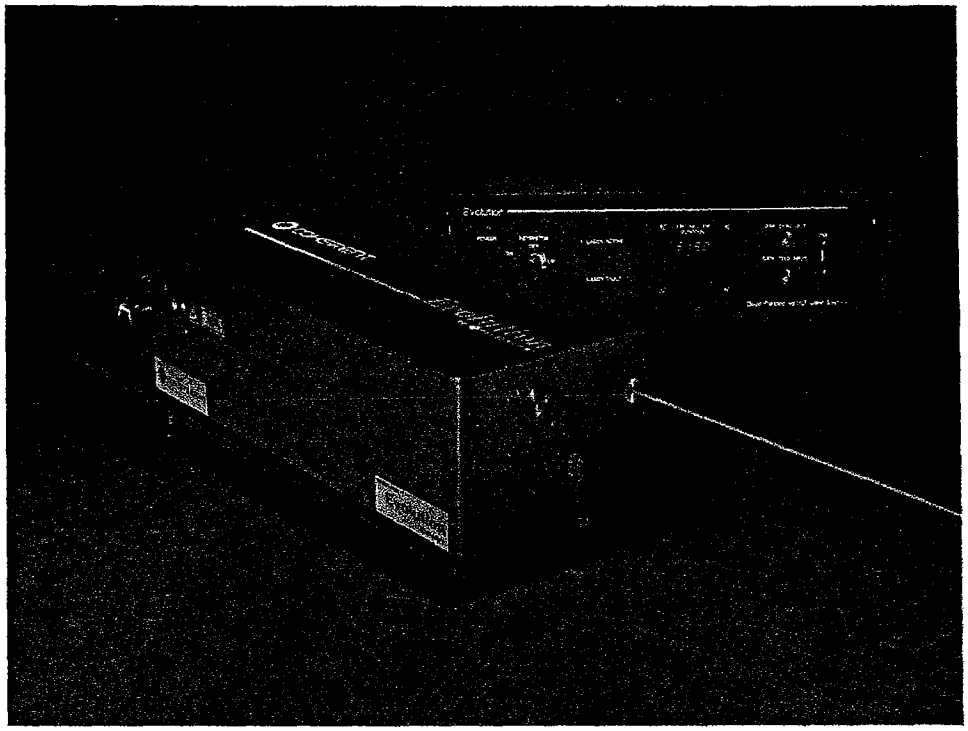
COHERENT®



EVOLUTION-30

HIGH ENERGY, HIGH AVERAGE POWER, DIODE-PUMPED, KILOHERTZ, Q-SWITCHED, INTRA-CAVITY DOUBLED, Nd:YLF LASER

Preface

Disclaimer

This manual provides information regarding the operation and maintenance of the Coherent Evolution-30.

Every effort has been made to ensure that the information in this manual is accurate. All information in this document is subject to change without notice. Coherent makes no representation or warranty, either express 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 this documentation.

Coherent personnel will install the laser system. We do not guarantee laser performance unless the laser is installed by Coherent personnel or by an authorized representative of Coherent.

Support Needs

If you have any technical questions or problems, please contact Coherent:

Coherent, Inc.
5100 Patrick Henry Drive
Santa Clara, CA 95054

Tel: 408.764.4000

Tech.sales@coherentinc.com
www.coherent.com

Manual: Version 2.3
Updated: May, 2003
Printed: March 17, 2004

Specifications

Performance[1]**:**	**1 kHz**	**5 kHz**
Average Power [W]	20.0	30.0
Energy per Pulse [mJ]	20.0	6.0
Wavelength	527 nm	
Beam Diameter (nominal at output)	5 mm	
Energy Stability (RMS)	< 1%	
Energy Stability (±% pk/pk)	< ± 3.0 %	
Beam Profile	Multi-mode, uniform intensity	
Polarization	Linear, horizontal	

[1] Specifications subject to change without notice. Specifications on purchase order supercede all other published specifications.

Table of Contents

Warning Conventions

The following warnings are used throughout this manual to draw attention to situations or procedures that require extra attention. They warn of hazards to your health, damage to equipment, sensitive procedures, and exceptional circumstances.

Warning Conventions

Danger! 	Possible injury or hazard to personal safety
Warning! 	Possible damage to equipment
Caution! 	Warns against or prevents poor performance or error
Note 	Exceptional circumstances or special reference
	Laser radiation present
Eyewear Required 	Safety eyewear required

Unpacking and Inspection

Your Evolution-30 was packed with great care, and its container was inspected prior to shipment. Upon receiving your system, inspect the outside of the containers immediately. If there is any major damage (holes in the containers, water damage, crushing, etc.) insist that a representative of the carrier be present when you unpack the contents.

The Evolution-30 system is shipped in two crates. The main crate is split into two levels – the top level contains the laser optical bench; the lower level contains the laser power supply cabinet, the laptop computer box, and a small accessory box (see packing list). The second crate contains the water chiller with hoses attached.

Carefully unpack both crates in a clean, dry area and inspect each component as you unpack it. Remove the clamps holding the top and front panel of the crate. Remove the laser bench and its attached umbilical from the top section of the crate, and set the head on a firm, flat surface, such as an optical table.

Remove the clamps from the bottom edge of the crate and lift off the top section of the crate. The Evolution-30 power supply is contained in cardboard box strapped to the shipping crate. Remove the straps, and lift the cardboard boxes containing the power supply, laptop computer, and accessories off the crate.

The water chiller is strapped to the base of its shipping crate. Remove the straps and carefully lift the chiller off the base of the crate. If any damage is evident, such as dents or scratches on the covers, broken knobs, etc., immediately notify the carrier and your authorized sales representative.

Keep the shipping crates. If you file a damage claim, you may need them to demonstrate that the damage occurred as a result of shipping. If you need to return the system for service at a later date, the specially designed container will assure adequate protection.

The Evolution-30 can now be moved to the location in which it will be installed (see Chapter 4).

Warning! 

Do not attempt to install the laser yourself, or remove the lid covering the optical cavity of the laser bench. Either action, if unauthorized, will void your warranty, and you will be charged for the repair of any damage incurred if you attempt installation yourself.

1 Introduction

1.1 Evolution-30

Evolution-30 is a diode-pumped, intra-cavity doubled Nd:YLF laser capable of producing Q-switched pulses with average energy > 20 mJ at 527 nm at repetition rates above 1 kHz. Evolution-30 represents a significant advance in this class of laser, offering the high efficiency, low maintenance and excellent beam quality afforded by laser diode pumping.

The Evolution-30 laser system comprises four main elements:

- Optical laser bench assembly
- Power supply assembly
- Control computer
- Closed loop chiller

1.1.1 Optical Laser Bench Assembly

The Evolution-30 optical laser bench is a sealed monolithic aluminum chassis containing integrated opto-mechanical, electrical, and cooling assemblies, including:

- Diode pumped, water-cooled, Nd:YLF laser head (pump chamber)
- Optical resonator
- Acousto-optical Q-switches
- LBO frequency doubling crystal in a temperature-controlled oven
- Safety shutter

Caution! 

The Evolution-30 was designed to provide optimum performance with minimal user intervention, and normal operation should not require the laser bench cover to be opened. Removal of the laser bench cover without prior authorization will void your warranty.

The Evolution-30 is available in two variants—OEM and Scientific. If you have purchased the Scientific version of the Evolution-30, the aluminum chassis described above is mounted in an external housing with an emission indicator, and four feet that allow adjustment of beam height. To minimize footprint and allow simple integration into other instruments, the OEM Evolution-30 is supplied without this external housing.

1.1.2 Power Supply Assembly

The power supply assembly includes a master control board and all the electronics to drive the laser diodes, stabilize the temperature of the LBO crystal, Q-switch the laser, and monitor interlocks. The power supply cabinet connects to the optical laser bench through a removable 3-meter long umbilical cable. The power supply contains:

- Electronic Control Module (ECM)
- Diode power supply
- LBO temperature controller
- Q-Switch driver
- Accessory electronics

1.1.3 Control Computer

The Evolution-30 comes with a commercial laptop computer and software to control and monitor the functions of the laser through an RS-232 interface. Because of frequent changes in the availability of specific computer models, the particular computer delivered with each laser may vary in brand and features, but in general it will have a Pentium class processor ≥400MHz, ≥32MB of RAM, ≥2GB hard drive, a CD-ROM drive, and a floppy drive. The control software for the Evolution-30 is pre-installed and tested with each laser, and is also delivered on floppy or CD-ROM.

1.1.4 Closed Loop Chiller

A small closed loop chiller is included to dissipate the waste heat generated and maintain the wavelength of the laser diodes to ensure maximum absorption of the pump light in the gain medium. The chiller has two hoses with quick-release connectors, a water filter, and an internal pressure regulator valve to reduce the water pressure at the laser bench. A chemical additive is included to prevent algae growth and corrosion in the water system.

2 Laser Safety

Warning!

This user information is in compliance with section 1040.10 of the CDRH Performance Standards for Laser Products from the Health and Safety Act of 1968. Use of controls or adjustments, or performance of procedures other than those specified herein, may result in hazardous radiation exposure.

The Evolution-30 is a Class IV-High Power Laser whose beam is a safety and fire hazard. Take precautions to prevent exposure to direct or reflected beams. Diffuse as well as specular reflections can cause severe eye or skin damage.

This safety section should be thoroughly reviewed prior to operating the Evolution-30 laser system described in this manual. Safety instructions presented throughout this manual must be followed carefully.

2.1 Hazards

Hazards associated with lasers generally fall into the following categories:

- Exposure to laser radiation which may result in damage to the eyes or skin.
- Exposure to chemical hazards such as particulate matter or gaseous substances released as a result of laser material processing or a by-product of the lasing process itself.
- Electrical hazards generated in the laser power supply or associated circuits.
- Secondary hazards such as:
  1. X-radiation from faulty power supplies
  2. Pressurized lamps, hoses, cylinders, etc.
  3. Pressurized liquids and gasses.

2.2 Optical Safety Precautions

The special nature of laser light poses safety hazards not associated with light from conventional sources. The safety precautions listed below are to be read and observed by anyone working with the laser. At all times, ensure that all personnel who operate, maintain or service the laser are protected from accidental or

unnecessary exposure to laser radiation exceeding the accessible emission limits listed in 'Performance Standards for Laser Products,' *United States Code of Federal Regulations*, 21CFR1040 10(d).

The following precautions are to observed at all times:

- Wear protective eyewear at all times; selection depends on the wavelength and intensity of the radiation, the conditions of use, and the visual function required. Protective eyewear vendors are listed in the *Laser Focus World, Lasers and Optronics,* and *Photonics Spectra* buyer's guides. Consult the ANSI, ACGIH, or OSHA standards listed at the end of this section for guidance.
- Avoid wearing jewelry or other objects that may reflect or scatter the beam while using the laser.
- Work in high ambient illumination. This keeps the eye's pupil constricted, thus reducing the possibility of eye damage.
- Never look directly into the laser beam.
- Avoid looking at the beam; even diffuse reflections are hazardous.
- Use an infrared detector to ascertain whether the laser beam is on or off before working on the laser.
- Work with the lowest beam intensity consistent with the application.
- Operate lasers only in well-marked areas with controlled access. Be sure to post appropriate warning signs, clearly visible to all.
- Limit access to the laser system only to qualified personnel who are essential to its operation and who have been trained in the principles of safety. When not in use, lasers should be shut down completely and made off-limits to unauthorized personnel.
- Provide enclosures for beam paths whenever possible.
- Terminate the laser beam with an appropriate energy-absorbing target.
- Shield unnecessary reflections and scattered laser radiation.
- Avoid blocking the output beam or any reflections with any part of your body.
- Set up the laser so that the beam height is either well above or well below eye level

2.3 Electrical Safety Precautions

Danger!

Normal operation of the Evolution-30 should not require access to the power supply circuitry. Removing the power supply cover will expose the user to potentially lethal electrical hazards. Contact an authorized service representative before attempting to correct any problem with the power supply.

The following precautions should be observed by anyone when working with potentially hazardous electrical circuitry:

- Disconnect main power lines before working on any electrical equipment when it is not necessary for the equipment to be operating.

- Do not short or ground the power supply output. Protection against possible hazards requires proper connection of the ground terminal on the power cable, and an adequate external ground. Check these connections at the time of installation, and periodically thereafter.
- Never work on electrical equipment unless there is another person nearby who is familiar with the operation and hazards of the equipment, and who is competent to administer first aid.
- When possible, keep one hand away from the equipment to reduce the danger of current flowing through the body if a live circuit is touched accidentally.
- Always use approved, insulated tools when working on equipment.
- Special measurement techniques are required for this system. A technician who has a complete understanding of the system operation and associated electronics must select ground references.

2.4 Protective Eye Wear

It is recommended that laser-safe eyewear protecting across at least the following wavelength ranges be worn at all times when the Evolution-30 laser is operating:

- 1047 to 1053 nm (covers the fundamental wavelength at which the Evolution-30 operates)
- 523 to 527 nm (covers the second harmonic wavelength output of the Evolution-30)
- 794 to 810 nm (covers the wavelength emitted by the laser diodes)

During normal operation of the laser, the operator should not be exposed directly to hazardous diode laser emission. Removal of the mechanical housing cover, however, will not only invalidate the user's warranty, but will also expose the laser operator to hazardous diode laser radiation.

2.5 CDRH Compliance

The safety features listed below have been incorporated into the Scientific version of the Evolution-30 to conform to Federal performance standards, as required by 21 CFR 1040.10(h)(1)(iv). Any modification or use of the Evolution-30 laser that changes, disables, or overrides the function of the engineering controls and safety features invalidates the Class IV certification of the laser described in this manual.

Key Switch
A separate key switch is provided to enable power to the laser. The key cannot be removed from the switch except in the OFF position. This assures that use of the laser by unauthorized or unqualified personnel can be prevented.

Warning Labels
Certification and warning labels are affixed to the Evolution-30 laser to verify compliance with 21 CFR 1040, to provide information on the wavelength and power emitted, and to warn the user against accidental exposure to laser radiation. The location and type of warning logotype labels used on the Evolution-30 bench for both the Scientific and OEM versions, as well as the laser power supply, are shown in Figure 2.1, 2.2 and 2.3 respectively.

For safety, translations of the warning labels are provided in Table 2.5 for non-English speaking operators. The number in parentheses in the first column corresponds to the label number listed on the previous page.

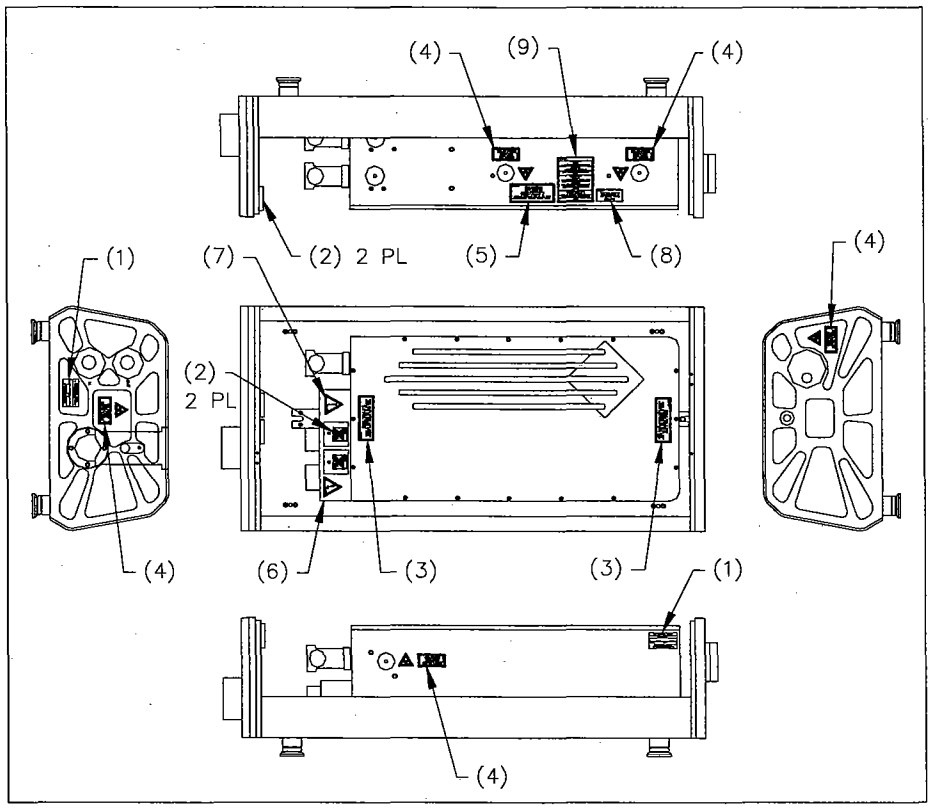


Figure 2.1: Evolution-30 CDRH/CE Radiation Control Drawing; Scientific Version

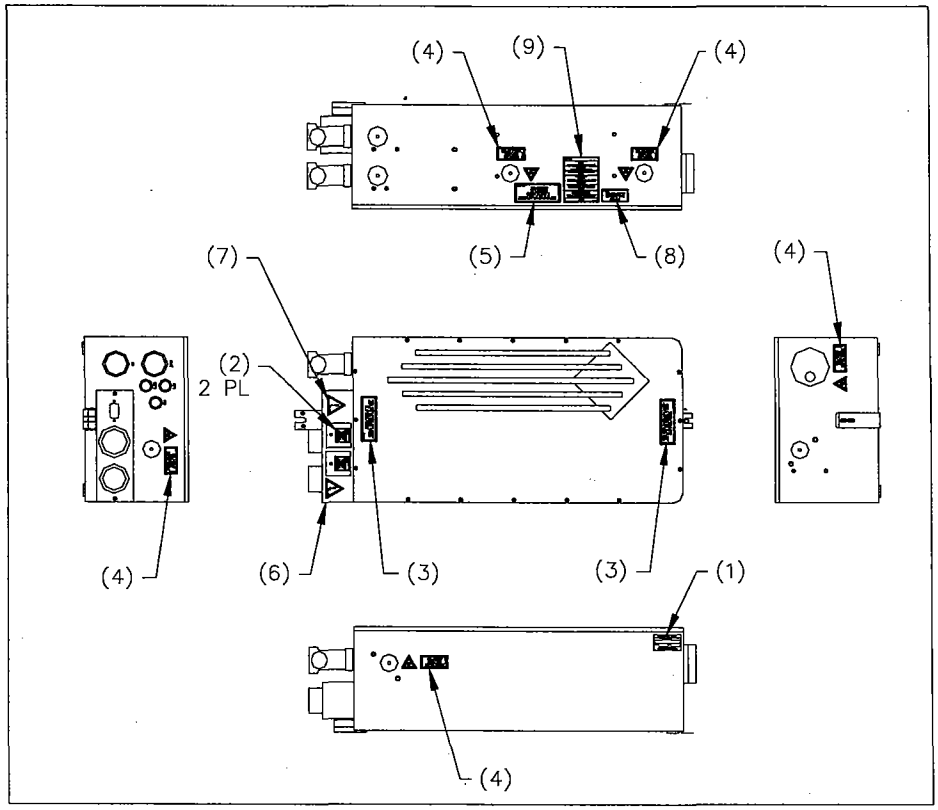


Figure 2.2: Evolution-30 CDRH/CE Radiation Control Drawing; OEM Version

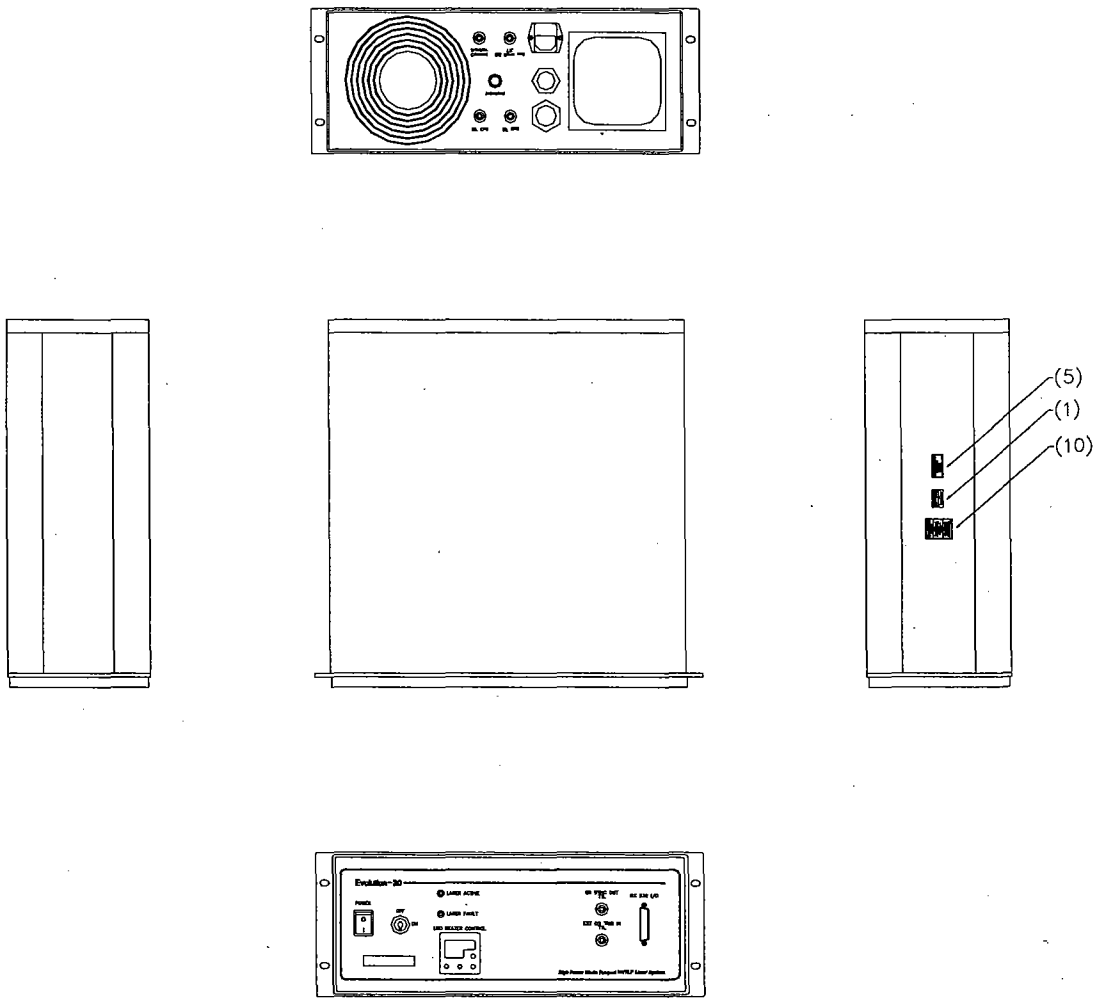
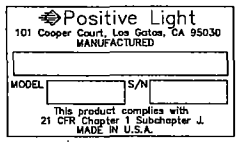


Figure 2.3: Evolution-30 Power Supply Cabinet CDRH/CE Radiation Control Drawing



IDENTIFICATION/CERTIFICATION LABEL (1)

DANGER LASER BEAM LABEL, HEAD (2)

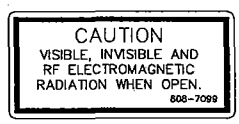
INTERLOCKED COVER LABEL, HEAD (3)

APERTURE LABEL, HEAD (4)

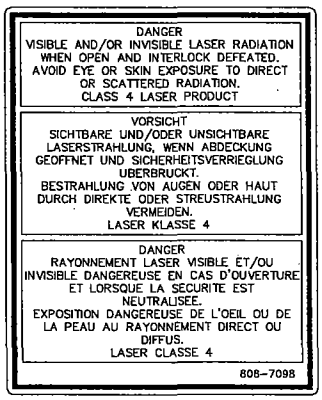
DANGER LABEL, HEAD–EVOLUTION 30 (5)

CAUTION LABEL (6)

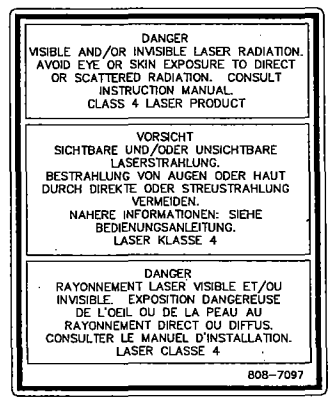
CAUTION LABEL (7)



RF CAUTION LABEL (8)



CE WARNING LABEL, INTERLOCK DEFEATED (9)



CE WARNING LABEL, POWER SUPPLY (10)

Figure 2.4: CDRH/CE Radiation Control Drawing Labels

Label #	French	German	Spanish	Dutch
Danger Label (5) Interlocked Cover Label (3)	Danger! Rayonnement Laser Visible et/ou Invisible en Cas D'Ouverture et lorsque la securité est neutralisée; exposition dangereuse de l'oeil ou de la peau au rayonnement direct ou diffus. Laser de Classe 4.	Vorsicht! Sichtbare und/oder unsichtbare Laserstrahlung wenn geöffnet und Sicherheits-verriegelung überbruckt. Bestrahlung von Augen oder Haut durch direkt oder Streustrahlung vermeiden. Laser Klasse 4.	Peligro! Al abrir y retirar el dispositivo de seguridad exist radiacion laser visible y invisible; evite que los ojos o la piel queden expuestos tanto a la radiacion directa como a la dispersa. Producto laser clase 4.	Gevaar! Zichtbare en onzichtbare laserstraling! Vermijd blootstelling van oog of huid ann direkte straling of terugkaatsingen daarvan! Klas 4 laser produkt.
Aperture Label (4)	Exposition Dangereuse! Rayonnement visible et/ou invisible est emis par cette ouverture	Austritt von sichtbarer und unsichtbarer Laserstrahlung. Bestrahlung vermeiden!	Por esta abertura se emite radiacion laser visible e invisible; evite la exposicion	Vanuit dit apertuur wordt zichtbare en onzichtbare laserstraling geemiteerd! Vermijd blootstelling!

Table 2.5: Label Translations

Remote Interlock Connector

The remote interlock connector (marked 'INTERLOCK') at the back of the power supply cabinet must be used to connect an external CDRH interlock (such as a switch on the door to the laser room, for example). The interlock circuit will then terminate laser action automatically if anyone enters the laser operating area. To connect the interlock switch, remove the external jumper plug supplied, and either re-wire according to the wiring diagram in Figure 2.5 or use a similar connector. Wire the external interlock switch 'normally closed', so that when the door or safety device opens and the switch opens, the power supply will immediately turn off the laser diodes as a safety precaution, and prevent any unaware personnel from inadvertent exposure to laser radiation.

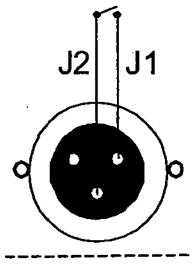


Figure 2.5: External interlock connector (Evolution-30 power supply).

The interlock function causes the diodes to switch off when the interlock contacts are opened. Lasing can only be resumed by closing the external interlock circuit contacts and then cycling the key switch to clear the interlock function. The laser should not be operated unless the remote interlock function is in use.

Protective Housings

The laser beam path is contained within the mechanical housing of the laser bench until it exits at the front (or side) output port. The diode-pumped head is also contained within this housing to shield the user from stray laser diode light and to protect the laser diodes from exposure to dust and electrostatic discharge.

Cover Safety Interlocks

Interlock micro-switches are used to ensure that the Evolution-30 cannot be operated if the machined metal cover protecting the optical cavity is not in place (and, in the case of the Scientific version, if the external sheet metal cover is not in place).

Danger!

Do not operate the Evolution-30 with any covers removed, except when necessary during required service. This may expose people to hazardous voltages and laser radiation, and also increases the rate of optical surface contamination. Unauthorized removal of the cover protecting the optical cavity will void your warranty.

Emission Indicators

After issuing a start command, an emission indicator lights at the laser bench to warn that the laser is about to emit laser radiation:

a) Scientific Evolution-30
An indicator light on the front of the laser housing lights any time current is supplied to the laser diodes. This warns the user that hazardous laser radiation is present or can be accessed. Note that, when the emission indicator is illuminated, diode laser light is present inside the housing, even though the laser cavity may not be emitting green or infrared laser radiation. (This situation may occur if the laser is in Hold-Off mode, for example.)

b) OEM Evolution-30
A detachable emission indicator is supplied with the laser that may be mounted on the laser bench, or removed and post mounted in a remote location by the user. This indicator illuminates in the same manner as described in section (a) above. The detachable indicator is useful if the operator installs the OEM Evolution-30 in an instrument, and the indicator would not be clearly visible if attached to the laser bench. If the indicator is detached from the laser bench, it must be placed in a clearly visible location no more than 10ft (~3m) from the Evolution-30 output port to maintain CDRH compliance.

All emission indicators remain on as long as the laser is capable of lasing. The indicators illuminate a few seconds prior to actual emission to give nearby personnel time to avoid exposure to laser radiation.

Beam Safety Shutter

A solenoid-actuated safety shutter is mounted in the optical cavity to interrupt laser action when necessary. The shutter is actuated when the laser is turned on (either by pressing the 'ON' button or by issuing a software command). The interlock fault and fail-safe mode is the closed position.

Beam Attenuator (Output Port)

A manually operated shutter mounted on the front laser output port is provided for blocking the beam if required. If the optional side port is used, a metal disc (supplied) may be inserted in this port by the user to block emission.

Location of Controls

Controls for operation of the Evolution-30 laser are accessed through the control software via RS-232 control so that operators need not be exposed to laser radiation during operation of the laser. If the software is terminated, the computer malfunctions, or the RS-232 connection is broken, the Evolution-30 will stop lasing within 3 seconds.

Operating Instructions

This manual contains instructions for operating and maintaining the Evolution-30 laser safely.

2.6 CDRH Requirements for Operating the Evolution-30 via RS-232 Software Commands

The Evolution-30 and power supply comply with all applicable CDRH safety standards when operated via RS-232 commands sent to the 'RS-232' port on the front of the power supply cabinet. A software indicator indicates that laser energy is present or can be accessed..

2.7 Maintenance Required to Keep Laser in CDRH Compliance

This section presents the maintenance required to keep this laser product in compliance with CDRH Regulations.

This laser product complies with Title 21 of the *United States Code of Federal Regulations*, Chapter 1, Subchapter J, Parts 1040.10 and 1040.11, as applicable. To maintain compliance, verify the operation of all features listed below, either annually or whenever the product has been subjected to adverse environmental conditions (e.g. fire, flood, mechanical shock, spilled solvents). This maintenance is to be performed by the user, as outlined below.

- Verify that removing the laser cover closes the intracavity shutter and illuminates the interlock LED on the remote box and on the laser power supply.
- Verify that, when the cover interlock is defeated, the defeat mechanisms are clearly visible and prevent installation of the cover until they are removed.
- Verify that all the warning labels listed in Figures 2.1 to 2.3, 'Evolution-30 Radiation Control Drawings' are present and firmly affixed in the correct locations.
- Verify that removing the auxiliary user interlock connector on the back panel of the power supply prevents laser operation. Figure 2.5 shows the interlock with the jumper plug in place.
- Verify that the time delay between turn-on of the emission indicator and start of laser emission gives enough warning to allow action to avoid exposure to laser radiation.
- Verify that the internal beam attenuator (shutter):
  a) Operates properly when the laser is turned off from the remote box (or remote computer controller, if being used)
  b) Closes when the key switch is turned off
  c) Blocks access to laser radiation

2.8 Sources of Additional Information

The following are some sources for additional information on laser safety standards and safety equipment and training.

2.8.1 Laser Safety Standards

SAFE USE OF LASERS (Z136.1)
AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)
1430 BROADWAY
NEW YORK, NY 10018
TEL: (212) 354-3300

OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION (OSHA)
U.S. DEPARTMENT OF LABOR
200 CONSTITUTION AVENUE N.W.
WASHINGTON, DC 20210

A GUIDE FOR CONTROL OF LASER HAZARDS
AMERICAN CONFERENCE OF GOVER NMENTAL AND INDUSTRIAL HYGIENISTS (ACGIH)
6500 GLENWAY AVENUE, BLDG. D-7
CINCINNATI, OH 45211
TEL: (513) 661-7881

LASER SAFETY GUIDE
LASER INSTITUTE OF AMERICA
12424 RESEARCH PARKWAY, SUITE 130
ORLANDO, FL 32826
TEL: (407) 380-1553

2.8.2 Equipment and Training

LASER FOCUS BUYER'S GUIDE
LASER FOCUS WORLD
ONE TECHNOLOGY PARK DRIVE
P.O. BOX 989
WESTFORD, MA 01886-9938
TEL: (508) 692-0700

PHOTONICS SPECTRA BUYER'S GUIDE
PHOTONICS SPECTRA
BERKSHIRE COMMON
PITTSFIELD, MA 01202-4949
TEL: (413) 499-0514

LASERS AND OPTRONICS BUYER'S GUIDE
LASERS AND OPTRONICS
301 GIBRALTAR DR.
P.O. BOX 650
MORRIS PLAINS, NJ 07950-0650
TEL: (210) 292-5100

3 Product Overview

The Evolution-30 laser is designed around a Nd:YLF laser head pumped by twelve AlGaAs laser diode arrays. The laser resonator is acousto-optically Q-switched at repetition rates from 1-10 kHz. In order to produce the maximum possible output power in the second harmonic, the laser uses intra-cavity frequency doubling with a non-critically phased matched LBO crystal. Overall doubling efficiency is excellent, and the damage threshold of LBO is five times higher than other commonly used crystals, ensuring long-term trouble free operation. Non-critical phase matching minimizes the angle sensitivity of the crystal for adjustment-free operation.

The Evolution-30 is ideally suited to pumping Ti:sapphire ultrafast amplifiers, and has been optimized as a pump source for the *Spitfire* and *Hurricane* Ti:sapphire regenerative amplifier systems.

3.1 Diode Pumping

The Evolution-30 employs laser diode pumping to excite the laser gain medium, as opposed to more conventional arc-lamp pumping schemes. Unlike the broadband light emitted by arc-lamps, the narrow spectral emission of laser diodes allows extremely efficient pumping of laser materials, with little or no diode light falling outside of the absorption band of the gain medium. This results in negligible waste heat generation and the high efficiency results in low electrical and cooling utility requirements. The low waste heat generation also results in negligible deleterious thermal effects in the laser rod (such as thermal lensing and depolarization). Another key advantage of laser diode pumping is that diodes offer lifetimes of many thousands of hours, compared to only hundreds of hours for arc-lamps.

3.2 Nd:YLF Laser Material

The Evolution-30 uses Nd:$LiYF_4$ (Nd:YLF) as its gain medium, which provides numerous advantages over other common neodymium-based lasers such as Nd:YAG. The long upper-state lifetime (470 µs) provides efficient energy storage for high pulse energy operation a low repetition rates. The low thermal lensing and natural birefringence of Nd:YLF enables scaling to higher power, avoiding the loss of beam quality and efficiency or the requirement for complex resonator designs.

With an intra-cavity polarizer one can select either the 1047 nm (extraordinary) or 1053 nm (ordinary) transition. All lines originate on the same Stark split $^4F_{3/2}$ upper level. The Evolution-30 lases on the 1053 nm transition because of the lower thermal lensing exhibited at this wavelength,.

The relatively high thermal conductivity of Nd:YLF allows efficient heat extraction, and its natural birefringence overwhelms thermally induced birefringence, virtually eliminating the thermal depolarization problems found in optically isotropic hosts such as Nd:YAG.

3.3 Acousto-Optic Q-Switching

In acousto-optic Q-switching, an ultrasonic wave is launched into a block of transparent optical material. The photoelastic effect couples the modulating strain field of the ultrasonic wave to the optical index of refraction of the material. The resulting optical phase grating has a period equal to the acoustic wavelength and amplitude proportional to the sound amplitude.

When a light beam is incident upon this grating, a portion of the intensity will be diffracted out of the beam into one or more discrete directions. By choosing beam parameters properly, the diffracted beam can be deflected out of the laser cavity, thereby providing an energy loss that is sufficient to spoil the Q of the cavity.

The ultrasonic wave is launched into the Q-switch block by a piezo-electric transducer that converts incident electromagnetic energy into ultrasonic energy. The laser is returned to the high Q-state by switching off the driving voltage to the transducer. With no ultrasonic wave propagating through it, the fused silica block returns to its usual state of high optical transmission, the deflected beam disappears and a Q-switched laser pulse is emitted.

3.4 Intra-Cavity Frequency Doubling

High frequency conversion efficiencies require power densities that are not normally available from a cw-pumped laser. One obvious solution to this problem is to place the non-linear doubling crystal inside the laser resonator, subjecting it to high circulating power. The power is coupled out of the resonator at the second-harmonic wavelength by replacing the output mirror with one that is 100% reflective at the fundamental and transmitting at the second harmonic wavelength. The second harmonic crystal acts as an output coupler in a manner analogous to the output coupler of a normal laser. Because of the advantage of the high power density inside the laser cavity, it is only necessary to achieve a conversion efficiency equal to the optimum mirror transmission to convert the available output power at the fundamental completely.

3.4.1 Lithium Triborate (LBO)

LBO is a nonlinear optical crystal characterized by good UV transparency, a relatively high optical damage threshold, and a moderate non-linear optical coefficient. The birefringence in LBO is small, which enables non-critical phase matching and provides a larger acceptance angle for high efficiency frequency-conversion. These properties, along with its mechanical hardness, chemical stability, and non-hygroscopic nature, make LBO a useful material for nonlinear optical frequency conversion.

3.5 Optical Laser Bench Configuration

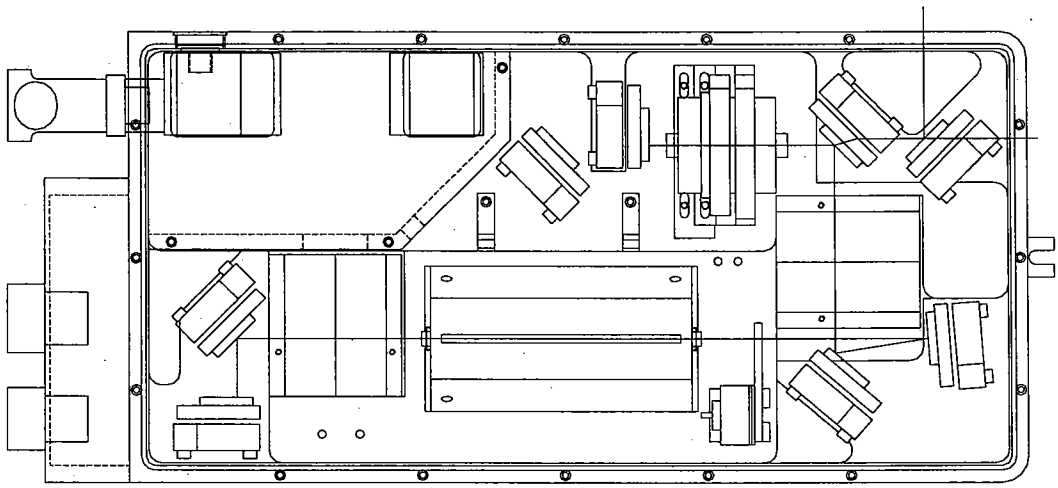


Figure 3.1: Optical Laser Bench

The optical laser bench of the Evolution-30 is shown in the diagram above. The laser resonator is in a folded configuration, which enables efficient output coupling of the second harmonic light and reduces the overall size of the Evolution-30. From left to right, the optical cavity consists of the following components (all mirrors are high reflectivity at 1053 nm unless otherwise noted):

- 0°, curved rear cavity mirror
- 45° turning mirror
- Acousto-optic Q-switch
- Diode pumped laser bench
- Intracavity safety shutter
- 0° curved intracavity mirror
- 45° turning mirror
- Acousto-optic Q-switch
- 45° intracavity dichroic folding mirror – high reflector at 1053 nm; high transmission at 527 nm
- LBO frequency doubling crystal in temperature stabilized oven
- 0°, flat end mirror – high reflector at 1053 nm and 527 nm

The laser head contains the Nd:YLF laser rod and laser diodes. The diodes provide optical excitation to the laser rod and lasing between the cavity mirrors is established. The 1053 nm radiation is entirely contained within the laser resonator because there is no output coupler at this wavelength. The laser is Q-switched (typically at 1-10 kHz), producing intra-cavity laser pulses of duration 100-350 ns depending on the pulse energy. Because of the high intra-cavity radiation fluence, the 1053 nm radiation is efficiently converted to

527 nm in the LBO crystal. This 527 nm light transmits through the dichroic mirror, and exits the laser bench directly from the forward output port, or reflects from a turning mirror and exits through the side output port. The beam waist is located at the 0°, flat end mirror, so the beam is diverging at either output port of the laser. A lens is located at the output port to collimate the beam.

Note

Please chose the ouput port (front or side) at the time of installation so that the service engineer can install the laser as you would like to use it.

3.6 Component Description

3.6.1 Laser Pump Chamber

The Nd:YLF laser rod and laser diodes are contained in the laser pump chamber. The pump chamber is mounted to the laser bench in a mechanically indexed bracket that allows for easy extraction and insertion of the pump chamber. The laser rod is held with o-rings in a water flow-tube. A gold-coated reflector surrounds the flow tube; slits in the reflector transmit the pump light from the laser diodes. Both the laser rod and laser diodes are water cooled in parallel by the internal cooling system that enters the pump chamber through o-ring sealed ports in the base of the pump chamber.

The diodes are arranged in three blocks of four high power diode bars that share a single water-cooled heat sink and electrical connections. Three blocks of diodes are mounted 120° apart down the length of the laser rod. The diodes are electrically connected in series to the Evolution-30 diode driver through a high-current connector on the pump chamber.

3.6.2 Q-switches

The two Q-switches are enclosed in a metal housing and mounted on a riser block with a coarse azimuthal adjust. The Q-switches are made of high quality fused silica to which an RF transducer is bonded. The fused silica is cut and optically polished to be optically oriented at Brewster's angle for the 's' polarized intra-cavity laser radiation.

Approximately 30-40 Watts of RF power are delivered to the Q-switches through two 50-ohm BNC cables. The Q-switches are water-cooled, and have built-in temperature interlock to shut off the RF power if an over-temperature condition occurs. The power supply for the Q-switches is located in the Evolution-30 power supply chassis.

3.6.3 LBO Crystal and Oven

The LBO crystal is located in a crystal housing which maintains its set temperature in the range 315 to 340 degrees Fahrenheit to within 0.1 degrees Fahrenheit. At this temperature the crystal is non-critically phase

matched for the intra-cavity 1053 nm radiation, ensuring high conversion efficiency to the second harmonic. The crystal should be constantly maintained at this temperature, even when the laser is not in use. If necessary, the crystal can be ramped down to room temperature for long-term storage of the laser (see Chapter 5). The LBO crystal is anti-reflection coated for both 1053 nm and 527 nm.

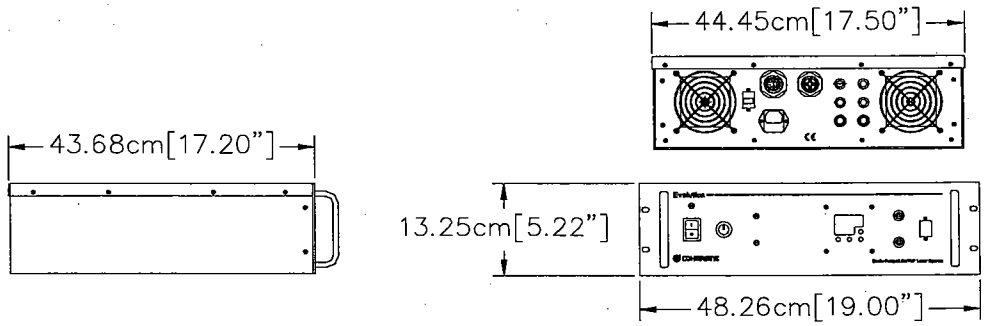
The temperature controller is a microprocessor-based device and is pre-programmed. It can maintain the crystal to within 0.1 °F, which ensures stable operation of the laser. If the LBO temperature is not maintained at the factory set-point, an interlock will prevent laser operation.

3.7 Power Supply

The power supply assembly consists of a rugged steel frame in a 19" rack-mount configuration. The power supply contains the master control board, diode power supply, Q-switch RF driver, LBO crystal temperature controller, and various control electronics. In general, it should not be necessary to access any components inside the power supply.

Danger!

Removing the power supply cover will expose the user to electrical hazards. Potentially lethal voltages and currents are contained in the power supply. Normal operation of the Evolution-30 should not require access to the power supply circuitry. Contact an authorized service representative before attempting to correct any problem with the power supply.



3.7.1 Power Supply Front Panel

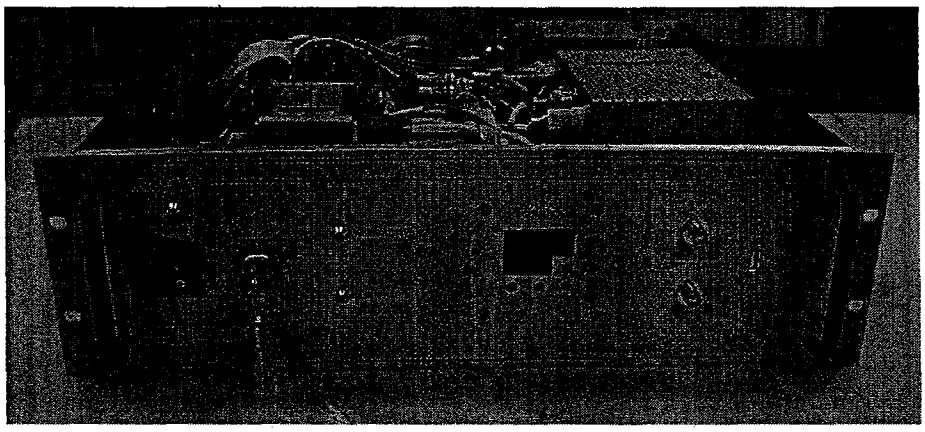


Figure 3.2: Power Supply Front Panel

Power Switch – Enables main AC power to the power supply. Green LED illuminates when AC power is activated.

Danger!

AC power to the LBO crystal heater circuit in the power supply is always present when the power supply is plugged in, even when the AC breaker is deactivated.

Key Switch – The key switch is an interlock function. In the 'OFF' position it prevents operation of the laser. The key switch is designed so that the key can be removed only in the 'OFF' position. The key switch is also used to reset latched interlocks by cycling from the OFF position to the ON position.

Laser Active – LED that illuminates when current is flowing through the laser diode arrays, regardless of the state of the laser output (Q-switched, CW, hold-off, etc.)

Laser Fault – LED that illuminates when the Evolution-15 encounters an interlock fault.

LBO Heater Control – Temperature controller programmed to maintain the temperature of the LBO crystal oven. Normally it is not necessary to change the settings of this controller.

USB I/O – D-USB Type A connector that is used with USB extension cable to connect the USB port of a computer for control of the laser.

QSW SYNC OUT – BNC output that provides a fixed TTL synchronization signal that is coincident with the triggering of the Q-switch.

QSW TRH INPUT – The Evolution-15 Q-switch can be triggered externally by applying a 4V TTL signal of >4 µs duration to this BNC input. The input is terminated with high impedance; if the external triggering source has a 50 ohm line drive output, a 50 ohm terminator should be added at the QSW TRH input to avoid multiple pulses from ringing. External triggering from 500 Hz to 10kHz is possible. Using this mode requires the user to select 'EXT' trigger mode in the control software.

3.7.2 Power Supply Rear Panel

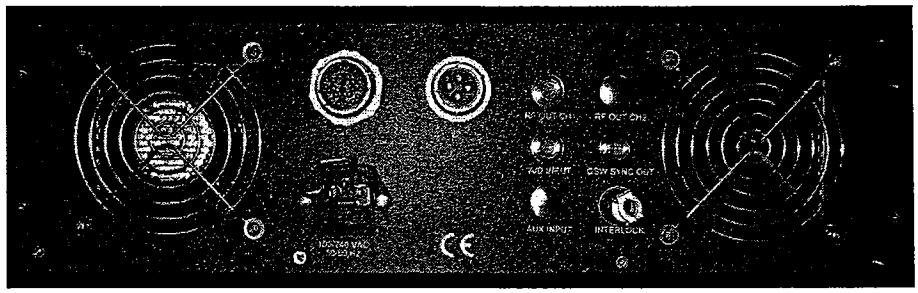


Figure 3.3: Power Supply Rear Panel

AC IN – Main input power required must be in the range 100 to 240 VAC ± 10%, 50/60 Hz. Fuses meeting the following specifications are used:

Line Voltage / VAC	F1/F2: 3AG SLO BLO®
200-240 100-120	10A/10A 15A/15A

Table 3.1 Evolution-30 fuse specifications

RF OUT CH1 & RF OUT CH2 – BNC output, 30-50 Watts, 100-150V RMS sine wave at 27.11 MHz into a 50 Ohm load, used to drive the two Evolution-15 Q-switches. DO NOT connect these signals to anything other than the supplied BNC connectors in the umbilical to the Evolution-15 laser bench.

26-pin connector (J1) – Supplies interlock and control signals to the laser bench. Connects to the 26-pin umbilical cable.

4-pin connector (J2) – Supplies current to the laser diode arrays in the laser bench. Connects to the 4-pin umbilical cable.

Interlock –Three pin connector used for interlocking the laser to a controlled access point, such as a laboratory door. Shorting pins J1 and J2 (shown in Figure 2.5) will enable laser operation.

AC INPUT – Main input power required must be in the range 100 to 240 VAC ± 10%, 50/60 Hz.

A/D INPUT – Reserved for future use.

AUX INPUT – Reserved for future use.

3.7.3 Electronic Control Module (ECM)

The Electronic Control Module (ECM) is a USB control device for setting and monitoring the laser diode power supply, the laser interlocks, and the Q-switch driver. The ECM is controlled via USB by software on the supplied laptop computer.

3.7.4 Laser Diode Power Supply

The laser diode power supply is a completely self-contained unit, enclosed in a metal housing to provide protection for the power supply components and to service personnel. The power supply operation is controlled and monitored by the ECM.

3.7.5 Q-switch Driver

The Q-switch driver provides RF power to the two Q-switches on the optical laser bench. It is an all solid-state electronics driver consisting of a crystal controlled oscillator, double balanced modulator, pulse generator with gate and broad band power amplifier that will provide > 30W of drive power into each Q-switch. The Q-switch driver is controlled and monitored by the ECM.

3.7.6 LBO Crystal Temperature Controller

The LBO doubling crystal is temperature tuned for non-critical phase matching. The LBO is housed in a temperature-stabilized oven. A resistive heating element, combined with a local temperature sensor, is used with the heater controller to stabilize the crystal temperature to within ±0.1°F. The heater controller is programmed to limit the rate at which the crystal temperature is changed (typically no faster than 10°F per minute) to prevent cracking of the crystal antireflection coatings. The power for the temperature controller is wired directly to the AC lines so that the crystal is kept heated, even when the front-panel breaker is turned off. The LBO crystal temperature should be ramped down before disconnecting power to the chassis. See Section 5.4 for instructions.

The LBO crystal temperature controller is programmed directly from the front panel of the Evolution-30 power supply. Under normal circumstances, it should be unnecessary for any adjustment of the LBO temperature or the controller parameters.

3.8 Control Computer

The Evolution-30 comes with a commercial laptop computer and software to control and monitor the functions of the laser through an RS-232 interface. Because of frequent changes in the availability of specific computer models, the particular computer delivered with each laser may vary in brand and features, but in general it will have a Pentium class processor ≥300MHz, ≥32MB of RAM, ≥2GB hard drive, a CD-ROM drive, and a floppy drive. The control software for the Evolution-30 is pre-installed and tested with each laser, and is also delivered on CD-ROM.

Caution! 

Your Evolution-30 was built and tested using the Control Computer and Control Software that shipped with the laser. Coherent does not endorse or support the use of other computers or software to control the Evolution-30; doing so may void the warranty and/or cause damage to the laser.

3.8.1 USB Connection

The control computer is connected to the Evolution-15 power supply using the included USB cable.

3.8.2 Control Software

The included control software for the Evolution-30 is called "Evolution-30 Control", and is accessed by a shortcut in the Programs folder in the Start menu. The exact layout of the front panel varies depending on the version of the software but all versions of the software share the same general controls. The latest version of the software is available by contacting your authorized service representative.

This section describes the controls for the Version 2.4.0 of the software.

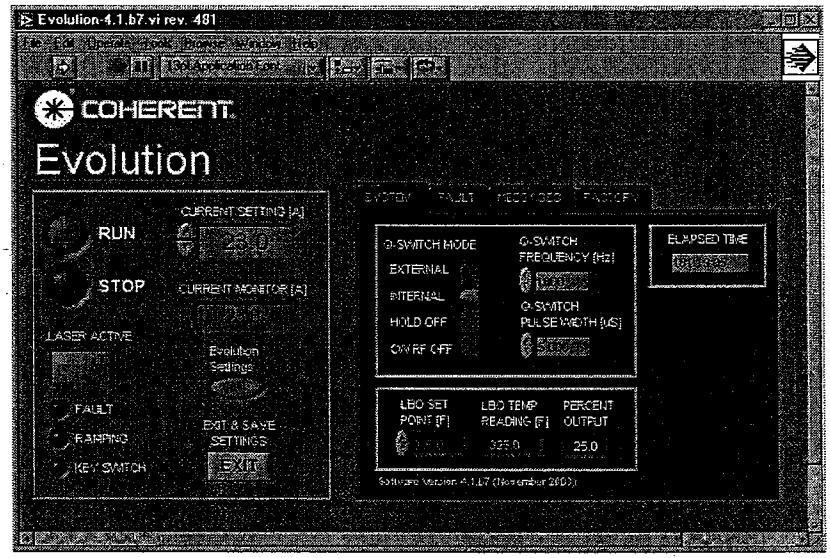


Figure 3.4: Evolution-30 Control software version 2.4.0.

Main Controls

RUN/STOP – Button control that changes the state of the Evolution-30. In Run state, the laser diodes will be turned on, and the Evolution-30 will start lasing. If the Run state is entered from the Stop state, a short Countdown state will occur before lasing begins, during which time a tone will sound and the LED on the power supply and laser bench will flash. In the Stop state the Evolution-30 will stop lasing; this the start-up state. If there is an interlock, the laser is put into a Fault state; in this state, the laser cannot be put into the run state until the interlock is cleared and Key Switch on the front of the power supply is cycled off and then on.

Run/Stop/Fault/Count Down/Ramping – LED indicators for the Evolution-30 state, described above.

Key Switch – LED indicator of the state of the access control key, illuminated if the key is in the OFF position, flashing if the key switch needs to be recycled to reset the Fault state.

Laser Active – LED indicator that is illuminated when current is supplied to the laser diodes.

Current Setting – Numeric control to set the output current of the laser diodes (in Amps) up to the factory limit set point. The setting can be entered directly, or incremented by 0.1 A using the adjacent buttons. When the current setting is increased, the current will ramp up to the setpoint at a factory set rate (e.g. 0.5 A/sec), and the Ramping LED will illuminate. When the current setting is decreased, the current will decrease immediately without ramping.

Current Monitor – Numeric/meter indicator of the current (Amps) detected by the power supply.

Exit & Save – Button control to stop the laser (if running), stop execution of the control program, and save the settings.

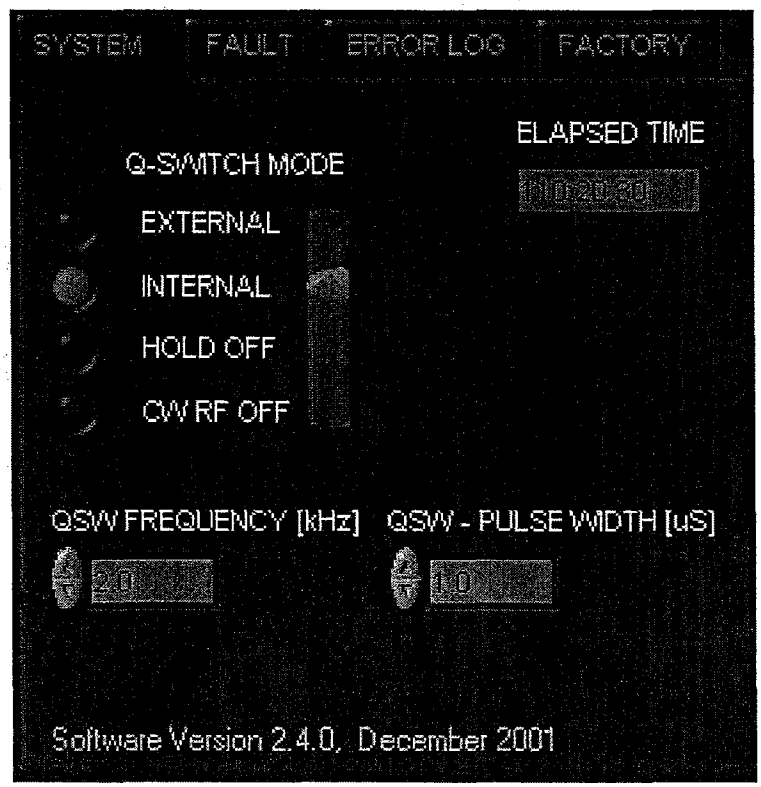


Figure 3.5: Control Software SYSTEM Panel.

SYSTEM Panel

QSW MODE – Slider control to set the mode of the Q-switch driver and LED indicators to show the active Q-switch mode:

Caution! 

Switching from non-Q-switching modes (CW and HOLD OFF) to lasing modes (INTERNAL and EXTERNAL) while the laser is running will cause the laser to switch into Stop mode. The user can restart the laser by switching into Run mode.

INTERNAL – RF power on, Q-switch trigger source is the internal clock on the SAB, rep-rate set by the software QSW Frequency control.

EXTERNAL – RF power on, Q-switch trigger source is the EXT QS TRIG IN BNC on the front panel of the power supply. The external trigger frequency must be > 500Hz or the laser will interlock.

HOLD OFF – RF power on, no Q-switch triggers. Used to check alignment of the Q-switches during construction and servicing of the laser.

CW RF OFF – (Continuous Wave) RF power off. Used for setting and checking laser cavity alignment during construction and servicing of the laser.

QSW Frequency [kHz] – Numeric control to set the frequency of the Internal Q-switch trigger source.

QSW Pulse Width [µs] – Numeric control to set the width of the Internal trigger pulse to the Q-switch driver.

Elapsed Time – Numeric indicator of the elapsed cumulative hours and minutes of laser operation.

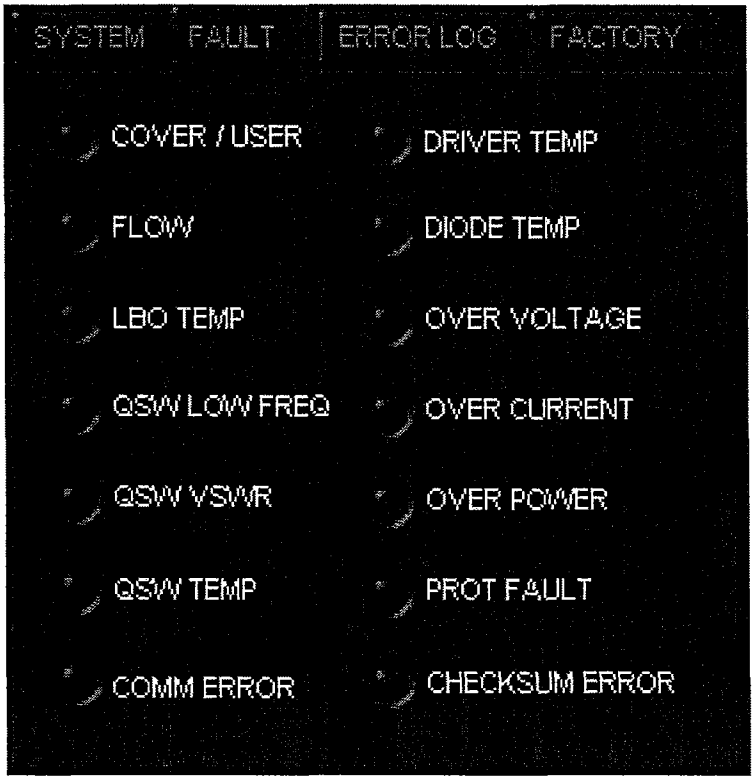


Figure 3.6: Control Software FAULT Panel.

FAULT Panel

COVER/USER – Illuminated if any of the micro-switches on the Evolution-30 laser bench are not engaged, or if the user interlock is open. Check covers or interlock defeats on laser bench and door interlock switch or interlock defeat, then cycle key switch to clear.

FLOW – Illuminated if the water flow from the chiller is less than 2.0 GPM. Check chiller function, water pressure, reservoir level, and water hoses to ensure adequate flow, then cycle key switch to clear.

LBO TEMP – Illuminated if the LBO temperature is outside a 3 degree window around the factory set point. Allow temperature to return to specified temperature range.

QSW LOW FREQ – Illuminated if the QSW MODE is EXTERNAL and the external source of triggers drops below 500 Hz. Ensure that the source of external Q-switch triggers is producing TTL pulses at 500 Hz or higher.

QSW TEMP – Illuminated if the thermal sensor in the LBO crystal exceeds safe operating temperature. Check chiller function, water pressure, reservoir level, water hoses, and water contamination, then cycle key switch to clear.

QSW VSWR – Illuminated if the Q-switch driver detects a significant amount of power reflected from either of the two Q-switches. Check cable connections between the power supply and the laser head. Also check for adequate water flow, then cycle key-switch to clear, and change to INTERNAL or EXTERNAL Q-switch triggering to test for error. If the problem persists, contact your authorized service representative.

COMM ERROR – Illuminated if communications are interrupted between the computer and the Evolution-30 power supply. Check RS-232 cable connections and ensure that the power supply is turned on. Exit the Control Software, cycle the AC on the power supply, and restart the Control Software to clear.

DRIVER TEMP – Illuminated if the temperature of the Diode Drive (FET) heat sink becomes overheated due to inadequate airflow to the driver, or a shorted or Over Current condition. Check airflow of the power supply and allow it to run without lasing for at 10 minutes, then restart the laser running.

DIODE TEMP – Illuminated if the temperature sensor located inside the laser head and mounted on the diode array heat sink exceeds safe operating temperature. Turn off power supply, allow the chiller to run for 10 minutes, then restart the laser running at a lower current.

OVER CURRENT – Illuminated if excess current is being delivered to the diode array. Lower current, then cycle power on the power supply to clear.

OVER VOLTAGE – Illuminated if excess voltage is required to supply the set current to the diodes. Check diode umbilical connection and cycle power on the power supply to clear.

OVER POWER – Illuminated if the internal drive FET exceeds a factory set power limit. Reduce the drive current, then cycle the power on the power supply to clear.

PROT FAULT – Illuminated if the internal drive FET protection circuit is activated. This is a serious internal driver failure, requiring repair – do no operate the Evolution-30 if this error occurs.

CHECKSUM ERROR – Illuminated if a garbled communications message is detected between the Control Software and the Evolution-30. Normally these can be ignored, but if they occur frequently, check RS-232 cable connections.

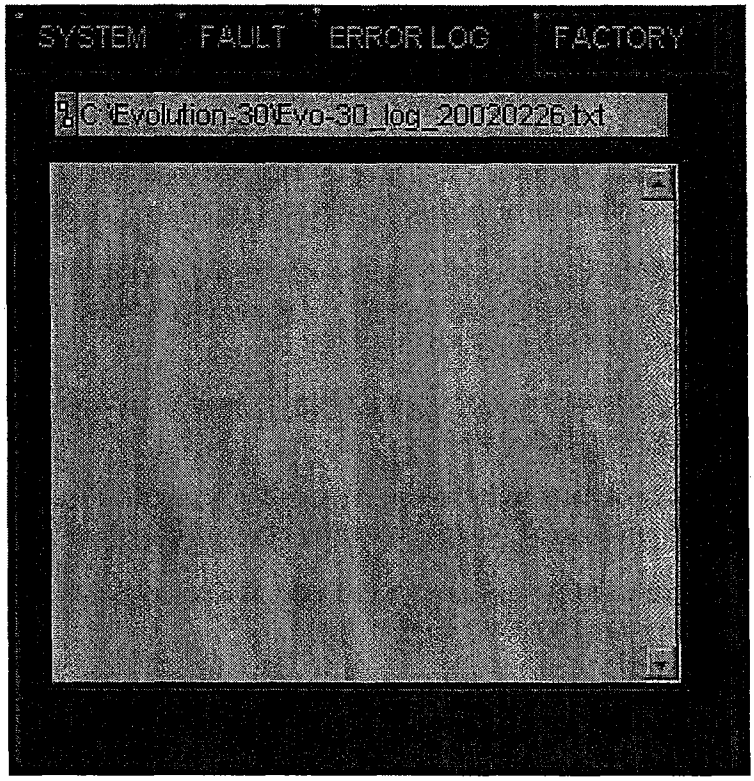


Figure 3.7: Control Software ERROR LOG Panel.

ERROR LOG Panel

Records all Fault conditions, fault corrections, and their timestamps. A new error log file is created each calendar day with the date included in the file name in the format YYYYMMDD.

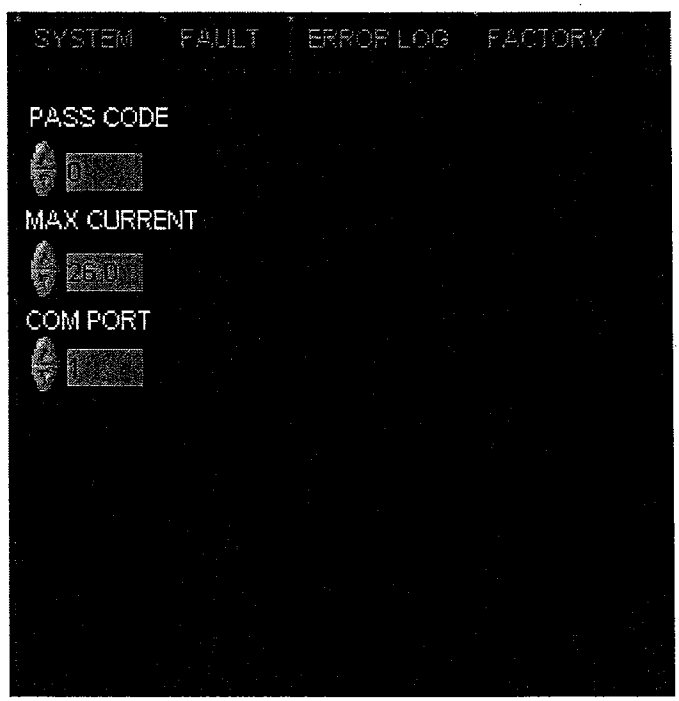


Figure 3.8: Control Software FACTORY Panel.

FACTORY Panel

PASS CODE – Factory use only.

MAX CURRENT – Maximum current setting for the laser diodes; set at the factory.

COM PORT – Sets the computer RS-232 communications port (user settable).

4 System Installation

Please read this manual thoroughly before installation. It is important that you become familiar with all aspects of installation and operation of the Evolution-30, and pay particular attention to the safety guidelines presented throughout this manual.

Warning! 

The information in this chapter is provided for reference only. Do not attempt to install the laser yourself, or remove the lid sealing the laser cavity. Either action, if unauthorized, will void your warranty, and you will be charged for the repair of any damage that may occur if you attempt installation yourself. Please call your authorized service representative to arrange an installation appointment, which is included as part of your purchase agreement. You may, however, unpack and locate your laser in the area that it will be used.

4.1 Installation

4.1.1 Location

Before installation, please select a suitable location for the Evolution-30. The Evolution-30 is constructed using a temperature-stabilized monolithic body, but it is recommended that the laser is located in a laboratory-type environment that is free from dust and drafts, with low humidity (<50%) and which does not exhibit temperature fluctuations greater than ±5°C.

4.1.2 Pumping a *Spitfire* Amplifier

When pumping a *Spitfire* regenerative amplifier, the Evolution-30 should be placed as close as possible to the *Spitfire*. The distance between the Evolution-30 and *Spitfire* is determined at the factory during the final test procedure. Relatively large deviations (> 1 foot) from this distance can affect the overall performance of the system. For safety, it is also inadvisable to have an exposed laser beam travel long distances. Please consult with your authorized service representative if necessary.

4.1.3 Required Utilities

Warning! 

Do not apply AC power to the power supply chassis. To do so will activate the LBO crystal heater. Improper programming of the crystal heater, and subsequent crystal heating, will permanently damage the crystal. Such damage will not be covered under warranty. Please wait until a service engineer arrives on site to provide installation.

Caution! 

The Evolution-30 power supply is compatible with 100-240VAC and 50-60Hz frequency, however each Evolution-30 is optimized to operate at the customer-specified line voltage and frequency. Do not attempt to operate your Evolution-30 at a different voltage or frequency unless you first consult with your authorized service representative.

Warning! 

The closed-loop chiller supplied with your Evolution-30 is only compatible with a specific line voltage and frequency range. Do not attempt to operate your Evolution-30 chiller at a different voltage or frequency under any circumstances.

The Evolution-30 system requires the utilities listed in Table 4.1.

Destination	Acceptable Line Voltage / Frequency (VAC/ Hz)		Current Requirements (A)	
			Laser	Chiller
USA	(110 ± 10) VAC, 60 Hz		15	15
Japan	OR	(110 ± 10) VAC, 50/60 Hz	15	15
		(220 ± 20) VAC, 50 Hz	10	10
Europe	(220 ± 20) VAC, 50 Hz		10	10

Table 4.1: Evolution-30 utility requirements.

4.1.4 Installing the Power Supply

Consider the following when placing the power supply:

- Place the power supply within 10ft (3m) of the laser bench to avoid straining the umbilical.
- If available, place the power supply in a ventilated 19" equipment rack.
- Allow 6 inches (15cm) of clearance to the front and back panels of the power supply cabinet for proper airflow and 3 inches (8cm) on each side.
- Take measures to prevent the heated air exhaust from the back panel fans from returning to the intake one the back of the power supply, or from exhausting toward the laser bench. Failure to do so will cause overheating in the power supply and instability in the laser output.
- Verify that the interlock jumper plug is in place from the back panel of the power supply. If you intend to use the laser in a limited access area, remove the jumper and wire it to a safety switch. The switch must be wired so that when the device is actuated (a door is opened, for example), the switch opens and the laser turns off (see Chapter 2, 'Laser Safety').
- Verify that the local line frequency and voltage are within the acceptable input ranges for your Evolution-15 and chiller.
- Ensure that all electrical cables and umbilical are safely routed and not under any strain or compression.
- Verify that the power cable is secured with the built-in bracket on the AC socket on the power supply chassis.

4.1.5 Installing the Laser Bench

Please note the following when placing the Evolution-30 laser bench:

- The laser bench is attached to the power supply chassis by a 10 foot umbilical consisting of four cable assemblies: a 4-pin current cable, a 26-pin signal cable, and two BNC cables that connect to the RF Out connectors on the rear panel of the power supply chassis.
- Take care when placing the laser bench that the weight of the umbilical does not drag the laser bench off the table or create a trip-hazard in the laboratory.

Note

Please chose the ouput port (front or side) at the time of installation so that the service engineer can install the laser as you would like to use it.

- Secure the laser bench in position on an optical table or other flat mounting surface as follows:

  OEM Evolution-30:

  Two slots are provided at the center of the front and back of the laser housing for securing the laser bench. Use standard table screws (M6 or ¼-20) to fasten the laser to the table.

  Make sure that the flexure arm at the front of the laser is bolted in place last, since securing this first will defeat its purpose in allowing for thermal expansion/contraction of the housing.

Scientific Evolution-30:

Place the laser bench on the table and adjust the four mounting feet for the correct height, making sure that the instrument is level. The height of the feet may then be locked in place using the locking ring on each leg. Secure the laser to the optical bench using a mounting clamp on each foot. If the laser is directed out the side port, remove the metal disk in the beam tube port on the skins.

4.1.6 Installing the Control Computer

Locate the Evolution-30 Control Computer within 10 feet of the power supply chassis. The computer should be set up according to the manufacturer's instructions included in the computer box. Connect the 9-pin connector of the included serial cable to the serial output of the computer, and attach the 25-pin connector to the RS-232 port on the power supply chassis. On Control Computers that ship with Windows 2000, the default user name is "Administrator", and the default password is "evolution" (passwords are case sensitive, and do not type the quotes). The Control Software is pre-installed on the Control Computer.

4.1.7 Installing the Chiller

When installing the chiller, please observe the following instructions:

- Check that the local line voltage and frequency is within the acceptable input range for the chiller supplied
- Place the chiller on the floor close enough to the Evolution-30 laser bench such that the cooling hoses will reach without causing undue strain

Caution! 

Position the chiller so that its warm air exhaust is not drawn into the laser power supply and does not adversely affect the stability of the laser bench or your experiment.

- Ensure that an air gap of at least 6 inches is left between the chiller and Evolution-30 power supply to avoid hot air exhausting from one unit being drawn into the other
- Do not place the chiller above the laser or power supply. Should the unit be installed incorrectly and a leak develops, dripping water may damage the laser system.

Attach the chiller hoses to the laser bench. The hoses connectors are not polarized, so check that the 'feed' line (marked with an arrow pointing towards the laser bench) is attached to the **lower** hose connector on the laser bench. This ensures that any air is purged upwards and out of the laser bench.

Danger! 

Before handling OPTISHIELD water treatment, read the Material Safety Data Sheet included in Chapter 9 that describes the potential hazards and handling precautions associated with this chemical. This chemical may be harmful if swallowed, inhaled, or absorbed through the skin or eyes.

Caution! 

Use only steam-distilled water in the Evolution-30 cooling system. The use of de-ionized water may cause corrosion damage.

- Add the contents of the one pint bottle of OPTISHIELD to the chiller reservoir.
- Fill the chiller with (or have available) approximately two gallons or 8 liters of high quality steam-distilled water.
- Turn on the chiller and verify that water is flowing. Inspect for leaks at the hose connections just made to the laser bench and at the chiller.
- Turn off the chiller.

  Please note that it takes the chiller about fifteen minutes to stabilize the temperature of the laser bench cold plate and, thus, the output of the laser. If the laser is used frequently, leaving the chiller on between periods of use will eliminate this stabilization period. If the laser is used infrequently, turn the chiller off after use.

5 System Operation

Safety glasses for all lasing wavelengths must be worn at all times when operating this, or any, laser system. Consult your laser safety officer to select appropriate safety glasses. See Chapter 2, 'Laser Safety'.

5.1 Current Settings

Your Evolution-30 laser comes with a set of performance data that gives the factory-measured output power as a function of laser diode current at the nominal Q-switch rep rate specified when the laser was ordered. Your authorized service representative will verify these measurements when the laser is installed.

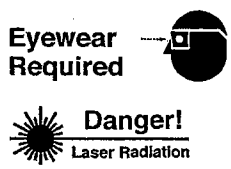
It is useful to establish at least three nominal current settings, a low, medium, and high setting that produce, for example, 6 Watts, 15 Watts, and 20 Watts for a standard 1 kHz system. In this section, we will refer to these current settings as Low, Medium, and High. If you do not normally operate your Evolution-30 at its maximum specified output power, scale these settings appropriately when following the procedures in this section and in the trouble-shooting section at the end of the manual.

After several hundred hours of operation, the laser diode output power will decrease slightly. The maximum possible current setting is set at the factory to ensure that your laser will meet its specification power for thousands of hours of operation.

5.2 Start-up Procedure

5.2.1 Diode Start-up and Lasing Initiation

The following procedures should be used during normal start-up and operation of the Evolution-30 laser system.



The following procedure will result in a laser beam being emitted from the Evolution-30 output port. Ensure all persons in the room are wearing adequate laser eye protection. Ensure that the anticipated beam is safely terminated into a high power beam block or power meter.

1. Ensure the power supply chassis is plugged in and the umbilical cables are connected properly.
2. Verify that the LBO Heater Control temperature is at the proper factory-set temperature.
3. Turn on the external cooling water supply.

If the Control Computer was disconnected, reconnect the cable between the Control Computer and the power supply chassis.

Boot the computer and log in (if necessary).

Set the Power switch on the power supply chassis to the ON position.

Insert the key switch and turn to the 'ON' position.

Launch the Evolution-30 Control software on the Control Computer.

After the Control Software communicates with the Evolution-30, and all interlocks are met, the STOP indicator will light, indicating that laser can be started. If the FAULT indicator on the power supply chassis is blinking, or if the FAULT state indicator on in the Control Software is illuminated, see the trouble-shooting guide for assistance in clearing the interlocks.

Set the Current Control in the Control Software to the nominal Low current setting.

If the Evolution-30 is to be internally Q-switched, set the QSW Frequency control to the proper rep rate (e.g. 1.0 kHz), and set the QSW MODE switch to INTERNAL.

If the Evolution-30 is to be externally Q-switched, connect a TTL-level signal (at least 1 µs duration) at the proper frequency to the EXT QS TRIG IN connector on the front panel of the power supply chassis, and set the QSW MODE to EXTERNAL. Q-switch operation is synchronized to the rising edge of the input pulse.

Caution!

The Evolution-30 was optimized at a specific Q-switch repetition rate. Operating the laser at a significantly different rate may result in decreased performance or optical damage.

Rotate the output shutter open on the front of the Evolution-30. Ensure that the laser output will be directed into an appropriate termination (e.g. beam dump, power meter, *Spitfire*, etc.)

Eyewear Required

Danger!
Laser Radiation

The following procedure will result in a laser beam being emitted from the Evolution-30 output port. Ensure all persons in the room are wearing adequate laser eye protection. Ensure that the anticipated beam is terminated.

Slide the Laser State slider to the RUN position. The LASER ACTIVE LED on the power supply chassis will illuminate, as will the LASER ACTIVE LED and the FIRE LED in the Control Software. The Current Monitor will ramp up to the set-point current in approximately five seconds.

Measure the output power with a power meter capable of measuring 30 Watts minimum. Within several minutes, the 527 nm power should be the same or close to the power that has been previously measured at the Low current setting.

Manually increase the current setting at a rate of no more than 1 Amp per second to the Medium current setting. Monitor the power continuously as you increase the current to ensure a monotonic increase in power with current. If the power is low, then wait ten minutes for the laser temperature to stabilize. When the power reaches the value corresponding to the Medium setting, increase the current to the High setting, and verify the power. If the beam does not reach operating power then it may be necessary to optimize the lasing output as described in Chapter 6.

5.3 System Shutdown

1. Slide the Laser State switch to STOP in the Control Software. The shutter will close and the diodes will shut off immediately.
2. Close the Control Software window.
3. Turn the main key switch to OFF.
4. Remove the key from the key switch.
5. Turn off the main power switch.
6. Turn off the water chiller.

5.4 Long Term Shutdown

If the Evolution-30 needs to be disconnected from line voltage for an extended period of time, the LBO crystal temperature must slowly be ramped down to room temperature to avoid thermal shock to the crystal. Use the following procedure.

1. Press and hold the down arrow (lower left) on the LBO Heater Control until the temperature setting is 75 degrees or cooler.
2. Allow the crystal temperature to ramp down until it reaches 75.0 degrees.
3. Turn off the Evolution-30 power supply and disconnect the power cord.
4. To return the Evolution-30 to normal operation, plug in the power supply, and reset the temperature to the factory set temperature. When the LBO crystal reaches the set point, the laser can be operated normally.

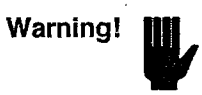
6 Maintenance

The Evolution-30 has been designed for minimal and easy maintenance. However, certain routine operations are recommended to maintain the system in good operating order. For more information contact your authorized service representative.

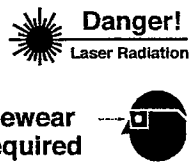
6.1 Lasing Optimization

6.1.1 Cavity Mirror Adjustments

All of the optical mounts in the Evolution-30 are securely fastened to the rigid base plate of the optical laser bench, which is temperature stabilized. Nevertheless, the mirrors may become slightly misaligned due to severe changes in room temperature, bumps or shocks, or other stresses on the optical bench. Under these circumstances, the end-mirrors of the Evolution-30 laser cavity may require adjustment.



Improper adjustment of the Evolution-30 laser can result in damage to the laser rod, LBO crystal, or Q-switch. Do not attempt to adjust the Evolution-30 mirrors until you have read this section. If you are uncertain about this procedure, contact your authorized service representative for assistance.



Laser protective eyewear MUST be worn to protect the eyes from all wavelength emitted by the Evolution-30. (See Chapter 2 of this manual, 'Laser Safety'.)

The following procedure may be used to optimize the cavity mirrors.

Materials required:

- Laser safety goggles
- Infrared viewer or card
- Two 1/8-inch ball-tipped Allen wrenches
- Calibrated power meter capable of measuring at least 30 Watts

Procedure:

1. If the Evolution-30 is operating, stop the lasing output by sliding the Laser State switch to STOP. It is not necessary to turn off the power to the power supply chassis.
2. [Scientific Evolution-30 only]. Lift the sheet metal cover from the Evolution-30 optical laser bench.
3. [Scientific Evolution-30 only]. Locate the two interlock defeat plates (with orange warning stickers), and use them to lock down the cover interlock switches. These defeats allow the Evolution-30 to be operated with the sheet metal cover removed. They should be removed and the cover replaced as soon as the optimization procedure has been completed.
4. Cycle the key switch on the power supply chassis to clear the cover interlock circuit.
5. Place the power meter at the Evolution-30 output.
6. Set the QSW MODE to INTERNAL and the QSW frequency to 1.0 kHz.
7. Start the laser at the Low current setting, allow the power to stabilize, and make note the stable power level.
8. Remove the set screws covering the mirror adjustment ports on the side of the housing. Place the screws in a safe place.
9. Using the hex wrenches, carefully adjust the vertical adjustment screw of the end-mirror while monitoring the power. Make **very small adjustments** (less than 1 turn total travel). Use this process to maximize the output power, and make a note of the maximum stable power.
10. Using the same procedure, carefully adjust the horizontal adjustment screw while monitoring the power. Again, make **very small adjustments** (less than 1 turn total travel). Use this process to maximize the output power, and make a note of the maximum stable power.
11. Set the Laser State switch to STOP and set the QSW MODE switch to HOLD OFF.
12. Set the current to the Low setting. Set the power meter to its most sensitive reading. Slide the Laser State switch to RUN to start the Evolution-30, and ensure there is no visible or IR laser output (using an IR viewer or IR card). If there is some laser output, **STOP**, turn off the laser, and contact Coherent for assistance.
13. Slowly turn the current up to the High setting while monitoring the laser power. The laser power should remain zero all the way up to 100%. Check for visible or infrared output (with an IR viewer or card). If there is any laser output at 100%, **STOP**, turn off the laser, and contact your authorized service representative for assistance.
14. Monitor the power meter and make **small** (< 1/4 turn) adjustments to the horizontal adjustment screw of the end mirror in both directions around the set point, and return the screw as close as possible to its starting point. Make the same adjustment scan for the vertical adjustment screw on the same mirror. If you measure **any** lasing at any time during these adjustments, **STOP**, turn off the laser, and contact your authorized service representative for assistance.
15. If no lasing was measured in the preceding step, turn the current back down to the Low setting at which the mirrors were optimized.
16. Stop the laser with the Laser State switch, and slide the QSW MODE selector to INTERNAL. Restart the laser with the Laser State switch. Note the output power

17. Fine-tune the vertical and horizontal adjustment screws on the mirror to return the output power to the maximum value you previously recorded.

18. Once the power is optimized, slowly turn the current control up to the Medium current setting and then to the High current setting while monitoring the power meter. When the current setting is at the High setting, allow the laser to stabilize, and note the stable power level.

19. If at any time the laser power starts to fluctuate rapidly, **STOP**, turn off the laser, and contact your authorized service representative for assistance.

If this procedure does not enable the Evolution-30 to meet is specified power, it may be necessary to optimize the LBO crystal temperature.

6.1.2 LBO Crystal Temperature Optimization

Depending on environmental conditions, the optimum temperature of the LBO crystal for efficient intra-cavity doubling may vary from the factory set point.

The LBO crystal temperature can be varied plus or minus 1.5 degrees Fahrenheit around the factory set temperature.

Warning! 

If, at any time, the Evolution-30 output power drops by more than 2 W while optimizing the LBO temperature at the Medium current setting, turn off the laser **immediately**. (If the LBO temperature is severely detuned and insufficient second harmonic light is coupled out of the optical resonator, optical damage may occur.) Reduce the current to the Low setting , perform the optimization procedure described below, then slowly increase the current to the Medium setting to check for optimized performance. If you are uncertain about this procedure, contact your authorized service representative for assistance.

Caution! 

If the temperature of the LBO heater deviates from the factory setting by more than 1.5 degrees, an LBO TEMP Fault will occur. In this event, return the setting to the factory setting, and restart the optimization procedure in the opposite temperature direction. If you believe the optimum LBO temperature setting is more than 1.5 degrees away from the Factory setting, contact your authorized service representative.

To optimize the LBO temperature:

- Note the factory temperature setting in the laser test document that shipped with your laser
- Note the present temperature setting if different from the factory setting.

- Set the current to the Medium setting, turn on the laser, allow it to stabilize for 10 minutes, and make a note of the power reading with a power meter.
- While monitoring the power, use the up and down arrows on the LBO HEATER CONTROLLER to change the temperature set point by 0.5 degrees. After the temperature stabilizes at the new setting, note the power. If the power has increased, change the temperature by another 0.5 degrees in the same direction (up or down). If the power has decrease, set the temperature 0.5 degrees in the opposite direction. Repeat until power is maximized.
- When the output power is maximized, make a note of the temperature setting for future reference

6.2 Cleaning Optics

The Evolution-30 is sealed against dust and debris, but depending on the cleanliness of the environment, it is possible that some dust may get into the optical laser bench.

Warning! 

Cleaning the Evolution-30 optics may result in misalignment of the laser cavity. After cleaning, the cavity should be realigned using the procedure in this chapter. Cleaning the optics will require opening the optical cavity. This procedure should not be executed without prior approval of your authorized service representative. Unauthorized opening of the seal will void your warranty, and may damage your laser. The Evolution-30 is assembled with chemically cleaned parts. To prevent contamination, do not work inside the housing unless wearing plastic gloves or finger cots.

Materials Required:

- Safety goggles
- Plastic gloves or finger cots
- Scientific-grade lens cleaning tissue (Kodak brand or equivalent quality)
- Reagent grade methanol or acetone
- Eyedropper
- Hemostat (surgical pliers)
- English hex-wrench set
- Bright lamp or flashlight

Danger! 

The LBO crystal is kept above 320 degrees Fahrenheit (160 degrees Centigrade). Prolonged contact with the LBO crystal housing can burn skin, melt plastic, and ignite flammable material.

Warning! 

Never attempt to clean the LBO crystal or the Nd:YLF laser rod in this system. Optical damage will occur and your warranty will be voided if these two optics have been tampered with. If you feel that optical damage has occurred or cleaning of these optics is necessary, contact your authorized service representative.

Accessing the Evolution-30 optics

- Turn off the Evolution-30 power supply
- Remove the external sheet metal cover (Scientific Evolution-30 only)
- Remove the screws holding the metal cover in place and remove. Put the screws in a safe place. Remove the lid and place it on a clean surface.

Mirrors

Mirrors should be carefully cleaned with soft optical tissue and reagent grade methanol or acetone as described below.

- Always wash your hands first in order to remove all dirt and oil residues.
- Wear finger cots or gloves at all times optics are handled.
- First attempt to remove any surface contamination from the optic with either a blower brush or gentle stream of dry, filtered nitrogen or air. This will remove any particulates that would otherwise be dragged across the optic's surface if cleaning with solvent is necessary. Take care that the contamination is not merely blown onto another optical surface!
- If solvent cleaning is necessary, hold one sheet of lens tissue over the optic to be cleaned.
- Using the eyedropper, place a single drop of good quality methanol on top of the lens tissue.
- Drag the lens tissue across the optic once only.
- If a residue of solvent is left on the optic, repeat the procedure using less solvent and a new lens tissue until no residue remains.

For hard-to-reach optics:

- Wear finger cots or gloves.
- Fold a piece of lens tissue repeatedly to form a pad approximately 1 cm wide.
- Hold the pad with a pair of hemostats so that about 3 mm of the folded edge protrudes from the hemostat blades
- Saturate the pad with methanol or acetone and shake to remove excess solvent.
- Reach slightly below the center of the optic and wipe the surface of the optic toward the outside in one motion. Be careful that the tip of the hemostats does not scratch the optic.
- Repeat the operation with a clean tissue on the other faces of the optic.

Q-switch

The Q-switch can be difficult to clean; attempt to clean only if dust or debris are clearly visible. When cleaning the Q-switch crystal faces, it is easier to remove the U-shaped cover around the Q-switch in order to gain unobstructed access to the quartz faces.

6.3 Routine Maintenance – Cooling Water

To prevent metal corrosion and algae growth in the closed loop cooling water system of the Evolution-30, we recommend the use of OPTISHIELD corrosion inhibitor. This chemical treatment prevents galvanic corrosion from dissimilar metals and prevents oxidation of ferrous metals in the system, and acts as an effective algaecide. The first time application of OPTISHIELD is normally done at the factory when the Evolution-30 is manufactured. We recommend changing the OPTISHIELD solution every year for most systems. Use the procedure below for changing OPTISHIELD in the cooling water system.

Danger! 

Before handling OPTISHIELD water treatment, read the Material Safety Data Sheet included in Chapter 9 that describes the potential hazards and handling precautions associated with this chemical. This chemical may be harmful if swallowed, inhaled, or absorbed through the skin or eyes.

Caution! 

Use only steam-distilled water in the Evolution-30 cooling system. The use of de-ionized water may cause corrosion damage.

Directions for New Systems "First Time Use"

1. Flush cooling circuit with distilled water.
2. Fill cooling system with distilled water leaving 5% volume for OPTISHIELD. Calculate system capacity/volume in gallons.
3. Add OPTISHIELD to the distilled water. (Example: 1 gallon of OPTISHIELD to 20 gallons of water for first "coating cycle")
4. Circulate this solution for about 30 minutes.
5. Drain fluid DO NOT RINSE!
6. Fill cooling system with distilled water leaving 10% volume for OPTISHIELD.
7. Add OPTISHIELD to the distilled water. (Example: 1 gallon of OPTISHIELD to 10 gallons of water)

Directions "After First Time Use"

1. Drain used fluid from system.
2. Fill cooling system with distilled water leaving 10% volume for OPTISHIELD
3. Add OPTISHIELD to the distilled water. (Example: 1 gallon of OPTISHIELD to 10 gallons of water)

7 Trouble-Shooting

This chapter contains a general user-troubleshooting guide. It is provided to assist you in isolating some of the problems that might arise while using the system. A complete repair procedure is beyond the scope of this manual. For information concerning repair by Coherent, see Chapter 8, 'Customer Service'.

7.1 Trouble-Shooting Guide

Use this guide if Evolution-30 performance drops unexpectedly. If you try the corrective actions and are unable to bring your Evolution-30 performance up to specification, call your authorized service representative for help.

Symptom: Laser will not start	
Possible Causes	***Corrective Action***
No AC power	Check red 'AC Power' LED is illuminated. If not, check breaker on front of supply is in correct position; check power cord at rear of supply is tight. Check fuse.
Interlocks not met	Check interlock display on power supply. If there are lighted interlock LEDs, turn key switch off and back on to clear latched interlocks. Investigate any interlocks that are not cleared by this action (e.g. make sure the chiller is turned on and the hoses are not constricted, make sure the cover is on, make sure the user interlock is in place, etc.). See Chapter 3 for more information on each interlock.
Key switch not in ON position	Turn the key switch to the ON position (vertical). The key cannot be removed when it is in the on position.
Communications error with laptop	Check for good connection of 9-pin to 25-pin serial cable. Exit Evolution Control Software application, then switch AC power OFF on the Power Supply, wait 5 seconds, switch AC power ON, and re-launch Evolution Control Software application.

Symptom: Variations in output power	
Possible Causes	***Corrective Action***
LBO crystal temperature has drifted	Check the output power across the tuning range of the LBO crystal for the highest output power, as described in Chapter 6.
Water temperature variation	Make sure that the water chiller temperature is adjusted to the correct temperature that was set when it was installed (typically in the range 17-27 degrees Centigrade).
Cavity optics out of alignment.	The cavity mirrors can be adjusted slightly to try to optimize the output power. Read the detailed instructions in Chapter 6 before attempting to adjust the mirrors.
Optics are dirty	Inspect the optics for dirt or contamination. If dirty, clean the optics as described in Chapter 6.
Q-switch breakthrough	With the current at the High setting, turn the QSW MODE selector to the HOLD OFF position, and turn the laser on. Using an infrared viewer or card, check that there is no infrared and/or visible output beam from the laser. If there is any laser power, the Q-switch is malfunctioning or misaligned. Contact your authorized service representative for help.

Symptom: Emission light comes on, but no output	
Possible Causes	***Corrective Action***
Output shutter is closed	If front port is being used, rotate shutter open. If side port is being used, check black disc has been removed.
QSW MODE set to HOLD OFF	Check the setting of the QSW MODE selector in the SYSTEM Panel of the Control Software.
Cavity optics are out of alignment.	If the cavity optics are misaligned so much that the laser will not start, call your authorized service representative for help.

Symptom: Power is below specification	
Possible Causes	***Corrective Action***
Diode current set too low	Verify the expected output power for the Low, Medium, and High power settings.
Q-switch frequency set higher or lower than 1 kHz	Power output depends on Q-switch frequency. If you operate your Evolution-30 at a different Q-switch frequency than specified at order time, contact your authorized service representative for the power specification at that particular frequency.
Cavity optics misaligned.	The cavity mirrors can be adjusted slightly to try to optimize the output power. Read the detailed instructions in Chapter 6 of this manual before attempting to adjust the mirrors.
LBO crystal temperature has drifted	Check the output power across the 3-degree tuning range of the LBO crystal for the highest output power.
Algae growth in cooling water	Follow maintenance procedure given in Section 6.3
Diode power is low	After several thousand hours of operation, the optical power of the laser diodes decreases, and the current to the diodes must be increased to compensate. Contact your authorized service representative for help.

Symptom: Laser does not Q-switch or CW laser output	
Possible Causes	***Corrective Action***
External Q-switch input not valid	If an external Q-switch signal is being used, ensure that the signal is at least 2 V into a 50-ohm load and at least 1 µs wide, and ensure that the frequency is the prescribed value (e.g. 1–10 kHz).
QSW MODE set to CW RF OFF	Change setting of QSW MODE control to INTERNAL.
QSW BNC cable removed	If either QSW cable is removed, the Evolution-30 will report a VSWR error and change to the to the CW RF OFF QSW MODE. Verify that both BNC cables are attached at the power supply and laser bench.

8 Customer Service

At Coherent, we take pride in the durability of our products. We place considerable emphasis on controlled manufacturing methods and quality control. Nevertheless, even the finest instruments need occasional service.

8.1 Warranty

Coherent warrants to the original purchaser that the equipment is free from defects in material or workmanship. Coherent will, without charge, make any necessary repairs or replacement of parts to remedy such defect within one year, or 90 days in the case of optical surfaces, provided that Coherent in writing of the nature of such defect within one year, or 90 days for optical surfaces, following the date of original sale of the equipment. The foregoing warranty does not cover equipment which has been damaged by accident or improper use. Coherent does not assume any liability if adaptations are made or accessories attached to the equipment which impair or alter the normal functioning of the equipment. Any repair or adjustment by persons not expressly authorized by Coherent shall relieve Coherent of all obligations. The limited warranty and remedy contained in this paragraph are the only warranty and remedy pertaining to the equipment. COHERENT DISCLAIMS ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, INCLUDING WARRANTY OR MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. Coherent shall in no event be liable for any incidental, consequential or other damages or costs, lost profits or inconvenience occasioned by loss of the use of the equipment or labor expended by persons not so authorized by Coherent.

8.2 Return of the Instrument for Repair

Contact your nearest Coherent field sales office, service center, or local distributor for shipping instructions or an on-site service appointment. You are responsible for one-way shipment of the defective part or instrument to Coherent.

We encourage you to use the original shipping boxes during shipment. If shipping boxes have been destroyed or lost, we recommend you order new ones. We can return instruments only in Coherent containers.

9 Material Safety Data Sheets

This section contains the material safety data sheet (MSDS) that is supplied by the vendor of the chemical algaecide that is used in the Evolution-30 closed loop cooling system. Please read the MSDS carefully before handling or disposing of the chemical described therein (or cooling water containing the chemical). The information contained in the MSDS description is applicable exclusively to the chemical substance identified therein and for its intended use and to the unit quantity intended for that purpose. The information does not relate to, and may not be appropriate for, any applications or larger quantity of the substance described. The product is intended for use by individuals possessing sufficient technical skill and qualification to use the material with suitable discretion and understanding of the risk of handling any potentially hazardous chemical. This information has been obtained from sources believed to be reliable and accurate but has not been verified independently. Accordingly, NO REPRESENTATION OR WARRANTY, EXPRESSED OR IMPLIED, WITH RESPECT TO MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE is made with respect to the information contained in the MSDS. For further information, contact the manufacturer at the address listed on the MSDS sheet.

Material Safety Data Sheet:

OPTISHIELD

DATE REVIEWED: **June, 1999**

DISTRIBUTOR:

OPTI TEMP INC.

P.O. Box 5246

Traverse City, Michigan

49696

Telephone: 231-946-2931

Emergency Hot Line

Chem-Tel 800-255-3924

International 813-977-3668
(Collect)

USE OF PRODUCT: Treatment of select cooling water systems.

SECTION I - Product Identification

Special Components Chemical Names

This is a proprietary blend that contains the following components:

Name	*% In Product*
Sodium Nitrate	<1%
Sodium Molybdate	1-2%
Sodium Hydroxide	1-2%
Phosphoric Acid	<1.5%
Triazole	<2.5%

The Hazardous Materials Index Rating is as follows: Health=1; Flammability=0; Reactivity=1

SECTION II- Physical Data

- % Volatiles: Nil
- Color: Light Golden-Yellow
- Odor: Mild
- Specific Gravity: 1.03
- Solubility: 100% in water
- pH of 100% solution (concentrated) 11 to 12; typical 11.5

SECTION III - Fire and Explosion Hazard

- Non-Flammable

- Flash Point: Unknown

SECTION IV - Reactivity Data

- Stability: Stable
- Polymerization: None
- Exposure to Other Chemicals: Keep away from concentrated acids
- Reactivity in Water: None

SECTION V - Shipping Information

Regulation: This material is not a DOT regulated material.

This product is a freezable liquid when and where applicable.

SECTION VI –Spill

Small spills: Small spills may be soaked up using common absorbent material, and using appropriate safety equipment. Dispose of and handle in accordance with local, state, and federal regulations.

Large spills: Large spills should be pumped into suitable containers located in diked areas. Residual material should be cleaned up with water. Dispose of and handle in accordance with local, state, and federal regulations.

SECTION VII - First Aid

- Ingestion: Give milk or water, induce vomiting, and get medical attention.
- Skin: Flush with fresh water, wash with soap and water. Remove contaminated clothes and shoes.
- Eyes: Flush with fresh water for at least 15 minutes. Get medical attention.
- Inhalation: Inhalation should not occur during normal operation. However, should it occur, close container and move to well-ventilated area. If irritation persists, get medical attention.

SECTION VIII - Special Instructions

- Do **NOT** pressurize container.
- Keep container closed at all times when not in use.
- Store in cool area above 60°F. Do not allow fluid to freeze.
- Use in well-ventilated area. Do not breathe mist or vapor.
- Wash hands thoroughly after handling product.
- Protect eyes with safety goggles or glasses with side shields.