| UL | none | Unlock to change reference temperature or PID coefficients | UL |
| VT | none | Automatically calibrate Detector Output 1 and 2 | VT |
| V1+, V1- | none or 1--999 | Increment (+) or decrement (-) Detector Output 1 (pin 21 of Extended I/O) | V1+; V1-55 |
| V1S | none | Save scale setting for Detector Output 1 | V1S |

***Table D-3. E400iCL Laser Command Set***

| COMMAND | OPERAND | DESCRIPTION | EXAMPLE |
|---|---|---|---|
| V2+, V2- | none or 1--999 | Increment (+) or decrement (-) Detector Output 2 (pin 11 of Extended I/O) | V2+; V2+125 |
| V2S | none | Save scale setting for Detector Output 1 | V2S |

**Clear Fault (CF):**

Under some operating conditions, the P-I-D integrator may overflow and trigger a loop fault. When this happens, the laser disables the output and sends a fault message to the user. To resume operation, the user must execute a CF instruction to clear the fault condition then re-enable output using E1.

**Closed Loop (CL):**

Executing the CL command puts the system into the Closed Loop mode of operation if it is in the Open Loop mode. If the system is already in Closed Loop mode when the command is executed, the command has no effect. In Closed Loop mode, the user inputs a target power level and the laser adjusts the duty cycle to achieve that power level using feedback from the internal power sensor. The Closed Loop mode is the default mode for the system.

**Duty Cycle (D):**

The Duty Cycle command allows the user to enter an operating duty cycle for the laser when the system is in Open Loop mode. See the “Open Loop (OL):” on page D-8 for a description of the Open Loop mode. The range is 0.1% up to the laser's maximum operating duty cycle (for example, 40% for the E-400iCL) in 0.1% steps. For example, the command D33.9 will cause the laser to operate at 33.9% duty cycle. The command D (with no operand) causes the laser to return the current duty cycle.

**Enable (E):**

When the laser system is first powered up, closed loop control is not enabled. The laser is in its normal operating mode which is compatible with E-400i and other E-series lasers. In this mode, laser output is controlled by a user supplied modulation signal. If operation in this mode is required, a Modulation signal must be is applied to the Modulation input on the REAL_TIME_I/O connector. To enable closed loop control, send command E1. To return to normal mode, send command E0. Note: if a modulation signal is present at the modulation input on the REAL_TIME_I/O connector when the E0 command is sent, the laser will immediately output power accordingly.

**CAUTION!**
**Exercise caution to protect against specular reflections since all reflections at the E-400i laser wavelength are invisible. These reflections, while weaker than the main beam, may be sufficiently intense to cause eye damage.**

**Frequency (F):**

The Frequency command allows the user to enter an operating frequency for the laser when the system is in Open Loop or Closed Loop mode. The range is 5 kHz to 200 kHz with a resolution of 0.1 kHz (100 Hz), although the system is not able to achieve this level of resolution at the high end of the range. For example, the command F5.7 will cause the laser to operate at 5.7 kHz. However, the command F199.2 will cause the laser to operate at 199 kHz, because this is the closest that the Pulse Width Modulator is able to approximate 199.2 kHz using its internal 40 MHz clock. Specifying a frequency higher than 200 KHz will return an error message and the frequency will be unchanged. Any changes made using this command are also saved to non-volatile memory and the new value will be recalled upon system power-up. The command F (with no operand) causes the laser to print the current frequency.

**P-I-D Coefficients (K):**

The UL command must be executed prior to executing any of the K commands. The K commands allow the user to change the gain coefficients of the P-I-D (proportional-integral-differential) loop. There are four constants which may be changed: KD (loop Differential gain), KI (loop integral gain), KP (loop proportional gain), and KT (loop differential time constant). All of these have a range of 0-100, except for KT which has a range of 0-255. Any changes made using these commands are saved to non-volatile memory and the new values will be recalled on system power-up. The command K (with no operand) causes the laser to return the current value of all of the K constants.

**Open Loop (OL):**

Executing the OL command puts the system into the Open Loop mode of operation if it is in the Closed Loop mode. In the Open Loop mode, the laser ignores the P command value and does not directly control power. Power is controlled by the D command value in Open

Loop mode. If the system is already in Open Loop mode when the command is executed, the command has no effect. Open Loop mode allows the user to run the laser at a fixed frequency and duty cycle without needing an external MODULATION signal.

**Power (P):**

The laser power is defined either by sending a serial command or by applying an analog voltage to pin 2 of the DCPS/AUXILIARY_I/O connector. The power is specified in 1 W steps from 1 W to 350 W. For example, the command P175 will set the laser output to 175 W. Specifying a power greater than 350 W will return an error message and the power will be unchanged. The command PA will cause the laser to switch to Analog Input mode. The laser output power will track the analog input voltage with a scale factor of 5 mV/W (or 0.2 W/mV). For example, an input voltage of 500 mV will result in an output of 100 W. The set point is limited to 350 W, However, applying a voltage higher than 2.5 V (2500 mV) will cause the laser to put out 500 W if it can. The laser will remember whether it was last run in Analog input or Command input mode, even if the DC power supply is turned off. To return from Analog input mode to Command input mode, simply send a new numerical power command, for example P75. If the laser is in Command input mode (that is, expecting a numerical set point), the power defaults to 10 W when the system is powered up. The Command P (with no operand) causes the laser to return the set point power, whether the laser is running in Analog input or Command input mode.

**Responsivity (R):**

The responsivity describes the gain of the preamp used to amplify the signal from the optical power sensor inside the laser. It is set at the factory for proper operation of the system, but because of aging of the detector and optical components in the laser system, it may change with time. The command R (with no operand) causes the current value of the responsivity to be returned by the laser. It is nominally 5.0 mV/W. The command R followed by a number between 0.001 and 37.999 will change the responsivity value stored in the laser. Making the R value smaller will decrease the laser output, and making the R value larger will increase the laser output (assuming a constant power input command). Entering an R value larger than 37.999 will cause the laser to return an error message, and the R value will be unchanged.

**Reset (RST):**

This command causes the loop microcontroller to return to the power up state. Response is the same as power up. The loop micro-controller version number is annunciated over the serial interface.

**Unlock (UL):**

The UL command must be executed before executing the CAL command or any of the K commands. The laser will remain unlocked until DC power is cycled off and then back on.

**VT:**

This command will cause the laser to automatically adjust the voltage gain (scale factor) of the internal detector analog output pins. It is equivalent to doing a single point scale calibration procedure at the power level currently being output by the laser at the time the VT command is received.

**Voltage (V):**

These commands are legacy commands for earlier versions. For newer versions the automated scaling command, VT is recommended. The voltage commands are for adjusting the voltage gain (scale factor) of the two internal detector analog output pins. Output 1 is pin 21 of the Extended I/O connector and Output 2 is pin 11 of the same connector. The scale factor of Output 1 is set at the factory for 1.5 mV/W and Output 2 is set for 5 mV/W. The commands V1+ and V1- are used for respectively increasing or decreasing the scale factor of Output 1, and the commands V2+ and V2- are for adjusting the scale factor of Output 2. These commands act on the settings for a 2-channel, 1024-step digital potentiometer. If the command is entered without an operand (for example, V1+ or V2-), the potentiometer setting is changed by one step. If the command is accompanied by a number from 1-999 (for example, V2+153), the pot is changed by the specified number of steps. If the pot reaches its limit, further increases (or decreases) will have no effect on the output voltage, although no error message will be returned. In order to save any changes to non-volatile memory, it is necessary to execute the command V1S (for Output 1) or V2S (for Output 2).

## *Laser Set Up and Quick Start*

The basic set-up of the E-400iCL laser with closed loop control is the same as a standard E-400i laser. (see Table 1-2 on page 1-10 for DC power and coolant requirements). In addition to these basics, it is necessary to satisfy the System Enable, the System Interlock, and the Shutter Interlock in order to operate the laser system, either in open loop or closed loop mode.

### System Enable:

The System Enable is pin 3 on the REAL TIME I/O connector. This pin must either be driven by a logic low signal (0 V), or connected to system ground (pins 14, 15, and 16 of the REAL TIME I/O connector) in order to enable laser output. Driving this pin to logic high (5 V), or disconnecting it from system ground, will cause the laser output to be disabled.

### System Interlock:

The System Interlock requires a low-resistance connection between pins 24 and 12 of the EXTENDED I/O connector. If the Interlock is opened up while the laser is running in closed-loop mode, the laser output will be disabled. Closing the Interlock again will cause the laser to resume operation at its previous power level.

### Shutter Interlock:

The Shutter Interlock requires a low-resistance connection between pins 25 and 13 of the EXTENDED I/O connector. If this interlock is not satisfied, the system will not allow you to open the shutter.

## Quick Startup Steps

1. Connect a serial interface cable and set up a terminal emulator program using “Serial Port Configuration” on page D-4.
2. Turn on laser coolant flow.
3. Turn on DC power supply. Within a few seconds, a start-up message on the computer will be seen that annunciates the loop controller's firmware revision number.
4. Close interlocks and set the System Enable input low.
5. Open the shutter. Make sure beam path is unobstructed and terminated at a suitable beam stop.
6. Enter the desired power level. For example, type P100 [enter] for 100 watts.
7. Enter desired modulation frequency. For example, F75 [enter] will make the modulation frequency 75 KHz.
8. Send command E1 [enter]. Laser output will be turned on.
9. To disable laser output, send command E0 [enter] (while not applying external modulation) or bring System Enable high or open the System Interlock.

# Troubleshooting

## Loop Fault Error

**Confirm Internal Detector Operation:**

1. Operate the laser in open loop mode (see "Open Loop (OL):" on page D-8 and "Duty Cycle (D):" on page D-7 for command descriptions).
2. Measure one of the Analog Outputs with a voltmeter.
3. Nominal operation of the internal power detector is confirmed if the output voltage is within expected range and it changes when the laser duty cycle is changed. If practical, compare voltage to expected value using a power meter to measure actual output power. See Table D-2 on page D-5 for signal scale factors.

**Confirm Loop Coefficient Values:**

1. Send UL Command
2. Send K Command
3. Confirm K values. Typical values are: KP=3; KI=3; KD=1;KT=64.
4. If one or more K values is much different than the typical value, then change it to typical value and retry closed loop mode.

# Calibration and Adjustment Procedures

## Output Power Calibration

**Recommended Interval:**

The E-400iCL is intended for use in material processing applications. Process quality control procedures, such as control chart methods, are the best indicator of lower level maintenance requirements, such as E-400iCL power control calibration. In the absence of established control chart procedures, a calibration interval of 12 months is recommended.

**Equipment required:**

Coherent LM-1000 or Equivalent Power Meter

**Procedure:**

1. Align Power Meter with E-400iCL output beam.
2. Set E-400iCL output power to 350 W using the P command.
3. Wait 5 minutes for optimum stabilization.
4. Read E-400iCL responsivity value using the R command.
5. Record power meter reading Rp.
6. Calculate the new responsivity value = $Rnew = \ Rold * \frac{350}{Rp}$
7. Download the new responsivity using the R command. Wait 1 second.
8. Send the VT command to adjust the analog output scaling factors.

## Adjusting Power Step Response

**Recommended Interval:**

None

**Equipment required:**

2 Channel Oscilloscope

Low Pass Filter 50 Hz < cutoff frequency < 1 KHz

**Function Generator:**

1 Hz square wave Low level = 0V, high level = 1V

**Procedure:**

1. Apply the Function Generator to the Analog Set Point Input and CH1 of the Oscilloscope.
2. Attach CH2 of the Oscilloscope to pin 21 of the Extended I/O Connector.
3. Enable the Analog Set Point Input using the PA command.
4. Adjust KP or KI to achieve the desired trade off between settling time and overshoot. Nominal Values for optimum settling time are: Kp=3; Ki=3. Kd and Kt should always be left at their default values of 1 and 64, respectively.
5. Send the UL, then the K command.

6. Write down the response (K values).
7. Change K values as desired using the K command.
8. Cycle laser power to terminate the unlocked state.

# APPENDIX E: ACCESSORIES AND OPTIONS

## Power Meters and Sensors

Coherent offers a variety of instruments for laser test and measurement. For additional detailed information, including product selection guides, please visit our web site at [www.Coherent.com](http://www.Coherent.com).

## Coherent's Recommendation

For the most common diagnostics, Coherent recommends the LabMaxII™-TO power meter with an PM1K power sensor to measure the DIAMOND E-400 Series laser output. This combination of power meter and thermal sensor is ideal for the high power E-Series lasers.

The power meter is a versatile, easy to use digital meter designed for field service and production applications. The thermopile sensor is liquid-cooled (water), surface absorbing and intended for Pulsed and CW powers up to 1,000 Watts covering a broad spectrum of wavelengths from 0.25 µm to 11 µm. See Figure E-1.


LabMax-TO Power Meter
Part Number 1104619

PM1K Thermopile Sensor
Part Number 1098392

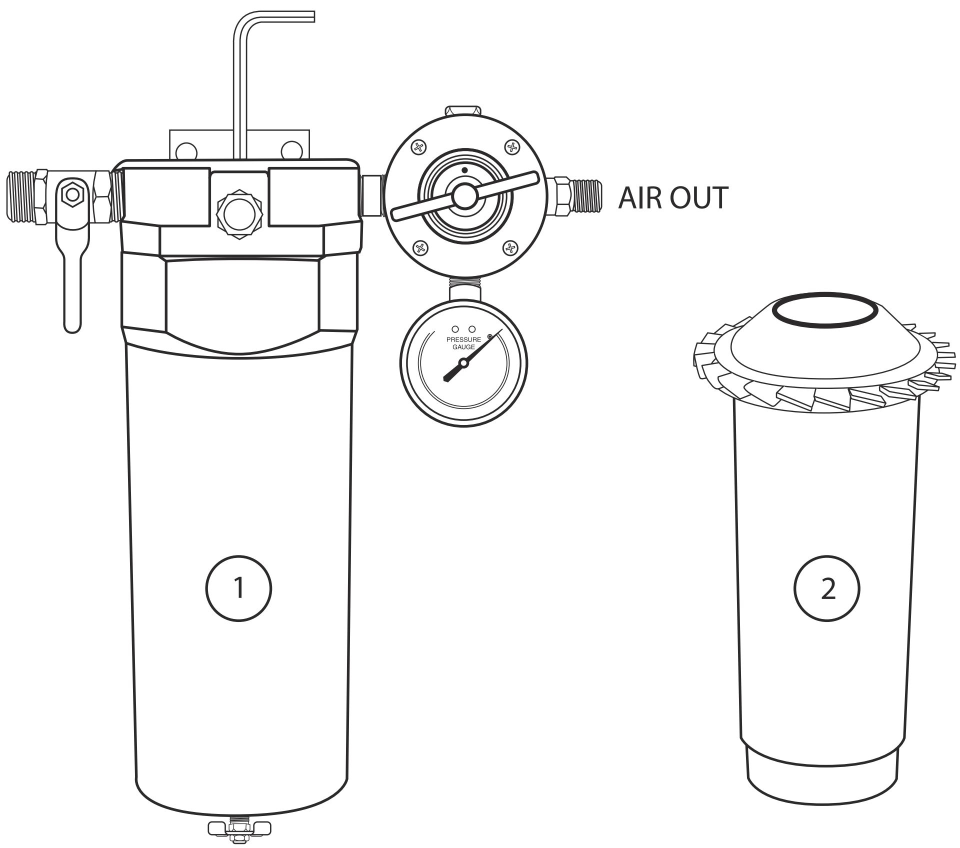
***Figure E-1. Coherent Power Meter & Sensor (Recommended)***

* Liquid cooling is customer provided.

## Air Filter Dryer Unit

A pre-assembled air filter dryer unit is available for those needing to filter compressed air. This unit is available from Coherent.

Coherent Part Number 1232642




1. Air Purge Filter Assembly; Part Number: 1232642
2. Replacement Dessicant Filter Cartridge; Part Number: 1236040

***Figure E-2. Purge Gas Filter Panel Assembly***

## Beam Quality Enhancement System (BQE-25)

The Beam Quality Enhancement System is designed to prevent back reflections from the laser process from re-entering the laser cavity. The system preserves the laser's intra-cavity conditions, mode quality, and power stability. In addition, the laser beam is converted from a linearly polarized beam to a circularly polarized beam. This system is available from Coherent, or directly from Haas Laser Technologies, Inc. (973) 598-1150, [www.haaslti.com](http://www.haaslti.com)

Coherent Part Number (w/ Mounting Flange) 1157332

Haas Part Number BQE-25-10.6-CFB

BQE-25 Specifications:

- Designed for E-series $CO_2$ Lasers (10.6 µm)
- All mirrors included
- Liquid cooled mirrors - 1/8” BSPT fittings
- Anodized aluminum construction with brass inserts for cooling passages.
- 25 mm clear aperture
- Can be mounted directly to the output flange of most E-series laser systems


***Figure E-3. Haas BQE-25 (Shown with Mounting Flange)***

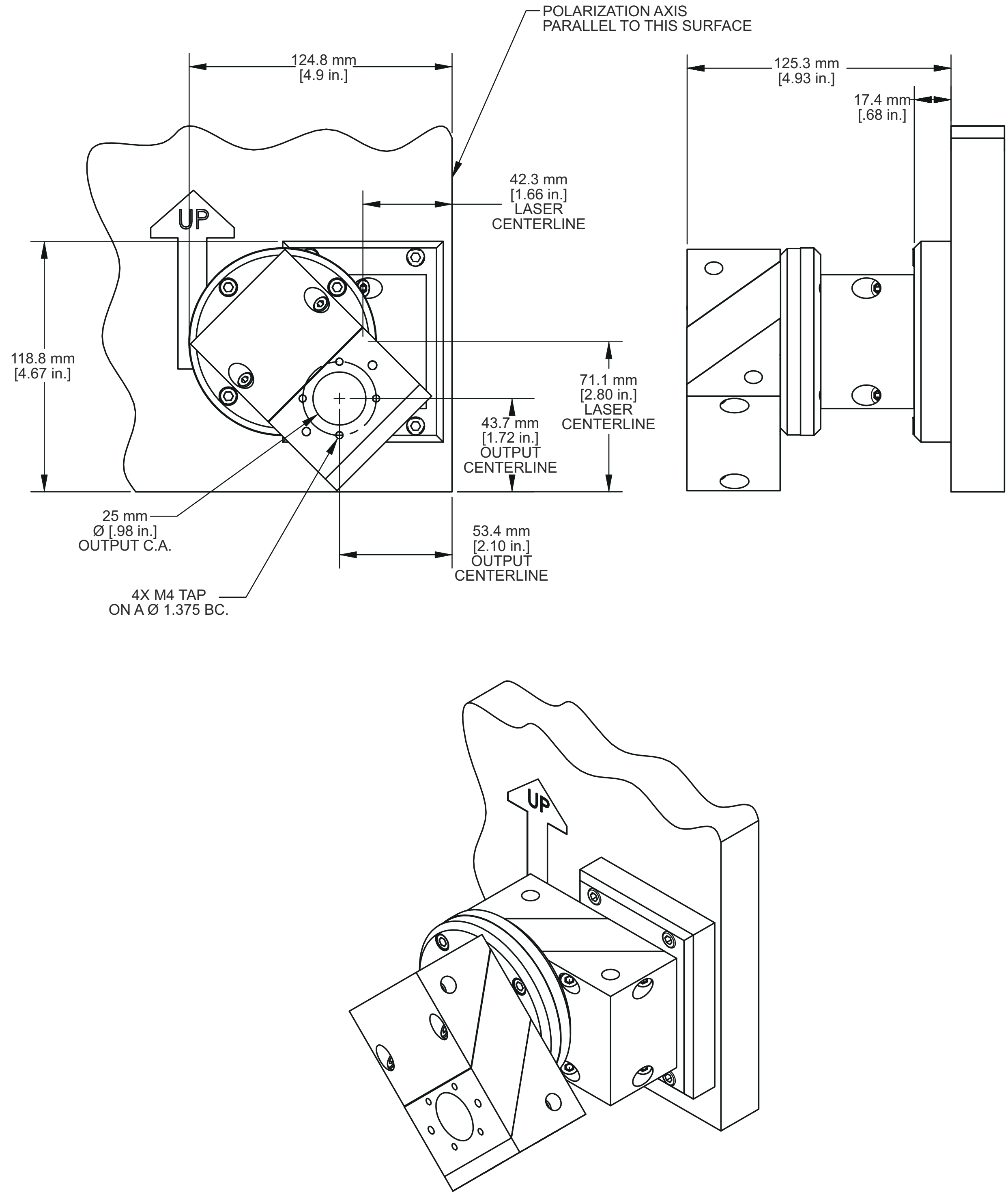



***Figure E-4. BQE-25 Mounting Illustration***

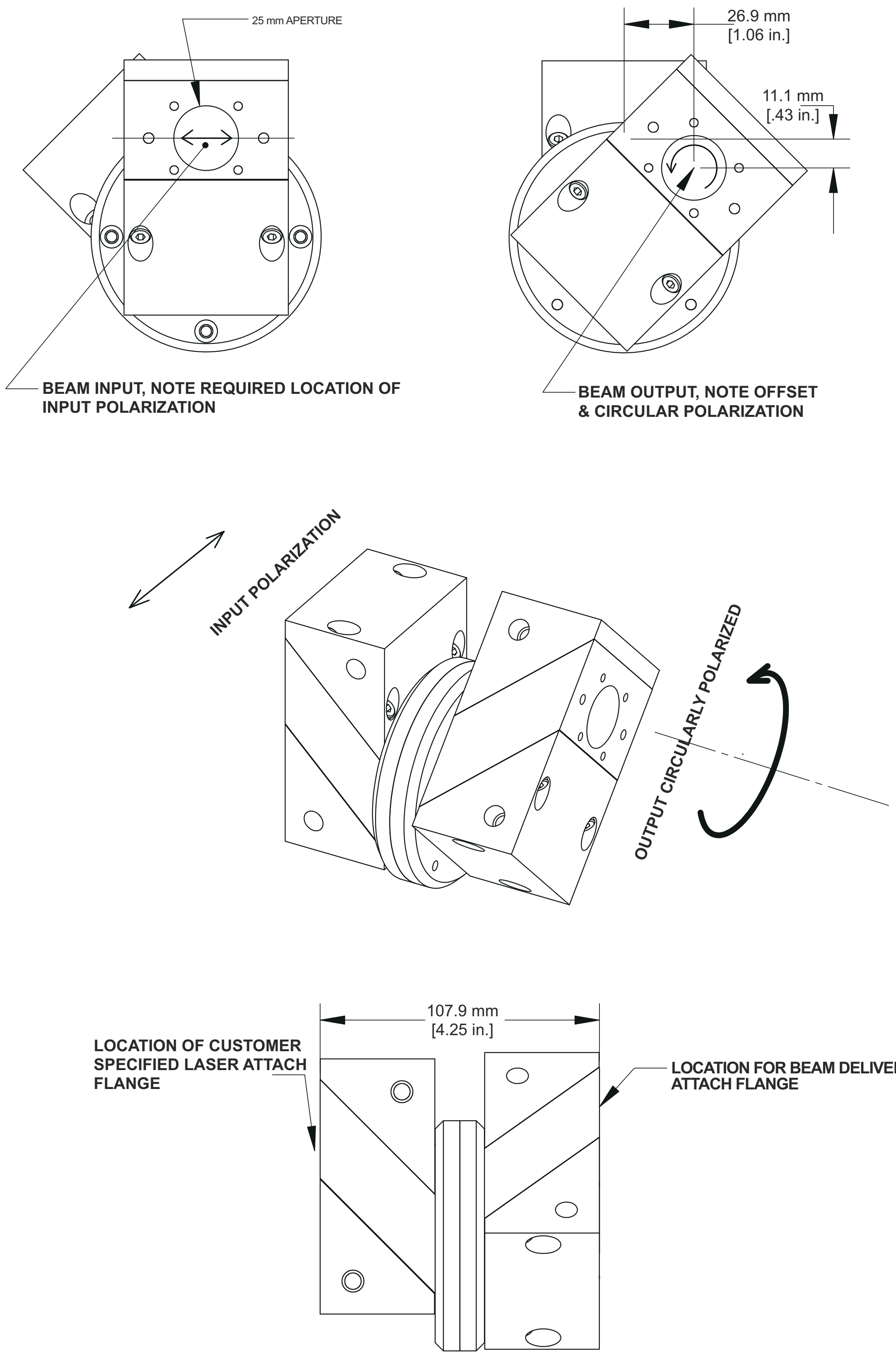



***Figure E-5. BQE-25 General Illustration (Mounting Flange Not Shown)***

# WARRANTY

## *E400 Series Laser System Warranty*

Coherent, Inc. warrants to the original purchaser that all E-400 Series laser systems conform to the specifications published by Coherent and is free from defects in materials and workmanship.

For specific warranty terms and conditions for your model E-400 Series laser system, refer to your sales contract.

E-400 Series laser systems do not include installation in the purchase price.

## *Conditions of Warranty*

For warranty service requiring the return of any product to Coherent, the product must be returned to a service facility designated by Coherent. The Buyer is responsible for all shipping charges, taxes and duties.

Parts replaced under warranty shall become the property of Coherent and must be returned to Coherent, Inc., Santa Clara, or to a facility designated by Coherent. All laser systems must be carefully packed in a suitable shipping container(s). Coherent does not assume responsibility for components broken in shipment due to improper packaging or handling. The Buyer will be obligated to issue a purchase order for the value of the replaced parts and Coherent will issue credit when the parts are received.

## *Responsibilities of the Buyer*

Damage to the DIAMOND E-400 Series laser system caused by failure of Buyer's utilities or the Buyer's failure to maintain an appropriate operating environment, is solely the responsibility of the Buyer and is specifically excluded from any warranty.

The Buyer is responsible for prompt notification to Coherent of any claims made under warranty.

## Limitations of Warranty

The foregoing warranty shall not apply to defects resulting from:

- Components or accessories with separate warranties manufactured by companies other than Coherent
- Improper or inadequate maintenance by Buyer
- Buyer-supplied interfacing
- Operation outside the environmental specifications of the product
- Improper site preparation and maintenance
- Unauthorized modification or misuse

Coherent assumes no responsibility for customer-supplied material.

Coherent considers hoses and cables that are repeatedly flexed or bent to be consumables. As such these items are not covered under warranty.

The obligations of Coherent are limited to repairing or replacing, without charge, equipment that proves to be defective during the warranty period. Replacement systems may contain reconditioned parts. Repaired or replaced parts are warranted for the duration of the original warranty period only. This warranty does not cover damage due to misuse, negligence or accidents, or damage due to installations, repairs or adjustments not specifically authorized in writing by Coherent.

# GLOSSARY

| | |
|---|---|
| % | Percent |
| $1/e^2$ | Beam diameter parameter = 0.13534 |
| °C | Degrees Celsius |
| °F | Degrees Fahrenheit |
| µm | Micrometers = $10^{-6}$ meters |
| µrad | Microradians = $10^{-6}$ radians |
| µsec | Microseconds = $10^{-6}$ seconds |
| Ω | Ohms |
| | |
| AC | Alternating current |
| Amp | Amperes |
| | |
| BNC | Type of connector |
| BQE | Beam Quality Enhancement system |
| | |
| $CaCO_3$ | Calcium carbonate |
| CDRH | Center for Devices and Radiological Health (U.S. Government) |
| CFR | Code of Federal Regulation |
| cm | Centimeters = $10^{-2}$ meters |
| $CO_2$ | Carbon dioxide |
| | |
| DC | Direct current |
| DVM | Digital voltmeter |
| | |
| FPT | Female pipe thread |
| | |
| gpm | Gallons per minute |
| | |
| hex | Hexagon |
| Hz | Hertz or cycles per second (frequency) |
| | |
| kg | kilograms = $10^3$ grams |
| kHz | kilohertz = $10^3$ hertz |
| kPa | kilopascals = $10^3$ pascals |
| kV | kilovolts = $10^3$ volts |
| kW | kilowatts = $10^3$ watts |
| LED | Light emitting diode |
| | |
| mA | milliamperes = $10^{-3}$ Amperes |
| mg | milligrams = $10^{-3}$ grams |
| MHz | Megahertz = $10^6$ Hz |
| mJ | millijoules = $10^{-3}$ Joules |
| mm | millimeters = $10^{-3}$ meters |
| mrad | milliradians = $10^{-3}$ radians (angle) |
| ms | milliseconds = $10^{-3}$ seconds |
| mW | milliwatts = $10^{-3}$ Watts (power) |
| | |
| $N_2$ | Nitrogen |

| | |
|---|---|
| nm | nanometers = $10^{-9}$ meters (wavelength) |
| NPT | American national standard taper pipe thread<br>(American National Standards Institute, B2-1-1968) |
| Ø | Phase |
| psi | Pounds per square inch |
| RF | Radio frequency |
| RMS | Root mean square (effective value of a sinusoidal wave) |
| STD | Standard |
| TTL | Transistor-to-transistor logic<br>(Designed to +5 V nominal maximum voltage) |
| V | Volts |
| VAC | Volts alternating current |
| VDC | Volts direct current |
| VSWR | Voltage, standing wave ratio |
| W | Watts |

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