User Manual

RB *Plus* Diode-Pumped Nd:YAG Rod Laser Modules

- RBA2X
- RBA3X

CEO-UMAN-0004 J

JUNE 2012

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Important Information

Warranty Summary

Cutting Edge Optronics warrants that the products that it manufactures and sells will be free from defects in materials and workmanship for a period of one year from the date of shipment from an authorized Cutting Edge Optronics distributor. If a product proves defective within the respective period, Cutting Edge Optronics will provide repair or replacement as described in the complete warranty statement.

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Safety Information

Product End-of-Life Handling

Cutting Edge Optronics is committed to protecting the environment. In accordance with the Waste Electrical and Electronic Equipment directive (WEEE) and Restriction of Hazardous Substances in the European Union (RoHS EU) directives, Cutting Edge Optronics accepts the return of our products for disposal. When you are ready to reclaim the instrument, you must properly transfer it according to local regulations concerning WEEE equipment. Contact Cutting Edge Optronics or your local distributor for shipping instructions. Please package the products as directed for a return for repair.

ROC ROHS Declaration

In accordance with the Clause 6.2 of Marking for Control of Pollution Caused by Electronic Information Products (SJ/T11364:2006) for Measures for the Administration on Pollution Control of Electronic Information Products No. 39, Order of the Ministry of Information Industry of the Peoples Republic of China, Cutting Edge Optronics includes the following translation about our laser modules.

中华人民共和国，电子讯息产品管理办法：自我声明

生产商	**Northrop Grumman Cutting Edge Optronics**
生产商地址	20 Pointe West Blvd St. Charles, MO 63301 USA
产品名称 / 编号	**Mirus Series Laser Systems** **Models: MI-xxx-xxxx-xxxx and AMI-xxx-xxxx-xxxx**

有毒有害物质或元素标认表

部件编号	部件名称	有毒有害物质或元素					
		铅 (Pb)	汞 (Hg)	镉 (Cd)	六价铬 (CrVI)	多溴联苯 (PBB)	多溴二苯醚 (PBDE)
第一组	外壳	O	O	O	O	O	O
第二组	电线/ 连接插头	X	O	X	X	X	X
第三组	安装组件	O	O	O	X	O	O
第四组	开关组件	O	O	O	X	X	X
第五组	电路板/ 开关组件	X	O	O	O	X	X
第六组	阵列前端次模组	O	O	O	O	O	O
第七组	接触板	X	O	O	O	X	X
第八组	热交换组件	O	O	O	O	O	O
第九组	16 进制硬件	O	O	X	O	O	O
第十组	焊锡	X	O	X	O	O	O
第十一组	电线/ 连接插头	X	O	O	O	X	X
第十二组	基部/ 端帽	X	O	O	X	O	O
第十三组	硬件/ 装配	O	O	O	X	O	O
第十四组	时计组件	X	O	O	X	X	X
第十五组	包装物料	O	O	O	O	O	O

O：表示该有毒有害物质在该部件所有均质材料中的含量均在 SJ/T 11363-2006 规定的限量要求以下

X：表示该有毒有害物质至少在该部件的某一均质材料中的含量超出 SJ/T 11363-2006 规定的限量要求

Conventions

The following conventions appear in this manual:

	This icon denotes a caution or a warning, which advise you of precautions to take to avoid injury, data loss, or a system crash.
Initial Capped	The first letter in uppercase refers to menu options, e.g., **Phase Delay**, **Pulse Width**.
CAPS	Front-panel buttons, knobs, and connectors appear in all uppercase letters, e.g., **MENU, CURRENT**.
▸	The ▸ symbol separates a sequence of button pushes, e.g., **MENU** ▸ **CHANNEL SETUP** ▸ **PULSE WIDTH** means that you push the **MENU** button, then push the **CHANNEL SETUP** soft key, and then push the **PULSE WIDTH** soft key.
italic	Italic text denotes references to other resources that may be helpful to you or to bring attention to important information.
	This icon denotes a note, which alerts you to important information.
I **O**	Power Switch Position Symbols I = On O = Off

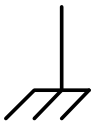
The following conventions may appear on the product:

DANGER	An injury hazard immediately accessible as you read the marking.
WARNING	A hazard not immediately accessible as you read the marking.
CAUTION	A hazard to property including the product.
	ESD: Handle Appropriately

Laser Emission: Use caution.

Shock Hazard: Use caution.

Caution: Risk of danger. Refer to manual.



Chassis Ground

General Safety Summary

The RB *Plus* module emits laser radiation that can permanently damage eyes and skin, ignite fires, and vaporize substances. The Laser Safety section (Chapter 2) contains information and guidance about these hazards. To minimize the risk of injury or expensive repairs, carefully follow these instructions.

Do not open the factory packaging before carefully reading this complete operation and maintenance manual. If you have any questions on the product which have not been discussed sufficiently within the manual, contact the manufacturer for complete instructions. **Failure to heed this warning may result in the destruction or serious damage to the device, and will void the product warranty.**

The *Service* section is intended to help guide you to the source of problems. Do not attempt repairs while the unit is under warranty; instead, report all problems to Northrop Grumman Aerospace Systems Cutting Edge Optronics (NGAS CEO) for warranty repair.

Use the form in *Appendix A: Customer Service* to describe issues with the module. We also suggest that you record information about the module such as power, settings, time and date.

About this Manual

This manual describes the installation, operation, and service of the RB *Plus* module. The manual consists of the following chapters:

- *Chapter 1: Introduction* provides a theory of operation description of the module and specifications
- *Chapter 2: Laser Safety* describes proper safety procedures you should understand before operating the module.
- *Chapter 3: Module* Details provides information about unpacking, storing and proper environmental conditions for operation.
- *Chapter 4: Installation and Operation* discusses how to setup your module and powering on your system for the first time.
- *Chapter 5: Maintenance* provides information on proper maintenance of your module.
- *Chapter 6: Service* provides resources to help fix problems with the RB Plus module
- *Appendix A: Customer Service* provides information to expedite any service request before contacting Cutting Edge Optronics.
- *Appendix B: System International Units* identifies commonly used units of measurement found in this manual.
- *Appendix C: Acronyms* provides a list of commonly used abbreviations and their descriptions used throughout this manual.

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Chapter 1: Introduction

This introduction provides the following information:

- Theory of operation
- Temperature Tuning of Laser Diodes
- RB *Plus* description
- Closed Loop Re-circulation Distilled Water Chiller
- Specifications

Theory of Operation

The RB *Plus* module was designed for use as a building block "engine" in the development or production of medium power rod laser systems or as a drop-in replacement for arc lamp pump chambers in industrial lasers. It is well suited for medium power applications such as laser marking, and can provide high stability and beam quality for more precise micro-machining and scientific applications.

Northrop Grumman Aerospace Systems Cutting Edge Optronics (NGAS CEO) diode pumped, solid-state lasers and pump modules use temperature-tuned GaAlAs laser diodes. These diodes replace arc lamps or incandescent light sources as the optical pump source. The principal advantages of this approach include:

- Longer lifetime
- More compact size
- More efficient operation

The RB *Plus* module is available in Nd:YAG with the laser rod AR coated for the highest gain wavelength of this material, 1064 nm. (NGAS CEO also offers the RB *Plus* module with a Nd:YLF rod. Throughout this manual, we will refer only to the Nd:YAG laser medium.) The RB *Plus* module is constructed within a durable and rigid structure. Exterior components and connections are shown in Figure 1-1. The diode optical output power is radially coupled into the laser rod.

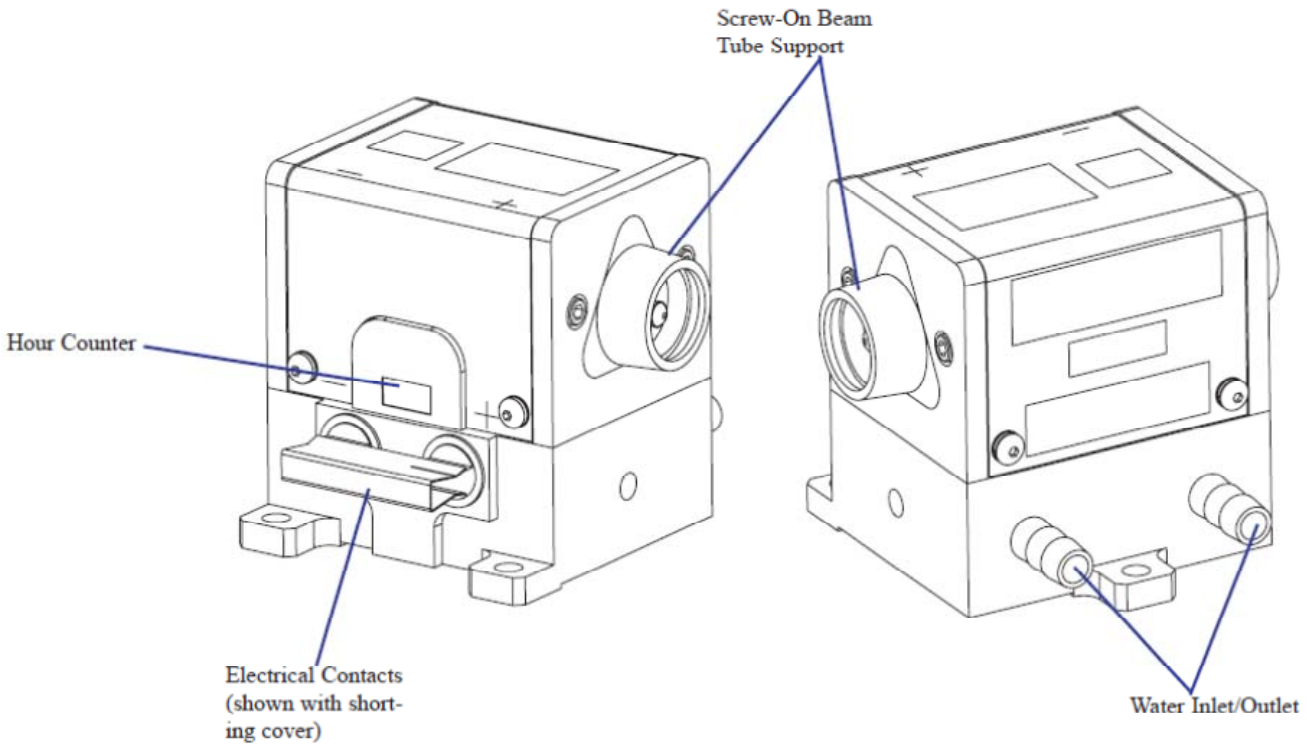

Figure 1-1 Exterior Components and Connections

Temperature Tuning of Laser Diodes

The laser diodes are located within the RB *Plus* module and tuned, wavelength matched, via the closed loop chiller. For maximum efficiency, the diode output wavelength must match the laser medium absorption characteristics (see Figure 1-2). The output spectrum of a conventional pump source for Nd:YAG operation, the xenon arc lamp, and 808 nm diode array is also shown.

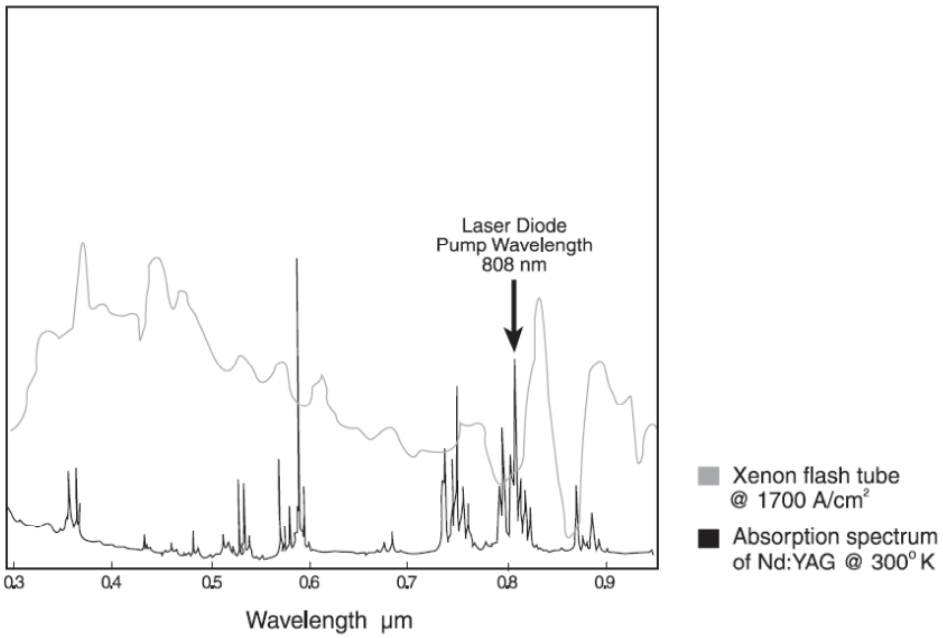

Figure 1-2 Nd:YAG Absorption Characteristics

A single GaAlAs laser diode bar has a 2 nm FWHM distribution of output wavelengths. However, the process used in the manufacture of GaAlAs laser diodes results in a peak output wavelength for each diode that fits within a 10 nm distribution of wavelengths from 800-810 nm. To match the diode output to an absorption peak of the laser medium, diodes are selected with similar peak output wavelengths within the manufacturing range. Temperature tuning is possible because GaAlAs diode characteristics are such that 0.25 nm of wavelength shift occurs for every 1°C change in temperature of the diode junction. Cooling shortens the wavelength, and heating lengthens it. Figure 1-3 shows the percentage of pump light of different wavelengths absorbed by two passes through a 6.35 mm thick rod of 0.6% doped Nd:YAG. In CEO modules, the laser diode center wavelength, under normal operating conditions, is near the absorption peak of the laser medium. The operating temperature of closed loop chiller is carefully chosen to shift the diode temperature, so that the wavelength matches the absorption peak. The final test report, included with each module, indicates the optimum operation temperature for that module.

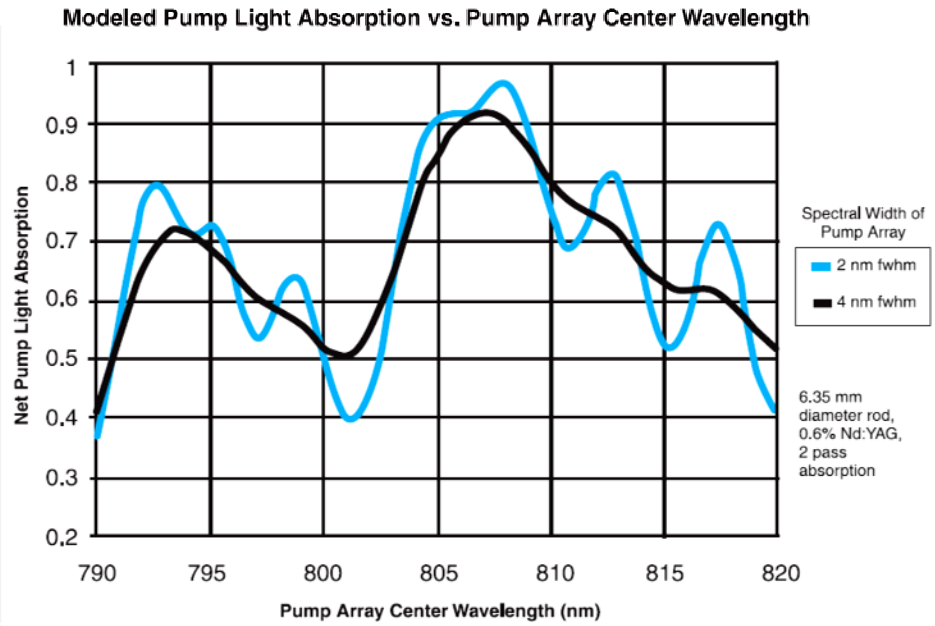

Figure 1-3 Pump Light Absorption vs. Pump Array Center Wavelength

RB *Plus* Description

The RB *Plus* module utilizes a radial transverse pump geometry to excite the solid-state laser medium (see Figure 1-4). This pump geometry results in excellent gain uniformity and lensing performance. The reflector directs the divergent diode light back to the laser medium, which is kept in a flow tube for coolant circulation. The laser medium is a rod of neodymium-doped yttrium aluminum garnet (Nd:YAG). Both ends of the rod are optically polished and include anti reflection coatings at the lasing wavelength. The ends of the Nd:YAG rod may be curved to compensate for thermal lensing, depending on module configuration.

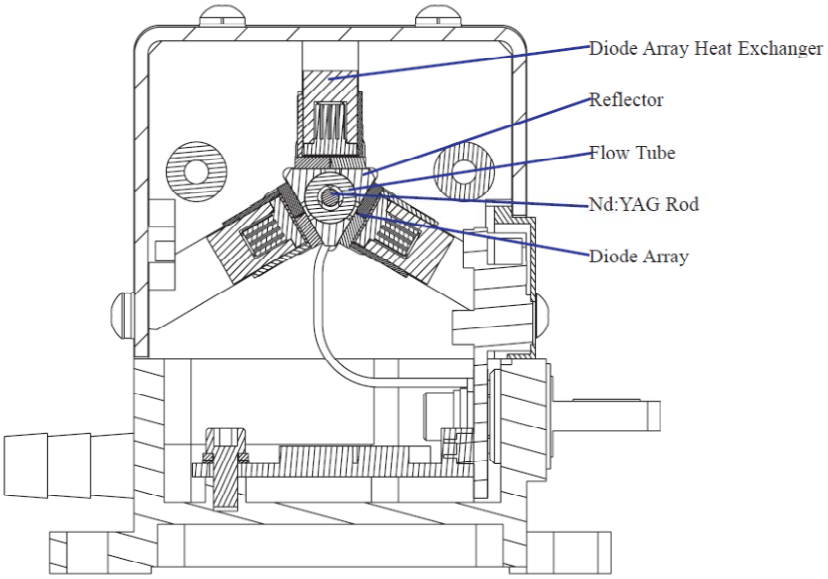

Figure 1-4 Radial Pump Geometry

The RB *Plus* is available in three physical sizes: 2.6 H x 1.82 W inches by 2.31 L, 3.47 L, or 3.81 L depending on model. The short version of the RB *Plus* is available in 3, 6, 9, and 18 diode bar versions. The mid-length model is a 12 diode bar model, and the long model has 15 diode bars. Each of the various versions is available with either a 2 mm or a 3 mm diameter rod of Nd:YAG in the appropriate length. See Figure 6 for specs.

Closed Loop Re-circulating Distilled Water Chiller

The module coolant loop is designed for an operating pressure of 50 psi. Chillers which deliver the required flow rate at lesser pressure do not provide adequate cooling. The selected chiller must have a heat capacity of greater than the waste heat for the specific model of RB *Plus* module. Depending on the model of RB *Plus*, the module dimensions, rod size, output power, and power consumption varies. Therefore, CEO recommends different model of chiller depending on the number of diode bars in a module and the local electricity which will power the chiller. The following table (Table 1-1) gives the CEO recommendations.

Table 1-1 CEO Recommended Chiller Table

60 Hz Electrical Outlets				
Model	EOL Current	Waste Heat	Polyscience Chiller No.	Chiller Capacity
RBAx0-0.33C2	32 A	212 W	6262T31CE10B	800 W
RBAx0-0.66C2	32 A	425 W	6262T31CE10B	800 W
RBAx0-1C2	32 A	635 W	6262T31CE10B	800 W
RBAx4-1C2	32 A	845 W	6362T31CE20C	1200 W
RBAx5-1C2	32 A	1060 W	6362T31CE20C	1200 W
RBAx0-2C2	32 A	1267 W	6762T41CE30D	2500 W
RBAx0-1C4	47 A	931 W	6362T31CE20C	1200 W
RBAx4-1C4	47A	1241 W	6762T41CE30D	2500 W
RBAx5-1C4	47 A	1551 W	6762T41CE30D	2500 W
50 Hz Electrical Outlets				
Model	EOL Current	Waste Heat	Polyscience Chiller No.	Chiller Capacity
RBAx0-0.33C2	32 A	212 W	6252T41CE30E	664 W
RBAx0-0.66C2	32 A	425 W	6252T41CE30E	664 W
RBAx0-1C2	32 A	635 W	6352T41CE30E	996 W
RBAx4-1C2	32 A	845 W	6352T41CE30E	996 W
RBAx5-1C2	32 A	1060 W	6752T41CE30E	2075 W
RBAx0-2C2	32 A	1267 W	6752T41CE30E	2075 W
RBAx0-1C4	47 A	931 W	6352T41CE30E	996 W
RBAx4-1C4	47 A	1241 W	6752T41CE30E	2075 W
RBAx5-1C4	47 A	1551 W	6752T41CE30E	2075 W

Specifications

RB *Plus* modules are tested to exceed the following specifications[1]. The standard production test configuration consists of a 165 ± 5 mm cavity utilizing a 0.75 mcc high reflector and a flat 80% reflective output coupler. The RBA20-0.33C2 requires a modified test configuration with a 90% reflective output coupler.

Table 1-2 RB *Plus* Series Model Specifications[1]

MODEL	RBA20- 0.33C2	0.66C2	1C2	2C2	1C4	RBA30- 1C2	2C2	1C4
Output Power[2] (W)	10	20	35	50	50	50	75	75
Rod Size (mm)	2 x63				3 x 63			
Diode Bias Voltage @ 25 Amps (VDC)	6	12	18	36	18	18	36	18
Power Consumption[3] (W)	200	400	600	1200	935	600	1200	935
Module Dimensions	2.6 H x 1.82 W x 3.07 L inches							

MODEL	RBA24-1C2	RBA34-1C2	RBA34-1C4	RBA25-1C2	RBA35-1C2	RBA35-1C4
Output Power[2] (W)	55	75	125	70	100	200
Rod Size (mm)	2 x 73	3 x 73	3 x 73	2 x 83	3 x 83	3 x 83
Diode Bias Voltage @ 25 Amps (VDC)	24	24	24	30	30	30
Power Consumption[3] (W)	800	800	1250	1000	1000	1550
Module Dimensions	2.6 H x 1.82 W x 3.47 L			2.6 H x 1.82 W x 3.88 L		

[1]Specifications subject to change without notice

[2] Output power from the production test cavity (165 mm ± 5 mm cavity utilizing a 0.75 mcc HR and flat 80% reflective output coupler)

[3]At end of life [(Operating current x Diode voltage) x 130%]

Table 1-3 RB *Plus* General Specifications

All RB *Plus*-Series Models	
Type	CW Diode Pumped Nd:YAG Rod[4]
Standard Dopant	0.6%
Output Wavelength	1064 nm
Polarization	Not Polarized
Cooling	Closed Loop Recycling Coolant[5]
Coolant Flow	> 1.0 GPM
Coolant Pressure[6]	50 PSI
Operating Temperature	20-35 ^{o}C
Optical Center from Base	1.75 inches standard (1.50 inches available)
eDrive Dimensions	3.48 H x 19 W x 17.65 D inches

[4]The Continuous wave diode arrays are sensitive to excessive thermal cycling. Current should not be turned off completely and then restored to full operating current more than 6 times per day. Current should be gradually (~3A/s) ramped up when operating current restored. See chapter 3 for more details.

[5]CEO recommends Optishield Plus$_{TM}$ /distilled water coolant (10% Optishield Plus$_{TM}$, 90% distilled water).

[6]CEO modules are leak tested to 80 psi with Nitrogen gas. CEO recommends 50 psi of chiller collant for actual operation

2

Chapter 2: Laser Safety

Please read this section carefully before installing or operating your RB *Plus* module. We recommend that all service and repair operations be performed by a NGAS Cutting Edge Optronics service engineer. If you do plan to service your laser module, please follow the procedures in the Service section of this manual.

Sections included in this chapter provide the following information:

- Caution & Warning Statements
- Precautions for Safe Operation of Class IV Lasers
- Center for Devices and Radiological Health (CDRH) OEM Product
- Key to Radiation Control Drawing
- Safety Device Checklist

Caution & Warning Statements

WARNING The NGAS Cutting Edge Optronics RB *Plus* component when used as a laser oscillator is a Class IV-High Power Laser whose beam is, by definition, a safety hazard. Avoid eye or skin exposure to direct or scattered laser radiation. Avoid direct viewing of the beam or its specular reflection. When energized, a large amount of high power invisible laser radiation is emitted from the laser module.

Follow instructions contained in this manual for proper installation and safe operation of your laser. We recommend the use of protective eyewear at all times; selection depends on the energy and wavelength of the laser beam as well as operating conditions. Consult ANSI, ACGIH, or OSHA standards for guidance.

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

WARNING At all times during installation, operation, maintenance, or service of your laser, avoid exposure to laser or collateral radiation exceeding the accessible emission limits listed in “Performance Standards for Laser Products,” United States Code of Federal Regulations, 21 CFR 1040 10(d).

ESD CAUTION The laser diodes in the RB *Plus* are sensitive to Electro-Static Discharge (ESD). Never handle the RB *Plus* module without being properly grounded through the use of properly installed and maintained grounding wrist straps or other ESD control devices. Subjecting the RB *Plus* to static shock can seriously damage or destroy the diode bars, and will void the product warranty.

ELECTRICAL WARNING The voltages in this system can be harmful or even lethal. Whenever handling or servicing the laser, always disconnect the power cord to the power supplies and drivers. Allow at least five (5) minutes for all electronics to discharge before touching or grounding of electrical connections.

Precautions for Safe Operation of Class IV Lasers

- Never look directly into the laser beam or at specular reflection, even with protective eye-wear on.
- Always wear laser safety eye-wear that is appropriate for the output power at the wavelengths of operation (808 nm pump light and 1064 nm fundamental).
- Set aside a controlled-access area for laser operation; limit access to those trained in the principles of laser safety.
- Post readily readable warning signs in prominent locations near the laser operation area.
- Use safety interlocks on all entryways. All NGAS CEO system control electronics are provided with interlock inputs to preclude operation with an open safety door. NOTE: when multiple interlocks are used, they must be connected in SERIES for proper function.
- Restrict access to laser areas to those who have been instructed in the necessary safety precautions.
- Enclose beam paths wherever possible.
- Set up experiments so the laser beam is below eye level.
- Work in an area that is well lit to avoid dilation of pupils.
- Set up a target for the beam.
- Set up shields to prevent reflected beams from escaping the laser operation area.
- The Q-switched output power of the laser emits extremely high peak optical powers, powers that can severely damage a wide array of optical components and detectors. Know the limits of your components before exposing them to the Q-switched beam.
- View an infrared laser beam with a protected image converter at an oblique angle reflecting from a diffuse surface. Do not use phosphorus cards in the Q-switched beam.
- Insure that all electrical connections are made in a safe manner.
- Where possible, position equipment so that electrical connections are shielded from accidental touch.
- No smoking, eating, or drinking should be allowed in laser areas.
- Never leave an operating laser unattended.

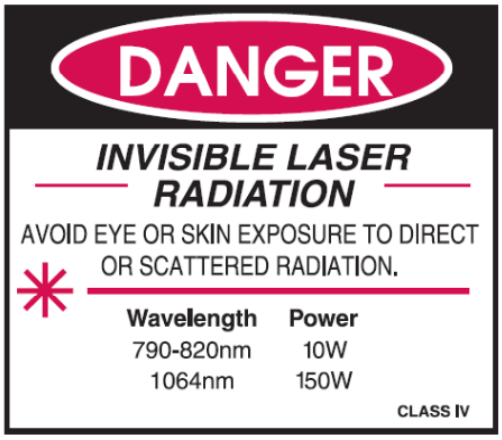

Figure 2-1 Standard Safety Warning Sign

Center for Devices and Radiological Health (CDRH) OEM Product

The RB *Plus* module is considered a component according to the Food and Drug Administration, Code of Federal Regulations Title 21, Section 1002.1(b) for use in an end system, and therefore does not fully comply with all the requirements of the Code of Federal Regulations for laser-based systems. The RB *Plus* module is capable of emitting Class IV radiation, and extreme care must be exercised in its installation and operation. Only persons familiar with the safety precautions and practices in this manual should operate the laser product.

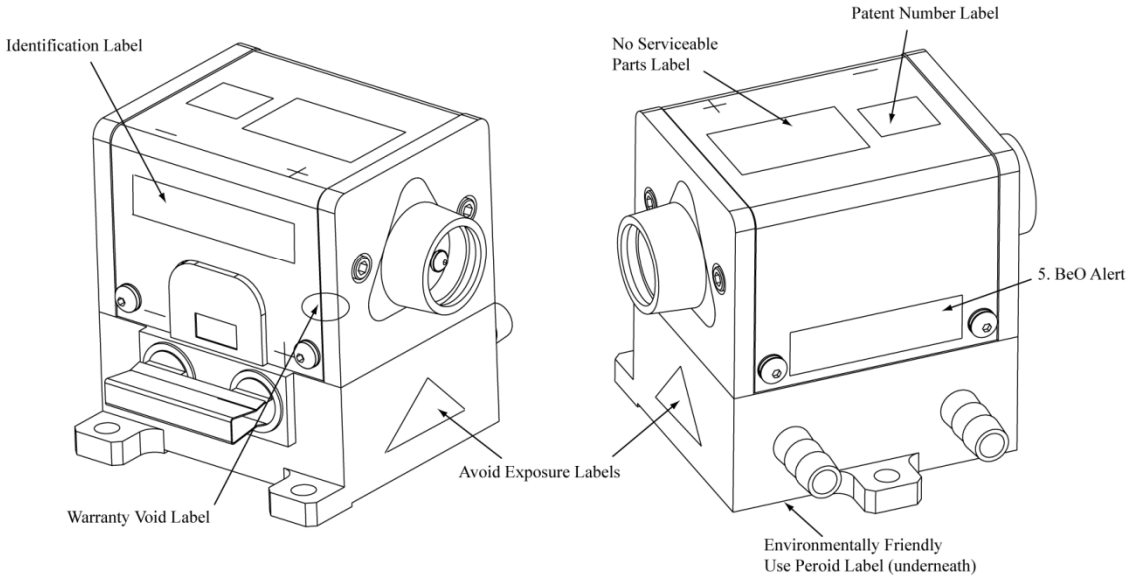

Figure 2-2 Radiation Control Drawing

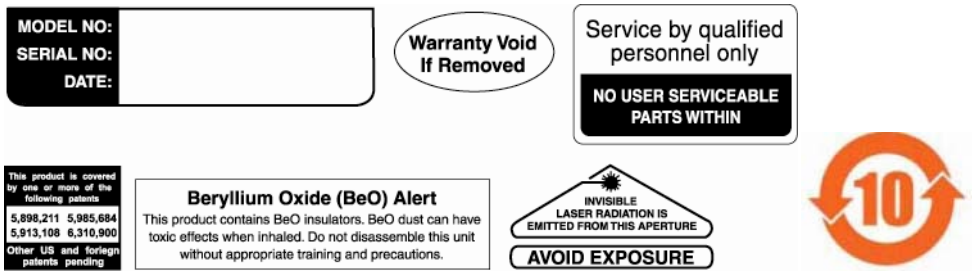

Figure 2-3 Warning Labels

Safety Device Checklist

1. Verify that all labels are securely affixed.
2. Verify that the safety interlock system is working properly.
3. Locate the module so that operation of laser and/or adjustment of control electronics do not require exposure to laser radiation.

3

Chapter 3: Module Details

This chapter describes basic operation of your RB *Plus* module. This chapter discusses:

- Unpacking your Module
- RB *Plus* Module
- Closed Loop Chiller

Unpacking your Module

Your NGAS Cutting Edge Optronics Model RB *Plus* module was carefully packed for shipment. If the carton appears to have been damaged in transit, have the shipper's agent present when you unpack.

CAUTION The module is susceptible to damage due to electro-static discharge (ESD). Always use proper ESD control devices when handling the module.

CAUTION Do not open sealed package until package has normalized to room temperature. Condensation can seriously damage the diode arrays in the laser module and may void warranty.

Inspect the unit as you unpack it, looking for dents, scratches, or other evidence of damage. If you discover any damage, immediately file a claim against the carrier and notify your NGAS Cutting Edge Optronics representative. NGAS CEO will arrange for repair without waiting for settlement of your claim.

Keep the shipping container. If you file a damage claim, you may need it to demonstrate that the damage occurred as a result of shipping. If you need to return the unit for service, the specially designed carton assures adequate protection. A manual and a final test report should accompany each unit shipped.

RB *Plus* Module

Proper storage of the RB *Plus* module involves three steps:

1. Remove all coolant from module by blowing dry air through it for 20 minutes.
2. Place a shorting connector across the module electrical contacts (see example Figure 1-1).
3. Store module in a clean, dry atmosphere (relative humidity less than 30%). If necessary, place module in a sealed bag with some form of desiccant.

The approximate diode bias voltage for the different models of RB *Plus* module can be found in the Specifications table at the end of chapter one. The electrical system should deliver approximately 10 more volts, depending on the FET used. The final test report shipped with the RB *Plus* module indicates the beginning of life current required to obtain the module's rated output power in a short cavity test. NGAS CEO recommends users not exceed the listed current, as overdriving the module reduces diode lifetime.

The RB *Plus* module connects to diode drive current via a ring tongue terminal (8-32 UNC-2B, see Figure 3-1). Positive and negative terminals are etched into the cover. NGAS CEO will sell cables for connecting this plug to customer's preferred electronic connector. Customer should specify connector type and cable length.

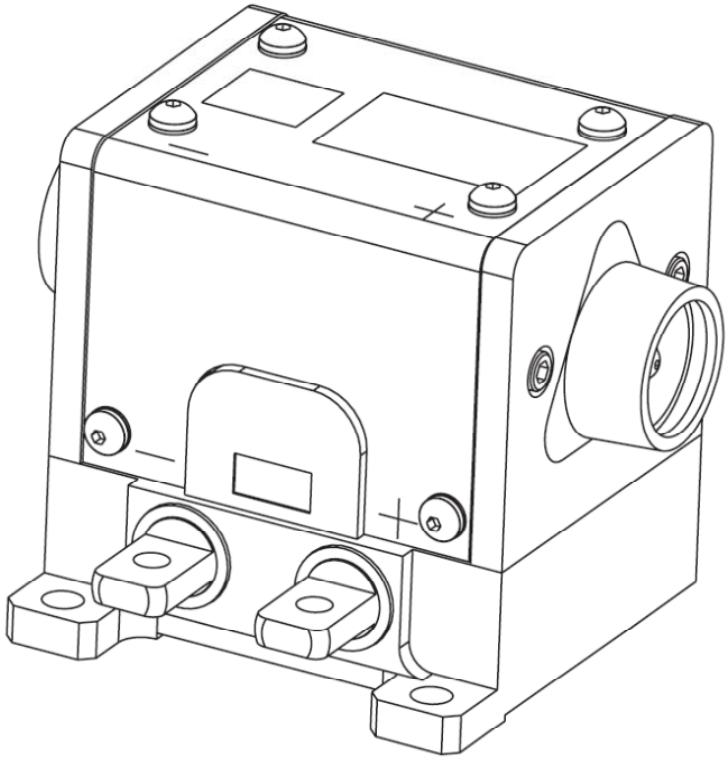

Figure 3-1 RB *Plus* with Ring Tongue Terminals

RB *Plus* module output is a result of the optical pump power from the continuous wave laser diodes. These *continuous* wave diodes are sensitive to thermal shock from repeatedly applying and removing drive current. Diodes should not be cycled on/off more than 6 times a day. When initially applying power to the module, the current should be gradually increased (~3 A/s) until the normal operating current is achieved (see final test report for initial recommended operating current). This "ramping" process reduces thermal shock and helps prolong diode lifetime. If the RB *Plus* module is going to be installed in a system where quick transitions between lasing and non-lasing are repeatedly required, then drive current to the diodes should be maintained at ~ 3 A below normal operating current when the system is not lasing. This "simmer" current will keep the diodes at close to the operating (lasing) temperature and thereby reduce thermal shock.

The diode arrays within the RB *Plus* module are aligned and sealed at the factory. Other than the laser rod, there are no user serviceable parts within the module. Contact a NGAS CEO field service engineer for repairs. Before lasing, the operator should verify that rod faces are clean. If necessary, the rod faces can be cleaned by following the procedure in the maintenance section of this manual.

Reverse Bias Protection

Diodes are polarized with respect to electrical flow. A forward biased diode readily conducts; while a reverse biased diode blocks conduction. If sufficient voltage is applied in the reverse direction, the diode is permanently damaged. Laser diodes are

the single most expensive component of a RB *Plus* module, so the customer should be careful to connect diode drive current correctly.

In order to provide the RB *Plus* modules with some protection against reverse biasing, all RB *Plus* modules are equipped with a reverse protection diode. This is another diode, usually located in the module, which forms a circuit across the laser diode arrays in the opposite flow direction (Figure 3-2). In the event of the laser diode drive current being reversed, the reverse bias protection diode will act like a short circuit, allowing the electricity to flow for a brief time with no resistance. However, the reverse bias protection diode is not able to withstand the high currents that laser diodes require. The protection diode will burn out after a brief time, and the drive current will be sent through the laser diodes in reverse.

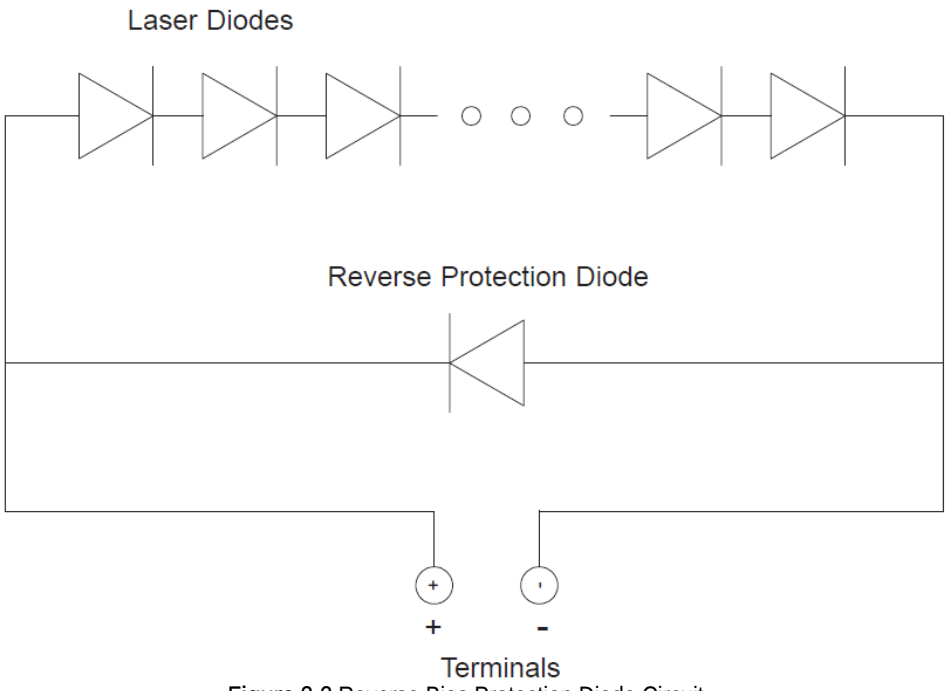

Figure 3-2 Reverse Bias Protection Diode Circuit

NGAS CEO drive electronics are designed to detect the shorted reverse protection diode, and suspend drive current before damaging the laser diodes. Customers who use third party manufactured drive electronics must configure them for use with NGAS CEOs reverse bias protection diodes. The driver should be able to detect the shorted condition because with a short across the array, the full power supply voltage will suddenly be impressed across the driver control FETs. For drivers which have a fixed power supply voltage, a much larger voltage across the drive FETs will increase the heat load and cause a dramatic rise in their temperature. For third-party drivers which have the capability to servo the voltage to produce the necessary current, a sudden decrease in output voltage should cause a corresponding large decrease in the voltage required internally within the driver, which could be detected and reported. If any of the conditions are detected, the driver should suspend diode drive current and send the operator an error message.

Closed Loop Chiller

The single most common cause of laser module return for repair involves customer damage. More than one third of all customer damaged laser modules involve cooling problems. Coolant problems almost always require the replacement of the diode arrays - the single most expensive component in NGAS CEO laser modules. Read the following section carefully to avoid damaging arrays.

CAUTION Do not operate module without cooling. Inadequate heat dissipation will seriously damage the laser diodes and will void warranty.

Table 3-1. Cooling System Requirements

Chiller and Cooling System Requirements
Optishield Plus™ /distilled water coolant (10% Optishield Plus™, 90% distilled water) [1, 2]
Coolant circulated at 50 psi.
Filter connected between chiller and inlet on module [3, 4]
Module first in coolant loop [5]
Chiller Heat Capacity > Power Consumption (Table 1-1)
Flow sensor (connected to coolant interlock on drive electronics) [6]

[1] Clean coolant is important to keeping coolant lines from clogging. Untreated tap water is not an acceptable coolant and may cause damage. Optishield Plus™ is the recommended coolant. It is made from DI water with additives to control the pH. By using DI water in the solution, scale will not form in the cooling loop. It contains biocide to prevent algae growth and corrosion inhibitors to protect yellow metals and aluminum.

[2] Optishield Plus is available from Opti Temp, Inc (http://www.optishield.net/home.php?cat=103).

[3] The filter should be capable of removing particles 5 µm or larger. The filter should be changed at a minimum of every six months. The filter should be changed more frequently if the chiller manufacturer recommends a shorter interval.

[4] Every six months, or whenever the filter is changed, the coolant should be drained. The chiller should then be cleaned. Finally clean coolant should be circulated.

[5] This ensures the cleanest, coolest coolant passes through the diodes (the most expensive component of most lasers).

[6] When not using CEO drive electronics, verify that flow sensor interrupts current to diodes less than 500 milliseconds after a low flow condition occurs.

Table 3-2. Avoid with Chillers

Avoid with Chillers
Untreated De-ionized water[1]
Iron or aluminum parts in plumbing loop
Operation below air condensation temperature[2]

[1] CEO recommends chiller water have a resistivity of less than 1.0 MΩ. Deionized water can be used if the resistivity is closely monitored and the coolant loop does not have iron or aluminum parts.

Operating the Chiller

WARNING. Do not operate module without cooling. Inadequate heat dissipation will seriously damage the laser diodes and will void warranty. If you notice coolant in the immediate vicinity of the module, shut the laser system down immediately. Check to see if the coolant is coming from the module. If so, return the module for repair. If not, repair the source of the leak and allow the module to dry thoroughly before resuming operation.

The RB *Plus* module has a coolant loop to prevent thermal damage to the laser diodes. The diodes should be kept at approximately 20 °C to 35 °C. See the final test report for optimum temperature and flow rate settings.

Operating the laser diodes for even a short period of time (less than 1 second) without coolant will cause permanent damage. To help prevent this, all Cutting Edge Optronics drive electronics are equipped with a coolant interlock. This interlock interrupts drive current to the diodes when coolant flow rate drops below set point. For this to function properly, a flow sensor must be used in the coolant loop. When setting up the laser system for the first time, Cutting Edge Optronics recommends testing the flow interlock before firing. This can be accomplished by setting the drive current to a very low level (~ 1 A) then attempting to fire the laser with the chiller off. In case interlock does not function correctly, be prepared to manually turn off laser. By testing the interlock with a minimal current, the risk to the laser diodes is minimized.

WARNING. Do not operate the coolant system below air condensation temperature (dew point) at the laser head. Condensation on the diode arrays can seriously damage the laser head and will void the warranty. Consult a Cutting Edge Optronics field service engineer if you have any questions.

Air Condensation Temperature

The air condensation temperature (or dew point) is the highest surface temperature that allows water to form from the ambient water vapor. The dew point is dependent on the surrounding air temperature and relative humidity. If a surface (such as a laser diode) is cooled at or below the condensation temperature, water may collect on that surface. A formula for calculating dew point is given below, along with a calculated table. All temperatures are given in Celsius.

Condensation Temperature
$T_d = \frac{237.7 \times \alpha(T, RH)}{17.27 - \alpha(T, RH)}$ $\alpha(T, RH) = \frac{17.27 \times T}{237.7 + T} + \ln\left(\frac{RH}{100}\right)$
where
T is the ambient air temperature in degrees Celsius (0 < T < 60)
RH is the relative humidity in percent (1% < RH < 100%)
T_d is the air condensation temperature

For example, suppose your chiller is running at 22 °C and the ambient air temperature near the laser is 28 °C (82 °F). Referring to Figure 3-4 and Table 3-4, find the intersection of the 28 °C air temperature and the curve for the 22 °C diode temperature. At a relative humidity of 70 percent or greater, condensation will form on the laser diodes.

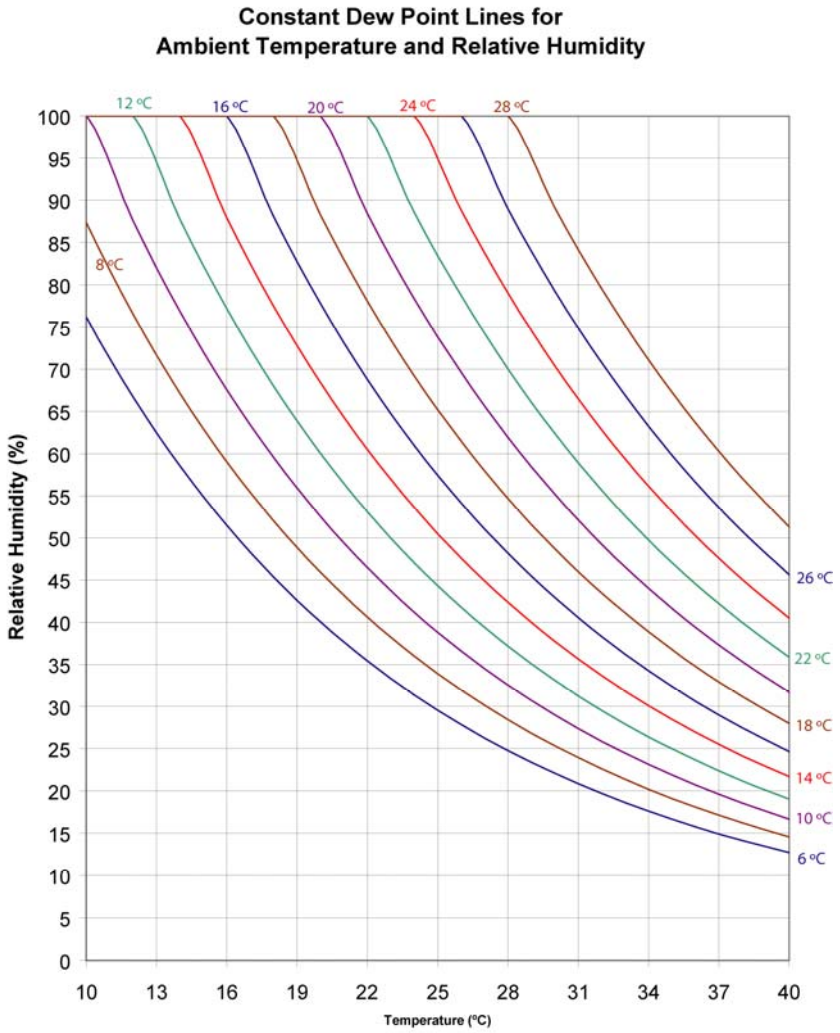

Figure 3-1. Constant Dew Point Lines for Ambient Temperature and Relative Humidity

Table 3-3. Table of Air Condensation Temperature at Given Ambient Air Temperature (Celcius) and Relative Humidity (percent)

	Relative Humidity										
	1%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
10	-43.9	-20.2	-11.9	-6.8	-3.0	0.1	2.6	4.8	6.7	8.4	10.0
12	-42.6	-18.7	-10.3	-5.0	-1.2	1.9	4.5	6.7	8.7	10.4	12.0
14	-41.4	-17.1	-8.6	-3.3	0.6	3.7	6.4	8.6	10.6	12.4	14.0
16	-40.2	-15.6	-7.0	-1.6	2.4	5.6	8.2	10.5	12.5	14.4	16.0
18	-39.0	-14.1	-5.3	0.2	4.2	7.4	10.1	12.4	14.5	16.3	18.0
20	-37.8	-12.5	-3.6	1.9	6.0	9.3	12.0	14.4	16.4	18.3	20.0
22	-36.6	-11.0	-2.0	3.6	7.8	11.1	13.9	16.3	18.4	20.3	22.0
24	-35.4	-9.5	-0.4	5.3	9.6	12.9	15.7	18.2	20.3	22.3	24.0
26	-34.2	-8.0	1.3	7.1	11.3	14.8	17.6	20.1	22.3	24.2	26.0
28	-33.0	-6.5	2.9	8.8	13.1	16.6	19.5	22.0	24.2	26.2	28.0
30	-31.8	-4.9	4.6	10.5	14.9	18.4	21.4	23.9	26.2	28.2	30.0
32	-30.6	-3.4	6.2	12.2	16.7	20.3	23.2	25.8	28.1	30.1	32.0
34	-29.5	-1.9	7.8	13.9	18.5	22.1	25.1	27.7	30.0	32.1	34.0
36	-28.3	-0.4	9.5	15.7	20.2	23.9	27.0	29.6	32.0	34.1	36.0
38	-27.1	1.1	11.1	17.4	22.0	25.7	28.9	31.6	33.9	36.1	38.0
40	-26.0	2.6	12.7	19.1	23.8	27.6	30.7	33.5	35.9	38.0	40.0

If required to operate a laser in conditions near to the condensation temperature, take precautions to keep the RB Module dry. The module should be operated inside an area that is purged with nitrogen (N_2) or encased in a sealed enclosure with a desiccant.

4

Chapter 4: Installation and Operation

NGAS CEO recommends using the eDrive diode drive electronics and a Polyscience chiller to operate the RB *Plus* module (see Chapter 1 for chiller capacities). The following chapter contains step by step procedures detailing the installation and operation of the RB *Plus* module with these peripherals. This chapter covers:

- RB *Plus* Laser Module Assembly and Connections
- Closed Loop Water Chiller Assembly
- Starting the Laser
- Pre-start Conditions
- Turning on the Laser System
- Powering the RB *Plus* Module
- Standby Condition
- Turning Off the System

The purchaser is responsible for any loss and injury during installation and use of the RB *Plus* module. NGAS CEO recommends that a qualified service technician install and maintain the RB *Plus* module. If you intend to service the RB *Plus* module yourself, please follow the following procedures.

RB *Plus* Laser Module Assembly and Connections

CAUTION. The module is susceptible to damage due to electro-static discharge (ESD). Always use proper ESD control devices when handling the module.

See Module Connection Diagram (figure 4-1).

1. Check to make sure the AC power switch located on the rear panel of the eDrive Laser Diode Controller is in the OFF position.
2. Connect ring-tongue terminals on the base of the RB *Plus* module to the Array Drive Output connector located on the rear of the eDrive.
3. Connect the lab door interlock switch (or other interlock used) to the Interlock connector on the rear of the eDrive. If multiple interlocks are needed, be sure all interlocks are connected in *SERIES* to this port. If no remote interlocks are used, short the connection to allow for normal laser operation.
4. If an external power supply is used, check to make sure the AC power switch located on the front of the external power supply is in the OFF (O) position. Then, connect the output of the supply to the input power lugs of the eDrive located at the upper left of the rear panel.
5. Verify the eDrive has clear space in rear and on each side of unit to allow proper air flow.
6. Plug the eDrive and external power supply (if used) cords into the appropriate facility power. The eDrive diode driver is equipped with universal power circuitry accepting voltages ranging from 100-260 VAC and a frequency range of 47-63 Hz.

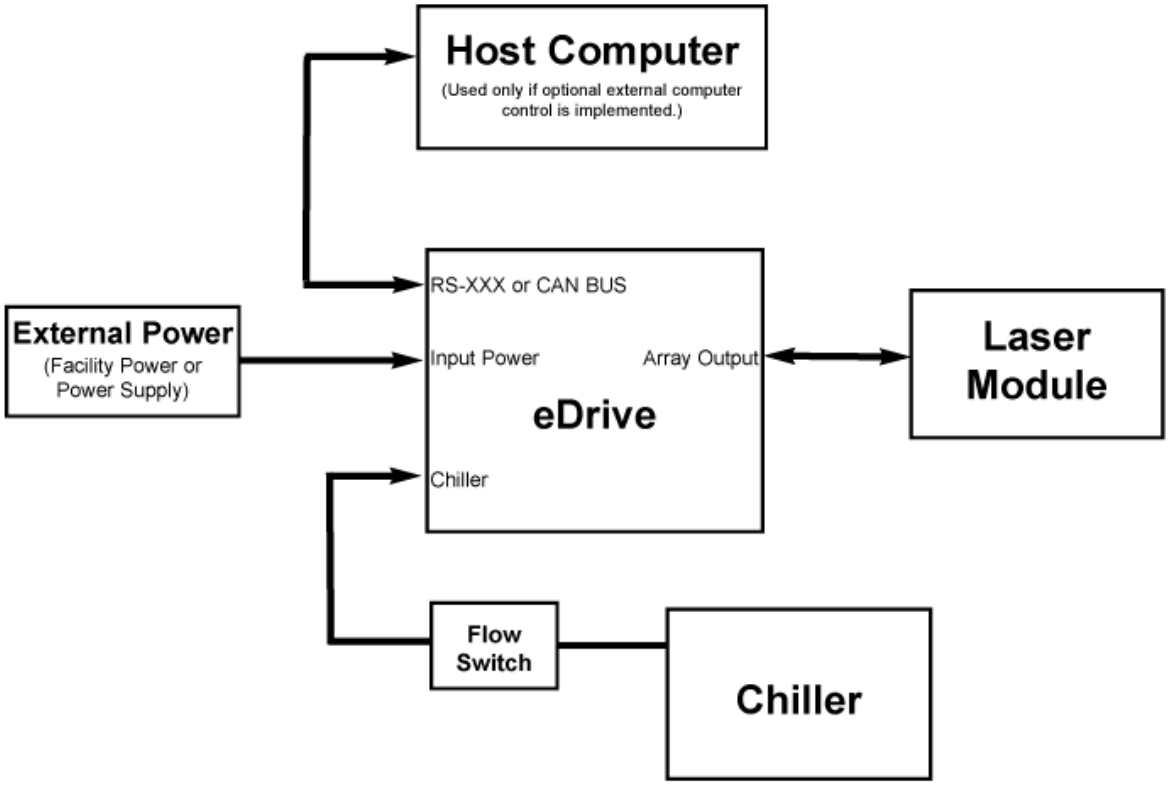

Figure 4-1 Connection Diagram

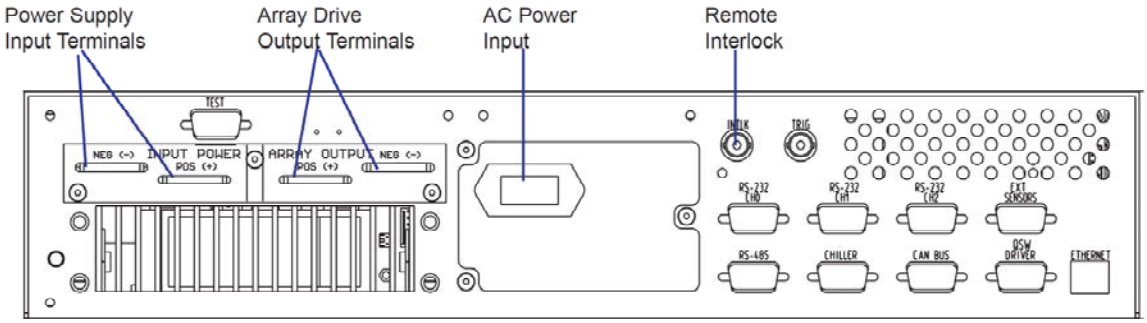

Figure 4-2 eDrive Rear Panel

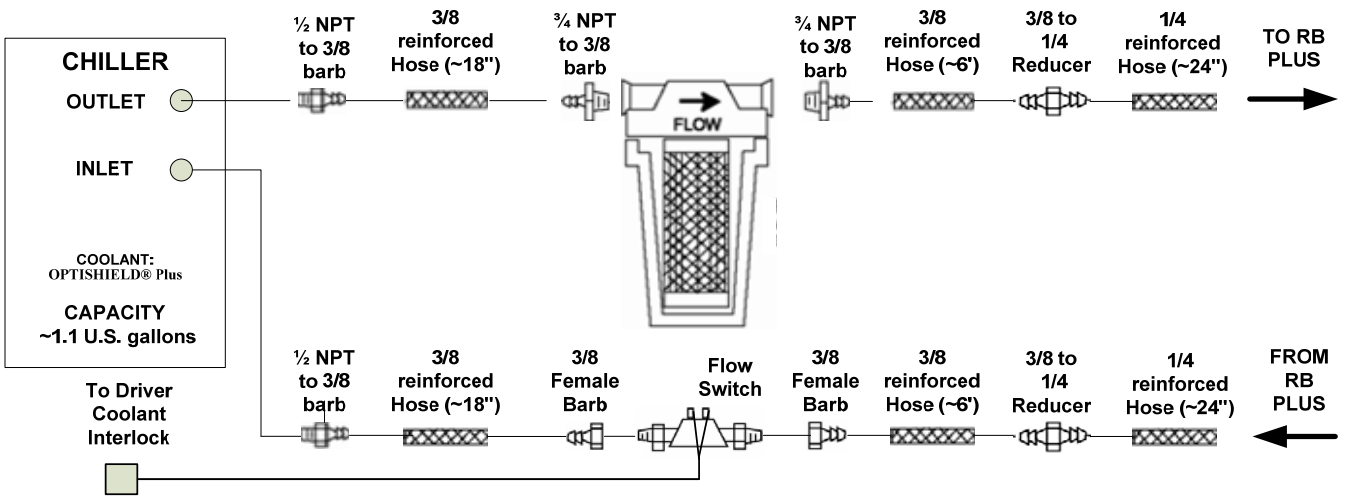

Figure 4-3 Chiller Assembly Drawing

Closed Loop Water Chiller Assembly

1. Place the chiller on the floor near the RB *Plus* laser module. Refer to the chiller instruction manual for power requirements, settings and instructions on how to set up the chiller.
2. Attach the cooling lines (included with the plumbing accessory kit) to the hose barb fittings on the chiller and on the RB *Plus* laser module. Remember to attach the coolant filter between the chiller and the laser head. The filter may be attached to the back of the chiller or to some other stable mounting point (i.e. wall).

The standard plumbing arrangement for a typical closed loop chiller (including hose diameters) is shown in Figure 4-3. The input/output coolant connections on the RB *Plus* are not polarized. Either hose barb on the RB *Plus* laser module can be arbitrarily chosen as the coolant inlet. Coolant flow direction is not important, as long as the coolant passes through the filter before entering the RB *Plus* laser module.

CAUTION. Do not use de-ionized (DI) water in the closed loop chiller based system. If you must use DI water, monitor the resistivity (less than 1.0 MΩ) closely and avoid iron or aluminum parts in the coolant loop.

3. Fill the chiller reservoir and filter housing manually with coolant (10% Optishield PlusTM, 90% distilled water) It is made from DI water with additives to control the pH. By using DI water in the solution, scale will not form in the cooling loop. It contains biocide to prevent algae growth and corrosion inhibitors.

CAUTION. Do not allow chiller to fill the filter housing, as air can become trapped within the system.

4. Power on the chiller
5. Make sure no air remains trapped in the lines resulting in a positive back pressure when chiller is turned off. Positive back pressure can hold the flow switch closed even though flow is not being supplied to the laser module. Air is trapped in the lines if coolant level drops when chiller is turned on and then rises when turned off. Failure to heed this warning may result in the destruction or serious damage to the device, and will void the product warranty.
6. Verify the pressure gauge located on the front panel of the chiller reads approximately 50 psi. If it does not, adjust the bypass valve on the rear of the chiller. Minimum coolant flow is one gallon per minute. See final test report for optimum flow rate.
7. Verify the temperature located on the front panel of the chiller reads appropriately. Optimum temperature is listed on the final test report but will be between 15 °C -30 °C.
8. Connect coolant flow switch to coolant interlock on rear of eDrive diode driver. When connecting the coolant flow switch, make sure that it is connected to the return line of the chiller and the arrow located on the top of the switch is pointing in the direction of coolant flow.

Starting the Laser System

Pre-start Conditions

1. Wear laser safety goggles which protect user from1064 nm (fundamental) and 808 nm radiation.
2. Position the RB *Plus* module in a laser cavity such the output will be directed toward a safe target.
3. Verify that the system is correctly assembled.
4. Verify that the rod faces are clean and not capped or covered.
5. Verify that the filter on the closed loop chiller is connected to the inlet hose barb.
6. Switch the Closed Loop Chiller to the **ON** position. Verify coolant flow from chiller.

WARNING. Do not operate coolant system below air condensation temperature (dew point) at laser head. Condensation on the diode arrays can seriously damage the laser head and may void warranty. Consult a CEO field service engineer if you have any questions.

Turning The Laser System On

1. Verify coolant temperature and flow rate are correct.
2. Turn power switch on external power supply to **ON** position.
3. Turn the AC power switch on rear of the eDrive to the **ON** position.
4. Turn the Key switch to the **ON** position.
5. Before applying current to diodes, shut off chiller to verify that the Coolant Fault interlock comes on.
6. Restart the chiller. Select **Clear** and verify the error display is no longer present.

Powering the RB *Plus* Module

1. Form main menu, select **Channel Setup ▸ Channel 1 ▸ Set Current Limit**. Use the selection knob to set your maximum current amplitude to a value considered safe for the intended module. The eDrive will not allow the current amplitude to be set higher than the limit. RB *Plus* modules should never be run with more than 32 Amps, however to prevent premature diode degradation, you may wish to set this limit at the beginning of module life to 5 Amps greater than the recommended operating current.
2. From the main menu, select **Channel Setup ▸ Channel 1 ▸ Set Current**. Use the selector knob to select a low current level of approximately 10A.
3. Press **EMISSION**. After a few warning beeps (approximately 4 second delay), the eDrive begins to drive the array.
4. Slowly begin to adjust the current amplitude setting until the desired current level is achieved. (For initial use, see final test report for current.)
5. Using an infrared viewer or phosphor card continue increasing the current checking for output at the laser threshold current indicated on the final test report.
6. Continue increasing the current until the desired output is obtained or until the current reaches approximately 5 A greater than the current used that last time an acceptable laser output was achieved. (For initial use, see final test report for current.)
7. If you cannot achieve desired output within 5 A, contact CEO for assistance.

Standby Condition

If you are finished using the module but want to use it again within the next hour, it is best to go to “standby”. To go to standby from a lasing condition, press the **EMISSION** button on the eDrive Laser Controller. In this condition, the drive

current to the laser diode shuts off but the closed loop chiller maintains the optimum diode temperature.

To resume lasing, press the **EMISSION** button on the eDrive laser controller. Again an audible warning will sound for approximately 4 seconds prior to firing the laser.

Turning Off the System

1. Press the **EMISSION** button to turn off drive current.
2. Close shutter (if installed).
3. Switch the main AC power switch on the external power supply, located on the front panel, to the **OFF** position.
4. Press the main AC **POWER** switch of the eDrive, located on the front panel. Hold down for approximately 5 seconds until the eDrive shuts down.
5. Allow chiller to run for a couple of minutes (1-2 minutes).
6. Switch the closed loop chiller to the **OFF** position.
7. Turn the key switch on the eDrive to the **OFF** position.
8. Remove the key. Do not leave the laser accessible to people who are untrained in laser safety or operation.

5

Chapter 5: Maintenance

The chapter contains information in these sections:

- Rod Removal and Replacement
- Rod Cleaning
- Leak Test Procedure
- Adjusting the Operating Current
- Cleaning the Chiller

Rod Removal and Replacement

The only user serviceable part in the RB *Plus* module is the Nd:YAG rod, which can be replaced by the user. YAG rods rarely break, frequent replacement may be a sign of another problem in the RB *Plus* module. Contact Cutting Edge Optronics if you have any further questions.

CAUTION. The module is susceptible to damage due to electro-static discharge (ESD). Always use proper ESD control devices when handling the module.

CAUTION. Ensure gloves or finger cots are worn during this procedure and that it is carried out in a clean environment, preferably under a laminar flow hood.

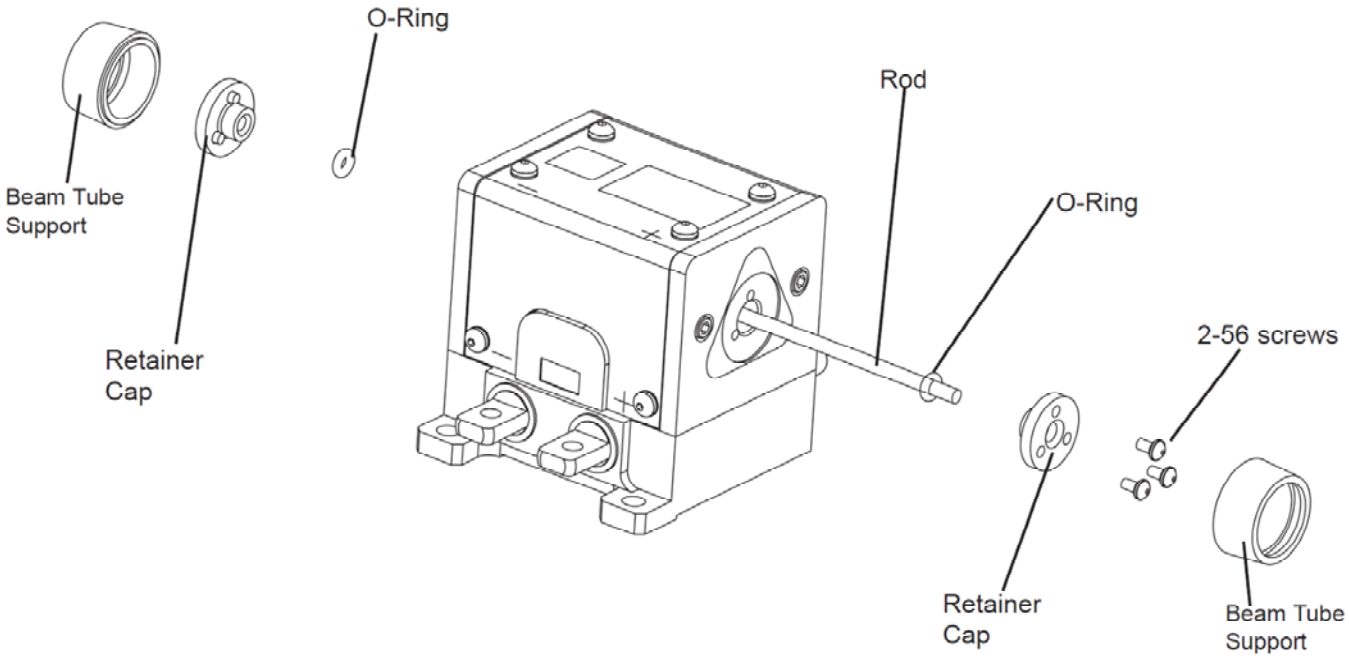

Figure 5-1 Rod Replacement Drawing

1. Remove the beam tube supports from the retainer caps. These are just threaded on.

2. Remove the retainer caps by removing the six 2-56 button head screws with a 0.50” allen wrench.

CAUTION. Use extreme caution during the remaining steps of this procedure to insure that the rod faces and/or coatings are not damaged. Never use a tool that can scratch the rod on the O-rings.

3. To extract the O-rings that hold the rod in position, place index fingers on each end of rod and apply pressure first at one end, then the other. Press back and forth until one of the O-rings slides out of its notch.
4. Once O-ring is dislodged, press on same end of rod to dislodge the other O-ring. Repeat this until O-ring moves to the end of the rod, where it can be easily removed by hand. Remove the rod. If necessary, loosen an O-ring with plastic or fiberglass tool. (CEO recommends Techni-Tool #43SO122.) Be careful not to damage the rod (end faces or barrel).
5. Unwrap the new rod and inspect the end faces.
6. Obtain two 70-60 Viton O-rings if using a 2mm rod or two 70-9855 Viton O-rings if using a 3mm rod. These o-rings are supplied with the module.
7. Place one of the corresponding O-rings over one end of the rod. Position the O-ring approximately 10mm from the end of the rod.
8. Insert the opposite end of the rod into the corresponding hole in one end of the module until it protrudes from the hole in the opposite end. Be careful not to chip or scratch the rod while inserting it.
9. Place one of the retainer caps onto the endplate and start the three 2-56 screws (with lock and flat washers).
10. Place the second O-ring over the opposite end of the rod.
11. Place the remaining cap onto the second endplate and start the three 2-56 screws (with lock and flat washers).
12. Position the rod equidistant from each end of the pump module using gloved fingers or the soft end of a cotton swab soaked in acetone or methanol.
13. Tighten the retainer caps with the 0.50” Allen wrench.
14. Inspect both rod ends for cleanliness. If necessary, clean the ends of the rod with a puff of dry nitrogen or moisture-free canned air.
15. Look at rod reflections with either an autocollimator or a HeNe to verify there is no rod stress. When a HeNe beam is shot down an unstressed rod the reflections from the front near and far surfaces align. If the reflections are separated, the rod is stressed.
16. Leak test according to the following procedure. Alternately, turn on the chiller and allow coolant to flow for approximately 20 minutes. Examine pump module for leaks.

17. If pumphead leaked: first fix the leak, then test again for leaks, finally allow module to dry thoroughly before lasing. Firing wet diodes will permanently damage them.

Rod Cleaning

CAUTION. Ensure gloves or finger cots are worn during this procedure and that it is carried out in a clean environment, preferably under a laminar flow hood.

First, blow optical surface with dry nitrogen. Then, use either hemostats and lens tissue or a tight-wrapped cotton tipped applicator, lightly wetted with acetone or methanol to wipe the rod face. The wipe pattern should be in a circular motion from center towards edge. Inspect the rod for cleanliness. Repeat if necessary.

Leak Test Procedure

Laser diodes are very sensitive to water damage. If you have access to pressurized nitrogen and a pressure gage, you can test for leaks without exposing the diodes to water.

1. Attach a nitrogen source to one of the coolant ports on the module being tested (test article) and attach the termination valve to the other coolant port on the test article.
2. Close the termination valve.
3. Open the inlet valve and adjust the regulator to obtain 80 psi on the pressure gauge.
4. Close the inlet valve. Wait.
5. Return after 30 minutes and record pressure on the gauge. Subtract this pressure from starting pressure of 80 psi to get the pressure drop over 30 minutes.
6. Pass/Fail requirements: if the pressure drop is greater than 3 psi FAIL, if the pressure drop is less than 3 psi PASS.

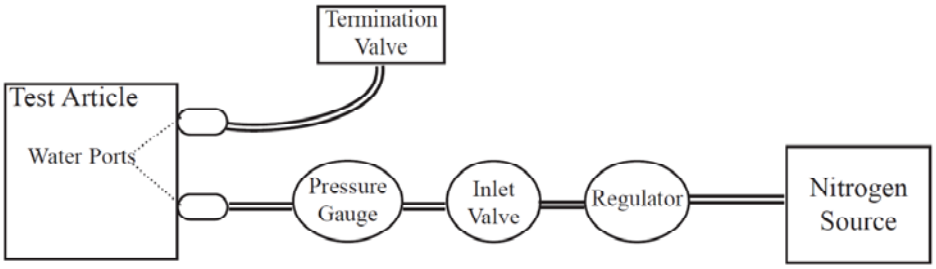

Figure 5-2 Nitrogen Leak Test Layout

Adjusting the Operating Current

The specification for laser module optical output is provided in the final test report delivered with the system. During its early lifetime, the laser diodes will deliver this specified power at or below 25 A of current. Due to the high average powers of the diode bars used in your NGAS Cutting Edge Optronics laser module, it is reasonable to expect the diode array to gradually degrade with use.

Determining when the current limit requires adjustment:

Make sure the temperature is at the correct set point. If the temperature is incorrect low output power can result, leading to unnecessary current increases. Check to make sure the rod faces are clean. If the rod faces are dirty low output power will result, leading to unnecessary current increases. Check to make sure the coolant and filter are clean. If the coolant is dirty, deposits accumulate on the Nd:YAG rod, which prevents absorption of diode light. This results in low output power, leading to unnecessary current increases. If the temperature is correct and the rod faces and coolant are clean, yet the output power is still low, the operating current may need to be slightly raised. Contact your NGAS Cutting Edge Optronics field service engineer if you have any doubts.

CAUTION. Raising the current limit before it becomes necessary can severely shorten diode lifetime.

Adjusting the Temperature Set Point for the Re-circulating Water Chiller

The temperature set point for the water chiller was determined at NGAS CEO and indicated on the Final Test Report. Normally the temperature will not need adjustment. It is possible however, that this adjustment may be recommended by your Cutting Edge Optronics field service engineer during the later part of the laser diodes' lifetime and after several current increases. Increasing the diode drive current increases the heat load on the diode, resulting in a shift in diode wavelength. In order to compensate for this shift a slight adjustment, most likely colder, of the

temperature set point on the recirculation water chiller may be required. Changing the temperature set point will change the output wavelength of the laser diode; this adjustment should be done in one degree Celsius increments. Look for an increase in optical output power on an external power meter. Wait a few minutes between each adjustment allowing the chiller to stabilize. Continue until you obtain the maximum possible power.

Cleaning the Chiller

Every six months, the chiller should be drained and cleaned. The filter should be replaced, and new clean coolant should be used in the chiller. The recommended procedure for cleaning a chiller is detailed below.

1. Drain chiller completely.
2. Remove filter from housing.
3. Add the 460-CCL2567 cleaning solution to the cooling system till full.
4. Circulate the cleaner for a minimum of 30 minutes.
5. Drain system completely.
6. Refill system with cleanest water available (preferably distilled, demineralized, or reverse-osmosis)
7. Circulate rinse water for 20 minutes.
8. Drain system completely.
9. Refill system with cleanest water available (preferably distilled, demineralized, or reverse-osmosis)
10. Circulate second rinse water for 10 minutes.
11. Drain system completely.
12. Install new 5 micron filter into housing.
13. Record cleaning date on sticker with a six-month reminder to drain & clean the system. Affix sticker to chiller (or cabinet).
14. Refill chiller coolant reservoir with coolant (10% Optishield Plus$_{TM}$, 90% distilled water).
15. Chiller ready to use.

6

Chapter 6: Service

At Northrop Grumman Aerospace Systems Cutting Edge Optronics, we are proud of the durability of our products. Our manufacturing and quality control processes emphasize consistency, ruggedness, and high performance. Nevertheless, even the finest instruments break down occasionally. We believe that the reliability record of our instruments compares favorably with that of our competition, and we hope to demonstrate our superior service by providing dependable instruments and, if the need arises, service facilities that can restore your instrument to peak performance without delay.

When calling for service in the U.S., dial (636) 916-4900. To phone for service in other countries, contact your sales agent.

This chapter provides reference to types of customer service needs:

- Contacting customer service
- Return the instrument for repair

Contacting Customer Service

To expedite your service needs, please complete the questionnaire in *Appendix A: Customer Service* ***before*** you contact Cutting Edge Optronics Customer Service. Complete the questionnaire with as much detail as possible and retain a copy for your records.

E-mail or fax the form to Cutting Edge Optronics (refer to the second page of this manual for contact information) and notify your customer service representative that it has been sent.

Return the Instrument for Repair

A return merchandise authorization (RMA) *is required* prior to shipping any instruments to Cutting Edge Optronics. Contact Cutting Edge Optronics or your local distributor for RMA and shipping instructions.

CAUTION. Failure to obtain proper shipping instructions may result in damage to the instrument.

Use the packing boxes supplied by Cutting Edge Optronics to ship your instruments. If shipping boxes have been lost or destroyed, replacements are available for a nominal charge from Cutting Edge Optronics.

Remove all coolant from module by blowing dry air through it for 20 minutes, prior to packaging for shipment. Place a shorting connector across the electrical connector (see example Figure 1-1). Place module in a sealed bag inside shipping container. Place some form of desiccant in bag with module.

WARNING. Damage from residual water due to condensation or expansion can be catastrophic to the diode arrays or laser rod if not dealt with properly. Such damage is excluded from warranty coverage.

A

Appendix A: Customer Service

This form has been provided to encourage you to tell us about any difficulties you may have experienced while using your Northrop Grumman Cutting Edge Optronics instruments or user manuals. Call or write our customer service department to bring attention to problems that you may not have personally experienced. We are always interested in improving our products and manuals, and we appreciate all suggestions.

Date:
Name:
Company or Institution:
Department:
Address:

RB Plus Model Number:	Serial Number:
Chiller Model Number:	Serial Number:
eDrive Model Number:	Serial Number:
RB Plus Manufacture Date:	RB Plus Operating Hours:

Questions

What is the coolant flow rate (GPM)?

What is the set temperature on the chiller (^{o}C)?

What is the coolant pressure on chiller (PSI)?

What are the set current and actual current from eDrive (A)?

What is the laser cavity configuration?

What is the measured CW power (W)?

When did the problem happen?

Have you changed any settings recently (yes/no)?

What are the changes made recently to the system?

Please describe the problem or RB Plus behavior as detailed as possible:

Suggestions

Email or fax to:

Northrop Grumman
Cutting Edge Optronics, Inc.
20 Point West Boulevard
Saint Charles, MO 63301 USA
Phone: (636) 916-4900
Fax: (636) 916-4994
Email: st-ceolaser-info@ngc.com

Appendix B: System International Units

The following System International (SI) units, abbreviations, and prefixes are used throughout Cutting Edge Optronics user manuals:

Quantity	Unit	Symbol
mass	gram	g
length	meter	m
time	second	s
frequency	Hertz	Hz
force	Newton	N
energy	Joule	J
power	Watt	W
electric current	Ampere	A
electric charge	Coulomb	C
electric potential	Volt	V
resistance	ohm	Ω
inductance	Henry	H
magnetic flux	Weber	Wb
magnetic flux density	Tesla	T
luminous intensity	candela	cd
temperature	Kelvin	K

Abbrv.		Prefixes
tera	(10^{12})	T
giga	(10^{9})	G
mega	(10^{6})	M
kilo	(10^{3})	k
deci	(10^{-1})	d
centi	(10^{-2})	c
milli	(10^{-3})	m
micro	(10^{-6})	μ
nano	(10^{-9})	n
pico	(10^{-12})	p
femto	(10^{-15})	f
atto	(10^{-18})	a

Appendix C: Acronyms

Acronym	Description
ACGIH	American Council of Government Industrial Hygienists
ANSI	American National Standards Institute
AR	Anti-Reflective
AO	Acusto-Optical (type of Q-switch)
CDRH	Center for Devices and Radiological Health - U.S. Food and Drug Administration
CEO	Cutting Edge Optronics, Incorporated
CFR	Code of Federal Regulations
CW	Continuous Wave
DC	Direct Current
EO	Electro-Optical (type of Q-switch)
ESD	Electro-Static Discharge
FET	Field Effect Transistor
FDA	U.S. Food and Drug Administration
FWHM	Full Width - Half Max
GaAlAs	Gallium Aluminum Arsenide
GPM	Gallons Per Minute
HR	High Reflector
HV	High Voltage
IR	Infrared
KTP	Potassium Titanyl Phosphate
LBO	Lithium Triborate
MCC	Meters Concave
Nd:YAG	Neodymium-doped Yttrium Aluminum Garnet
Nd:YLF	Neodymium-doped Yttrium Lithium Floride

Acronym	Description
NGAS	Northrop Grumman Aerospace Systems
NIR	Near Infrared
OEM	Original Equipment Manufacturer
OSHA	Occupational Safety and Health Administration
PRF	Pulse Repetition Frequency
PSI	Pounds per Square Inch
SHG	Second Harmonic Generator
TEC	Thermo-Electric Cooler
TTL	Transistor - Transistor Logic
USA	United States of America
VAC	Volts, Alternating Current