User's Manual

ULTRA CFR Nd:YAG Laser System

BIG SKY LASER TECHNOLOGIES, INC.

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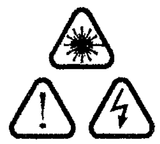
PREFACE

This User's Manual contains the technical information needed to properly operate and maintain Big Sky Laser Technologies' Ultra Series Nd:YAG laser system. It provides instructions for set up and installation, operation, service, preventive maintenance, and troubleshooting (fault-isolation). The laser system consists of two major subassemblies: (1) the compact Laser Head (with optional nonlinear optics), and (2) the power supply/cooler, also known as the ICE (Integrated Cooler and Electronics).

The laser system is truly "turn-key" and has been shipped fully functional. No adjustments are necessary to operate the laser. The cable and coolant interconnects are coded for simplicity of installation and are of the quick-connect type. Hardware interlock and safety features are included in the ICE to ensure hookups are proper and complete before the laser can be operated.



Caution labels, in accordance with CDRH and CE requirements, are prominently displayed on the Laser Head and ICE. The maximum ratings indicated on the system labels are in excess of the normal operating parameters. Please refer to the data summary in Appendix I for specific information pertaining to your system.

The laser system produces laser radiation, which is hazardous to eyes and skin, can cause burning and fires and can vaporize substances. The safety chapter contains essential information and user guidance about these hazards.

CHAPTER 1

SYSTEM OVERVIEW

Block Diagram

Figure 1 shows the laser system block diagram which consists of the Ultra CFR Laser Head and Integrated Cooler and Electronics (ICE).

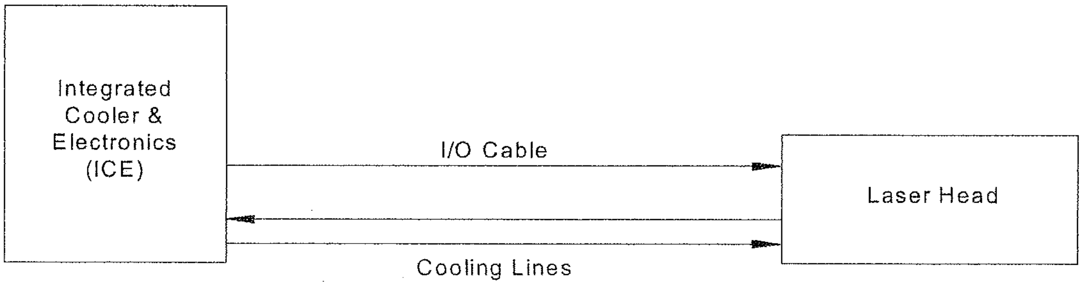


Figure 1: System Block Diagram

Since laser action is relatively inefficient, it generates more heat than light. The laser uses a closed loop, distilled water cooling system with a liquid-to-air heat exchanger to keep the laser rod and flashlamp cool. The ICE provides the charging supply to flash pump the laser rod. It also provides system timing, synchronization, controls and safety interlocks. Some electronic assemblies, such as lamp trigger transformer and Q-switch driver, are in the Laser Head. The ICE includes all controls and indicators necessary to operate the system.

Principles of Operation

Many laser physics textbooks are available which describe the lasing action in detail. The key points, in summary form, are explained below:

1. The term "LASER" is an acronym for "Light Amplification by Stimulated Emission of Radiation." By flashing a rare gas filled lamp in close proximity to an Nd:YAG laser rod, some of the broadband graybody radiation from the lamp is absorbed by the rod and is momentarily converted to stored energy within the excited state of the neodymium ion. This excited (metastable) state has a radiative lifetime of about 250 microseconds.

2. Optical energy packets called photons (i.e., laser radiation) can be extracted from the rod in its laser resonator through judicious control of the spontaneous emission (holdoff) and stimulated emission (Q-Switching). A transient condition called population inversion can be made to exist whereby the rod has sufficient gain to overcome the losses within the oscillator. A giant pulse of energy, initially building up from the "optical noise" of spontaneous emission, can be generated by the control of stimulated emission of radiation. The laser output is comprised of infrared photons that are essentially identical in phase and amplitude. The laser output beam is highly directional, spectrally pure and coherent. These properties, collectively, make the laser source unique.

3. The primary function of the power supply is to provide the charging supply for the Pulse Forming Network (PFN), which capacitively stores the electrical energy. This energy is subsequently discharged through the flashlamp. The power supply also provides other key functions including lamp simmer supply, timing and control, lamp and Q-Switch trigger, system status and safety features (like time delays and interlocks).

4. The cooling loop consists of a magnetically coupled coolant pump, coolant reservoir, flow and temperature interlocks, compact liquid-to-air heat exchanger, plumbing and laser pump cavity, which contains the laser rod and flashlamp. Most of the heat generated as a result of lamp discharge is removed by the cooling system.

5. Nonlinear crystals in combination with other optics can be used to generate wavelengths other than the fundamental 1064 nm. They include 532 nm, 355 nm, and 266 nm, as well as more eye-safe 1574 nm radiation. Dichroic optics can be used to separate output wavelengths.

The Laser Head

Figure 2 shows the Laser Head components in a compact, rigid, stable structure with a folded resonator geometry. Although primarily a precision optomechanical assembly, some electronics are required within the Laser Head for proper operation.

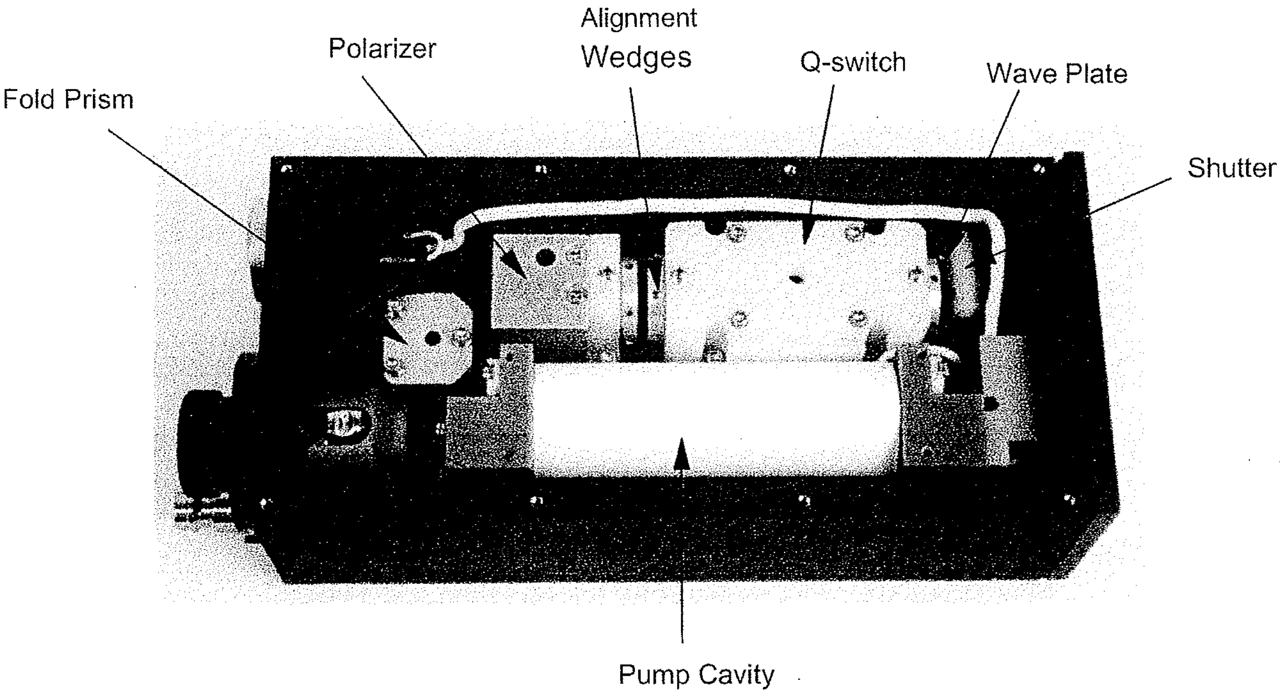


Figure 2: Compact Folded Resonator

Compact Folded Resonator

The Compact Folded Resonator (or oscillator) is widely used in Big Sky Laser Technologies' systems. Figure 2 shows most of the resonator components. The key design features, starting at the rear of the optical train, are detailed below.

1. Both the 100% reflecting back mirror and the output mirror are hard mounted to precision flat surfaces on the resonator. This unique feature minimizes the relative motion of the mirrors which is critical to overall resonator alignment, integrity and stability.

2. The thin (low order) quarter-wave plate, rotatable in its mount, ensures proper holdoff without Q-Switch bias and proper phase retardation over wide temperature changes. Precautions are taken to ensure the wave plate mounting is strain-free.

3. The Q-Switch assembly has relatively low quarter-wave voltage, high transmission (due to its AR coatings) and low sensitivity to temperature. Applying high voltage to the crystal changes its polarization retardation characteristics from high loss (normally closed) to low loss (open). With no voltage applied and when properly aligned, the Pockel cell does not affect the polarization of light passing through it.

4. The dual alignment wedges are rotatable in their mounts to allow optimum resonator alignment. These wedges avoid the misalignment tendencies of conventional spring-loaded or antagonistic optical mounts. The physical wedge angle in these optics is sufficient to compensate for accumulative angular deviation due to mechanical tolerancing and fabrication. The wedges are also insensitive to tilt error.

5. The low loss polarizer, in unison with the quarter-wave plate and the Electro-optic Q-Switch, control Q-Switched (giant pulse) operation. The polarizer transmits p-plane polarized radiation and the quarter-wave plate, when properly rotated for best holdoff, converts it to circularly polarized. As the circularly polarized light returns upon reflection from the back mirror, the quarter-wave plate converts it, in the second pass, to orthogonal s-plane polarization when no voltage is applied to the Q-Switch. The polarizer reflects the s-plane of polarization to accomplish holdoff (suppresses premature lasing action). With voltage applied, the lithium niobate Q-Switch crystal, in effect, cancels the polarization retardation of the quarter-wave plate so the radiation remains p-plane polarized and suffers minimal loss in a round trip, resulting in efficient Q-Switched operation.

6. The folding prism makes for a compact Laser Head with excellent mechanical strength and structural stability in its optical bed. It also provides alignment insensitivity in one axis and brings the rear mirror and output coupler close together.

7. The pump cavity, the most critical subassembly within the resonator, contains both the laser rod and flashlamp. Its design achieves uniform rod pumping and proper rod/lamp cooling. The coolant flow is of single pass, flooded cavity type.

8. The flashlamp excites some of the neodymium ions to their metastable state (for approximately 250 microseconds) creating a population inversion and photonic gain. The oscillator transmission is kept low (the "low Q" condition) during this time. If a fast high-voltage pulse is then applied to the lithium niobate crystal, the transmission changes from high to low loss. This process is repetitively done at the selected pulse repetition rate.

9. The output coupler is chosen to provide the proper mix of reflection for feedback (amplification) and transmission for efficient energy extraction. It is also chosen to keep the circulating fluence acceptably low at all intra-resonator optical elements. It, like the high reflector, is hard mounted and not adjustable.

10. Harmonic generation is performed using non-linear crystal(s). The crystal temperature is tightly regulated by mounting it in a temperature controlled oven assembly. The Laser Head can have one or two nonlinear optic (NLO) crystals mounted inside a Nonlinear Optics Module. The oven contains two optical mounts that can be independently rotated in one axis for best conversion efficiency.

11. A dichroic mirror pair can be used to separate the generated wavelength from the 1064 nm fundamental radiation, and from 532 nm radiation in the case of tripled and quadrupled lasers.

12. A KTP OPO module can also be used to convert incident 1064 nm radiation to more eyesafe 1574 nm radiation.

All of these optical elements are kept in accurate relative alignment through precision mounting techniques onto a stiff and stable optical bed structure. The optomechanical design for the Compact Folded Resonator (CFR) has evolved over many generations of iterative refinements based on usage and experience.

Integrated Cooler and Electronics (ICE)

The Power Supply and Cooler are provided in a single, compact, portable unit. The ICE front panel has all the functions and displays necessary to manually operate the system. This unit can also be computer controlled through an RS-232 port. The cooling system is automatically powered up when the system prime power is turned on via the Key Switch. Coolant interlocks prevent laser operation without coolant flow and during over-temperature conditions. Figure 3 shows this assembly.

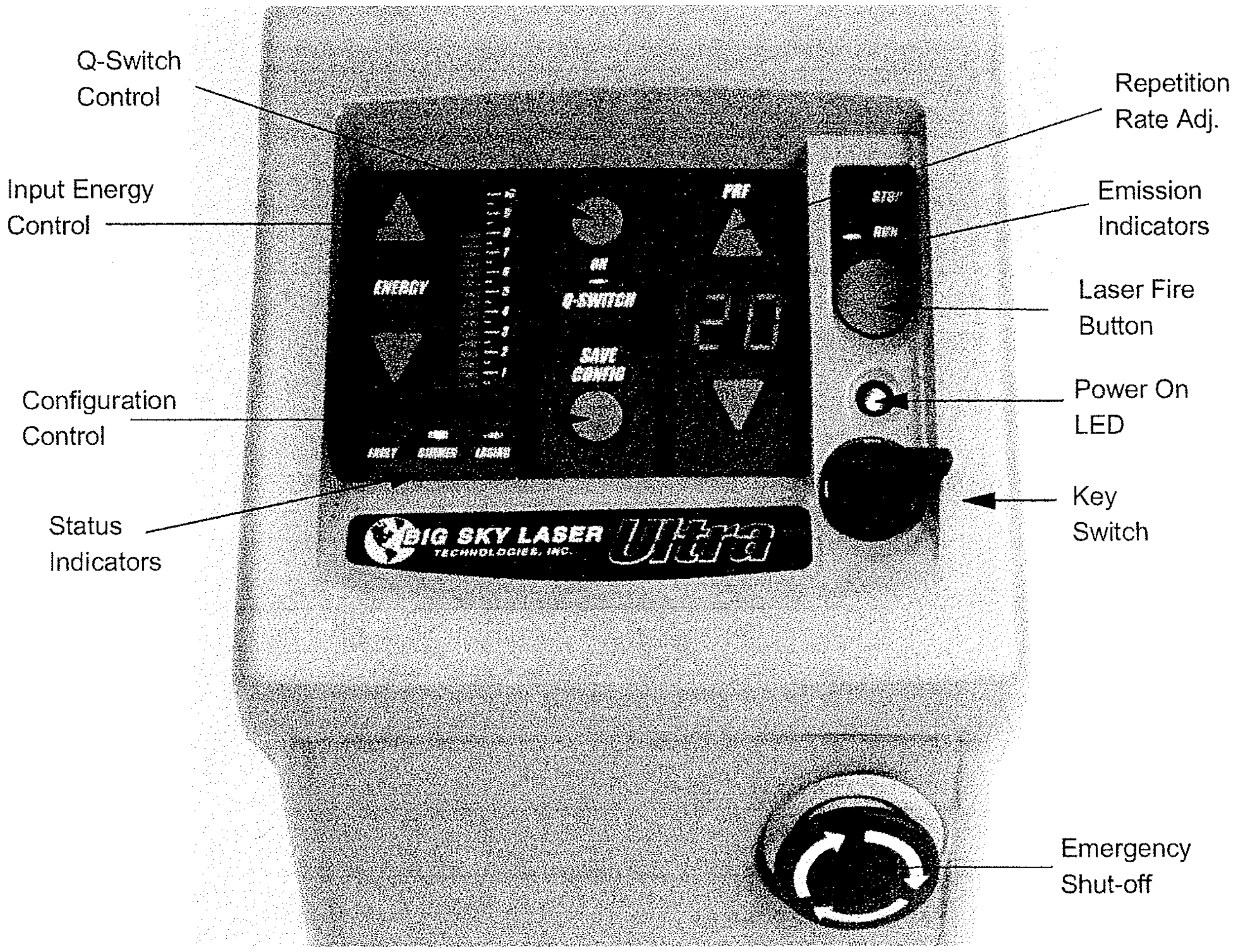


Figure 3: Ultra Integrated Cooler and Electronics (ICE)

Laser Electronics

The Laser Electronics portion of the ICE is completely self-contained and connects directly to the Laser Head and to prime power. It contains all of the high voltage electronics (charging supply, simmer supply, PFN, etc.) to flash the laser flashlamp. It also contains the interface electronics for system control. The

front control panel contains a keypad to configure and operate the laser system. The various functions available to the operator include pulse repetition frequency (PRF) control, Q-Switch enable, save configuration, pump energy control, and various status indicators. Figure 3 shows a front view of the ICE. See CHAPTER 4 for detailed information on the laser electronics control interface.

Cooling System

Figure 4 shows the cooling system loop. The coolant motor pumps coolant to the pump cavity at greater than 0.25 gallons per minute. A flow interlock switch ensures proper coolant flow and prevents damage, should the flow rate drop below this level. A temperature interlock on the heat exchanger senses the coolant temperature, and in the event of an over-temperature condition (i.e. the coolant level gets too low, coolant pump or fan motor fails) shuts the laser down. These safety features prevent catastrophic damage to the Laser Head. The 16 oz. reservoir capacity is sufficient, when coupled to the 250 watt liquid-to-air heat exchanger, to properly cool the laser. All materials in the coolant loop have been selected to be compatible with the coolant and pump cavity to ensure reliability and long life. Normally, distilled water is used for the coolant, but for system requirements where the laser must operate at temperatures below 5°C, a coolant mixture of 50% distilled water and 50% ethylene glycol may be used. See CHAPTER 6 for more details on using ethylene glycol coolant.

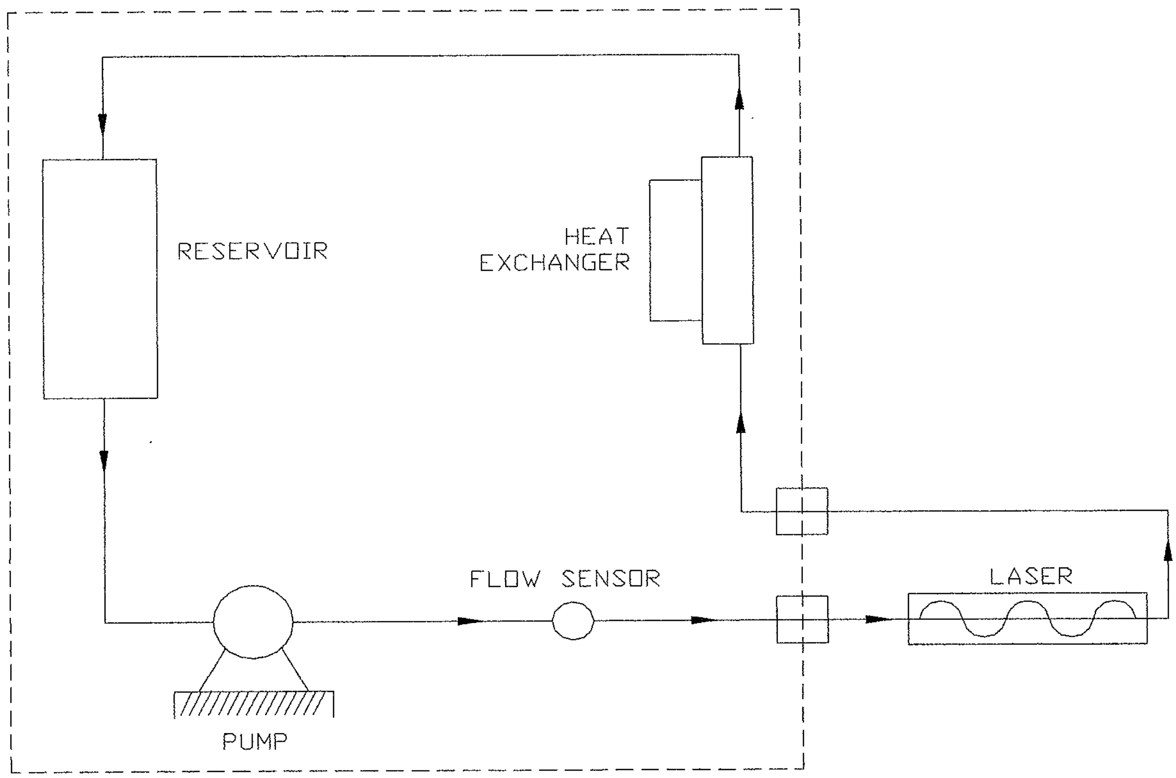


Figure 4: Coolant Loop

Wavelength Options

The Ultra can be configured to output many different wavelengths including 1064 nm, 532 nm, 355 nm, 266 nm, or 1574 nm laser radiation. Several add-on wavelength separation modules are available.

Note: If your laser system has been configured for any of these options, please refer to Appendix I for the specific output characteristics.

Second Harmonic Generation (SHG)

The Ultra uses a temperature-controlled KTP doubler inside a nonlinear optics module to generate 532 nm radiation. When the system is initialized, there is a short oven warm-up time of less than 10 minutes. If the oven is not yet to its operating temperature (approximately 65°C), the 532 nm output energy will be below the specified level.

Spectral purity can be gained by the use of dichroics or harmonic beam splitters. Without dichroics, both the 1064 nm and 532 nm laser light exit the Laser Head through the same output aperture. With the double-bounce dichroic module the 532 nm beam exits from the right aperture, when viewed from the front of the Laser Head, while the residual 1064 nm laser radiation may be either internally absorbed, or emitted from the left aperture.

Output polarization of the 532 nm laser light is vertical. Polarization of the residual 1064 nm light is elliptical.

Third Harmonic Generation (THG)

A KTP doubler, as described above, is used to generate 532 nm radiation. The 532 nm radiation is then mixed with the residual 1064 nm radiation to produce 355 nm light. This process is done using a temperature stabilized BBO or KD*P crystal.

When the system is initialized, there is a short oven warm-up time of less than 10 minutes. If the oven is not yet to its operating temperature (approximately 65°C), the 355 nm output energy will be below the specified level.

Better spectral purity can be obtained by the addition of dichroics beyond the tripler module. Without the dichroics, the 1064 nm, 532 nm and 355 nm laser radiation exit the Laser Head through the same output aperture. With the double-bounce dichroic module the 355 nm beam exits from the right aperture, when viewed from the front of the Laser Head, while the residual 1064 nm and 532 nm laser radiation may be either internally absorbed, or emitted from the left aperture.

The output polarization of the 355 nm laser radiation is horizontal, the residual 532 nm radiation is vertical and the residual 1064 nm radiation is elliptical.

Fourth Harmonic Generation (FHG)

A KTP doubler, as described above, is used to generate 532 nm radiation. The 532 nm radiation is then doubled to produce 266 nm light. This process is done using a temperature stabilized BBO or KD*P crystal.

When the system is initialized, there is a short oven warm-up time of less than 10 minutes. If the oven is not yet to its operating temperature (approximately 65°C), the 266 nm output energy will be below the specified level.

Better spectral purity can be obtained by the addition of dichroics beyond the quadrupler module. Without the dichroics, the 1064 nm, 532 nm and 266 nm laser radiation exit the Laser Head through the same output aperture. With the double-bounce dichroics module the 266 nm beam exits from the right aperture, when view from the front of the Laser Head, while the residual 1064 nm and 532 nm laser radiation may be either internally absorbed, or emitted from the left aperture.

Output polarization of the 266 nm laser light is horizontal, the residual 532 nm radiation is vertical and the residual 1064 nm radiation is elliptical.

1574 nm KTP OPO Module

The KTP OPO module is used to convert incident 1064 nm radiation to more eyesafe mid-IR radiation, near 1574 nm. The standard OPO unit is not wavelength controllable. Consequently there is no temperature or mechanical adjustment required. The warm up time is the same as the 1064 nm configuration.

CHAPTER 2

SAFETY

SAFETY SUMMARY

This product complies with safety standards EN61010:1993+A2:1995, EN60825:1994+A11:1996, and CDRH 21 CFR 1040.10(d). Do not install substitute parts or perform any unauthorized modifications to the product. Return the product to Big Sky Laser Technologies for service or repair to ensure that all safety features are maintained.
Do not operate this product beyond its specifications.

SYMBOL	DEFINITION OF SYMBOL
	**CAUTION:** Calls attention to a procedure, practice, or condition that could cause damage to the product, or cause bodily injury to the user. Refer to accompanying documentation. **ATTENTION:** Ce symbole signale une procédure, une méthode ou une condition qui peut endommager le produit ou blesser l'utilisateur. Se référer à la documentation jointe. **ACHTUNG!:** Beachten Sie Verfahren, Praktiken oder Zustände, die das Produkt beschädigen oder zu Verletzungen fuhren können. Lesen Sie die deigefugte Dokumentation. **ATTENZIONE:** Porre estrema cautela alla procedura, uso o condizioni che potrebbero danneggiare il prodotto o l'utilizzatore. Far riferimento alla documentazione inviata insieme al prodotto. **ADVERTENCIA:** Llamar la atención de un producto, practica, o estado que puede causar daño al producto o puede herir el usario.
	**CAUTION:** Risk of Electric Shock. **ATTENTION:** Risque d'éléctrocution. **ACHTUNG!:** Gefahr durch Stromschlag. **ATTENZIONE:** Rischio di shock elettrico. **ADVERTENCIA:** Riesgo de choque eléctrico
	**CAUTION:** Risk of exposure to hazardous laser radiation. **ATTENTION:** Risque d'exposition à un rayonnement laser dangereux. **ACHTUNG!:** Gefahr durch gefährliche Laserstrahlung. **ATTENZIONE:** Rischio di esposizione a pericolose radiazioni laser. **ADVERTENCIA:** Riesgo de exposición a radiaciên láser peligrosa.

Laser Safety

VISIBLE AND/OR INVISIBLE LASER RADIATION

CAUTION: The Model Ultra Nd:YAG Laser System is a Class 4 laser. Its output beam is, by definition, a safety and fire hazard. Precautions must be taken to prevent accidental exposure to both direct and reflected beams.

Precautions for Safe Operation of Class 4 Lasers

1. Keep the protective covers on the Laser Head as much as possible. Do not operate the laser with the covers removed for any reason.
2. Avoid looking at the laser output beam.
3. Do not wear reflective jewelry while using the laser, as it might cause inadvertent hazardous reflections.
4. Use protective eyewear at all times. Consult the ANSI, ACGIH, or OSHA standards listed at the end of this section for guidance on goggles and safety matters.
5. Operate the laser at the lowest possible beam intensity, given the requirements of the intended application.
6. Increase the beam diameter wherever possible to reduce beam intensity and thus reduce the hazard.
7. Avoid blocking the laser beam with any part of the body.
8. Use an IR detector or energy detector to verify that the laser beam is off before working in front of the laser.
9. Establish a controlled access area for laser operation. Limit access to those trained in the principles of laser safety.
10. Maintain a high ambient light level in the laser operation area so the eye pupil remains constricted, thus reducing the possibility of hazardous exposure.
11. Post prominent warning signs near the laser operation area.
12. Provide enclosures for the beam path whenever possible.
13. Set up an energy absorber to capture the laser beam, preventing unnecessary reflections or scattering.

CAUTION: Use of controls, adjustments or performance of procedures other than those specified in this User's Manual may result in hazardous radiation exposure.

Follow the instructions within this manual carefully to ensure the safe operation of your laser. At all times during laser operation, maintenance, or servicing, avoid unnecessary exposure to laser or collateral radiation that exceeds the accessible emission limits listed in "Performance Standards for Laser Products," United States Code of Federal Regulations, 21 CFR 1040.10(d). This information is also available in EN60825-1:1994, Section 8.2, titled "Measurements of Laser Radiation for Determining Classification."

Preventative Maintenance for Safety

Preventative maintenance is required to ensure the laser remains in compliance with Center for Devices and Radiological Health (CDRH) Regulations and European Norm (EN) requirements. This laser product complies with Title 21 of the United States Code of Federal Regulations, Chapter 1, Subchapter J, Parts 1040.10, as applicable, and with EN60825-1:1994, Part 1 for a Class 4 laser, 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, which may have affected these features and functions.

1. Verify that removing the remote interlock connector prevents laser operation. This connector is located on the back panel of the ICE.
2. Verify that the laser will operate only with the key switch in the ON position, and that the key can be removed only when the switch is in the OFF position.
3. Verify that a time delay exists between turning on the Key Switch and the start of laser firing. It must give enough warning to allow action to be taken to avoid exposure to laser radiation.

Electrical Safety

HIGH VOLTAGE

High Voltage Precautions for Safety

CAUTION: Both the Laser Head and ICE contain electrical circuits operating at lethal voltage and current levels. Always unplug the system Mains connection and wait at least one (1) minute to allow capacitors to discharge before servicing any part of the laser system.

Consult with Big Sky Laser Technologies' Customer Service Department if repair of the laser electronics is required. Only those trained in high voltage, high current electronics, and who understand the laser circuitry, should be allowed to service and repair the laser electronics. If any such action is required, it is recommended that you contact Big Sky Laser Technologies for details.

Sources of Laser Safety Standards

1. "Safe Use of Lasers" (Z136.1)
   American National Standards Institute (ANSI)
   11th West 42nd Street
   New York, NY 10036 USA
   Phone: (212) 642-4900

2. "A Guide for Control of Laser Hazards"
   American Conference of Governmental and Industrial Hygienists (ACGIH)
   6500 Glenway Avenue, Bldg. D-7
   Cincinnati, OH 45211 USA
   Phone: (513) 661-7881

3. Occupational Safety and Health Administration
   U.S. Department of Labor
   200 Constitution Avenue N.W.
   Washington, DC 20210 USA
   Phone: (202) 523-8148

4. "Safety of Laser Products" (EN60825-1:1994)
   Global Engineering Documents
   15 Iverness Way East
   Englewood, CO 80112-5704 USA
   Phone: (303) 792-2181

Safety Labels and Locations

The following figures show the safety, model number, serial number and origination labels, and their locations on the Ultra CFR laser system. These labels are installed at the factory and should not be removed by the user. If for some reason a label becomes removed, obscured or damaged in any way, please contact Big Sky Laser Technologies, Inc. for a replacement.

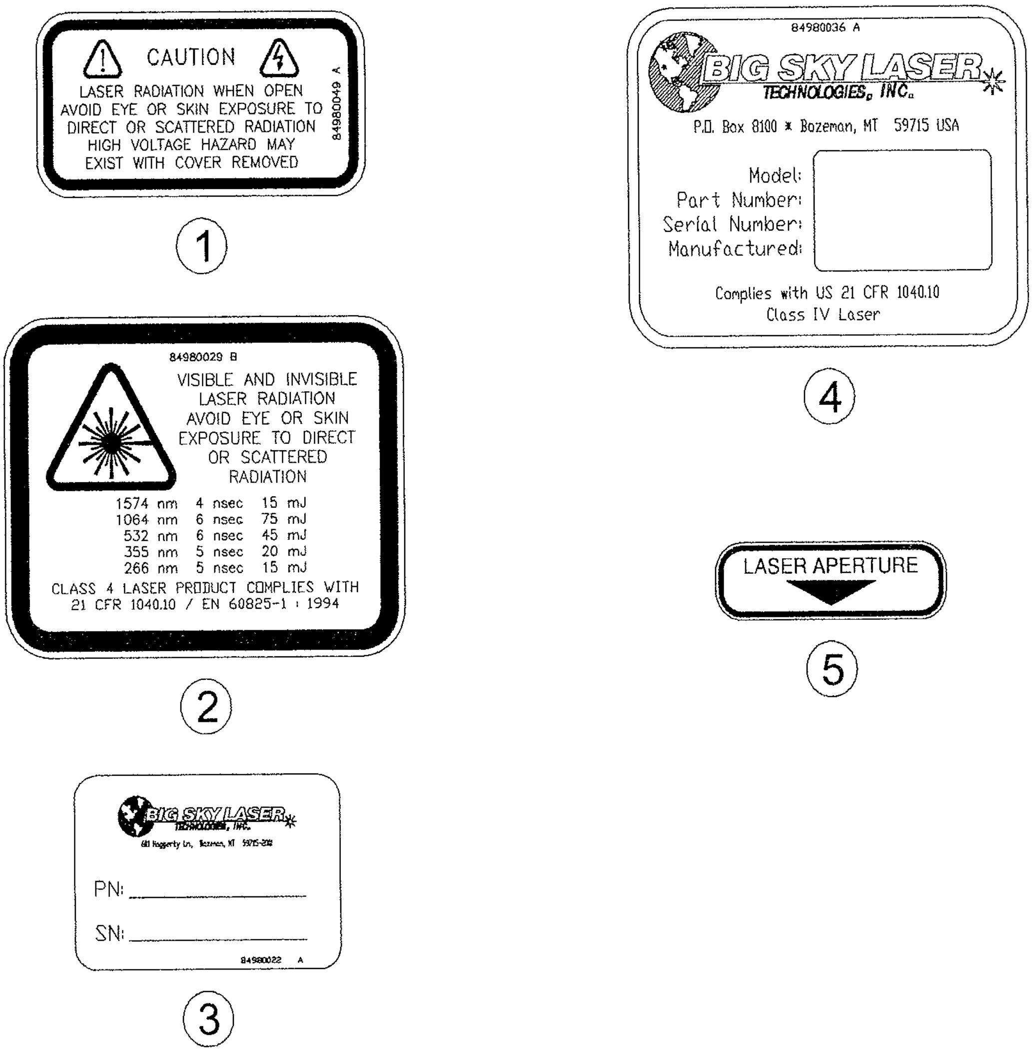
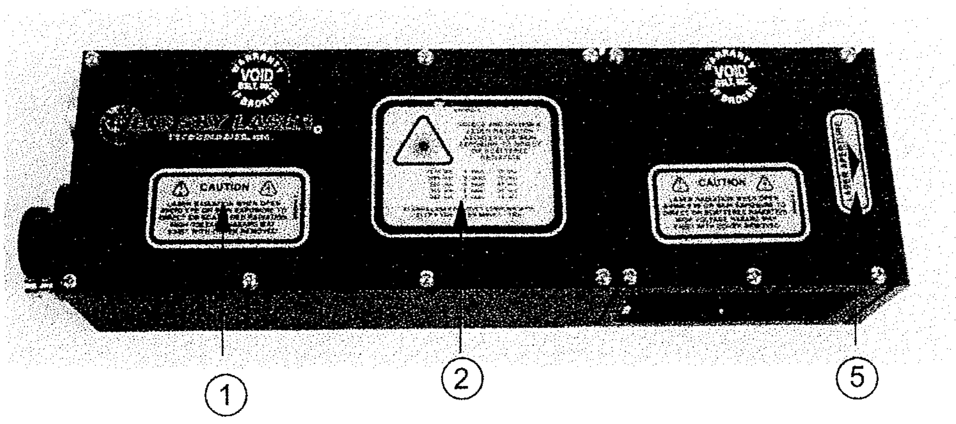
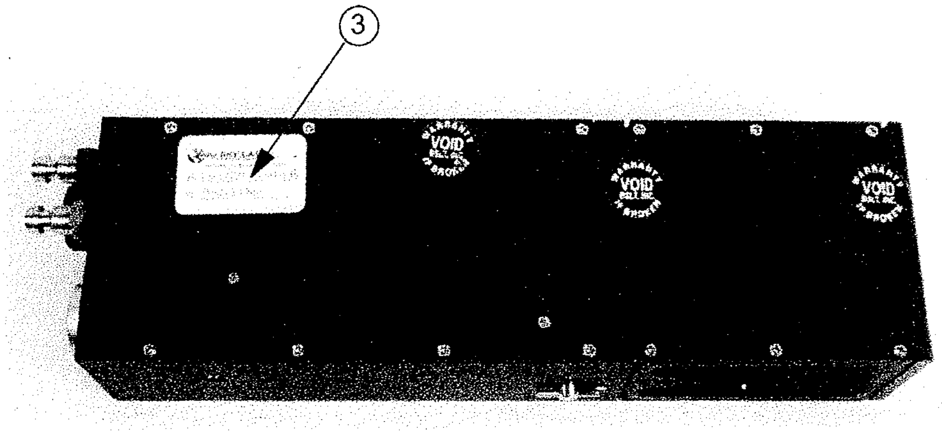


Figure 5: Safety Labels

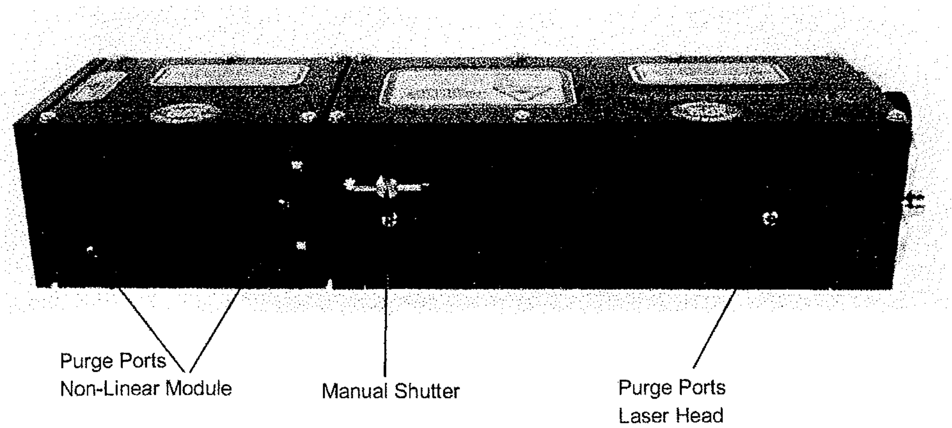
Figure 6: Laser Head Safety Label Location



Top View



Bottom View



Side View

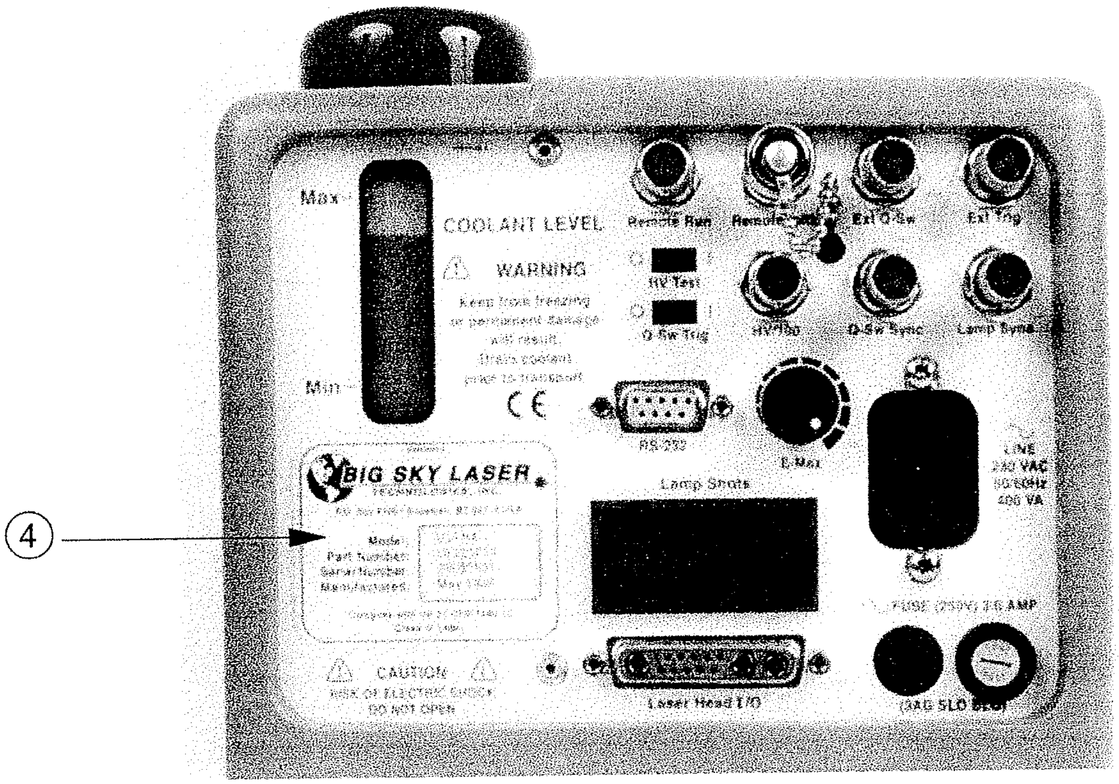


Figure 7: ICE Safety Label Locations

CHAPTER 3

INSTALLATION

Unpacking the Laser

The laser system has been carefully packaged for shipment. If the container arrives damaged in any way, please contact the shipper's agent to be present for the unpacking. Inspect each unit as it is unpacked, looking for dents, scratches, or other damage. If damage is evident, immediately file a claim against the carrier and notify Big Sky Laser Technologies, Incorporated. We will do whatever possible to quickly get the laser system fully operational.

It is recommended that the container be kept in storage for possible further shipping purposes, should the unit require repair or maintenance services. If a damage claim has been filed, the container will be needed to prove shipping damage.

The laser system is a turn-key system, designed so that a field service engineer is not required to get the system up and operating properly. The system has undergone extensive testing to verify its conformance to the specifications prior to delivery.

Before operating the laser however, it is important to fully understand its main features and controls.

⚠ **CAUTION: Do not power up the system before thoroughly reading the system description. Use of controls or adjustments, or performance of procedures other than those specified in this User's Manual may result in hazardous radiation exposure, laser system damage or result in voiding the warranty. Please refrain from connecting the main power until you make sure the Key Switch is in the OFF position and the coolant reservoir has been properly filled.**

System Inventory

The laser system consists of the following items. Verify that they are all present in the shipping container. If there are any shortages or discrepancies, contact Big Sky Laser Technologies immediately.

1. Ultra Laser Head
2. Integrated Cooler and Electronics (ICE)
3. External I/O Cable
4. Power Cord
5. Coolant Hoses
6. 2 Keys
7. Accessory Kit
8. Application Specific Hardware [1]

[1] See Appendix I

System Installation

1. Secure the Laser Head with three (3) 6-32 UNC screws (see Figure 11) to a flat mounting surface. If this method of mounting is used, it is important that the mounting surface be flat, to prevent distortion of the Laser Head (and subsequent misalignment of the resonator). Figure 8 identifies the Laser Head mounting hole pattern.

2. Connect the External I/O cable to the Laser Head. All connectors are unique and keyed to ensure proper connection. Connect the External I/O cable to the ICE. Secure all non-locking connectors using the captive fasteners.

3. Connect the coolant lines to the Laser Head. The red-labeled hose connects to the red-labeled quick-disconnect on the Laser Head and the blue to the blue. When viewing the back of the Laser Head, the coolant should go INTO the connector on the right and EXIT the connector on the left. When initially turning the system on, the air bubbles in the coolant lines (visible through the black nylon mesh) can be used as an indicator to verify proper coolant flow direction.

4. Verify that the Key Switch is in the OFF position.

5. Verify that the Emergency Stop switch is in the OUT position.

6. Ensure that the remote interlock connector is shorted. The laser system has been shipped with this shorting connector already in place. The remote interlock can be connected to lab door interlocks or other system interlocks for safety.

CAUTION: When utilizing the Remote Interlock capability, use an isolated contact closure such as a relay to avoid generating undesirable ground loops.

7. Connect the system to prime power, using the supplied power cord.

CAUTION: Ensure that the system is connected to the proper Mains voltage. The voltage rating is marked on the ICE back panel. Operating the system at the incorrect voltage may result in damage to the unit.

CAUTION: Ensure that the Mains power outlet that the Ultra ICE connects to is properly grounded. Poor ground quality could result in exposure to electrical shock.

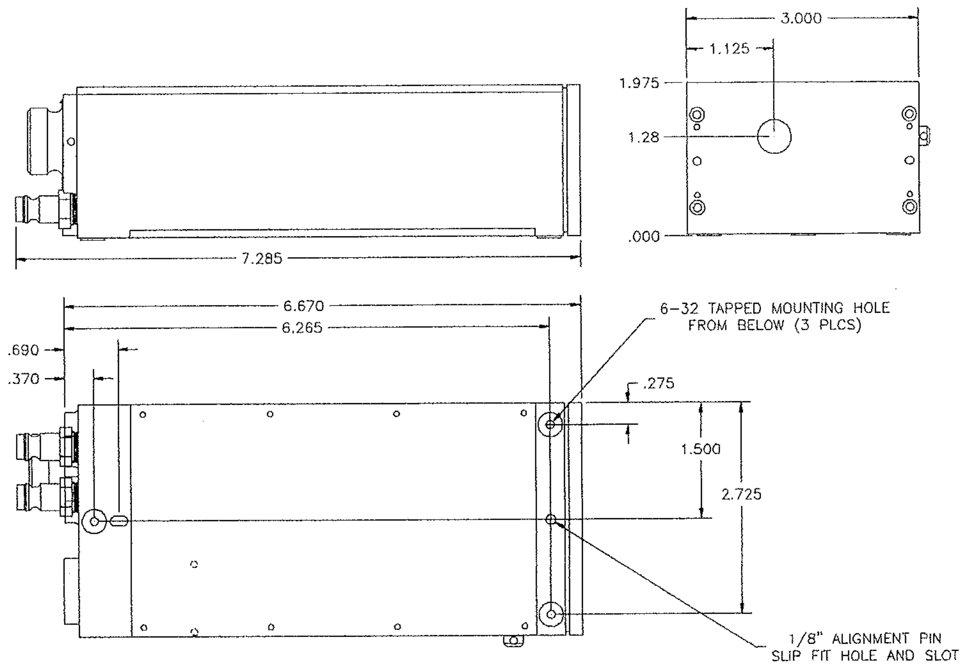


Figure 8: Laser Head Mounting

Filling the Cooling System

The cooling system must be filled prior to running the laser. The coolant capacity of the Ultra Laser System is approximately 24 fluid oz. Complete the following steps to fill the cooling system.

CAUTION: For safe operation, the system must first be filled with coolant. Systems with distilled water coolant are initially shipped dry to avoid freezing during transport. The coolant level can be checked at any time through the view port on the back of the ICE. The level should be kept between the Min and Max level markers. Do not turn the system ON until the coolant reservoir has been filled and the Laser Head has been connected. Running the pump dry may cause pump damage. Running the pump without the Laser Head connected can cause over pressure and may result in pump failure. Avoid spilling coolant since there is electronic circuitry within the ICE. Clean up any spills immediately.

1. Remove the coolant reservoir cap, and add coolant until the maximum level is reached in the coolant level window.

CAUTION: Do not fill the reservoir to the top. Air volume is required to allow for expansion of the coolant as the system warms up.

2. To prime the pump, tilt the entire ICE to the left (when facing the front of the unit) at a 30-45^0 angle. Air should bubble out of the lower fitting inside the reservoir with the ICE in this position. Tapping lightly on the side of the ICE will assist in breaking any internal air-locks that may have formed in the plumbing between the reservoir and the pump. When the bubbles cease, the pump is primed.

3. Turn the key switch ON (Ensure the Emergency Stop Switch is in the OUT position. If not, rotate the red knob in direction of arrows to release). The pump will turn on automatically after power up. If coolant fails to flow through the system, repeat step 2 above. Add coolant to the reservoir until the maximum level is reached in the coolant level window.

Note: The ICE will briefly make a "buzzing" sound when the key switch is turned on. This is normal. The A/C front-end electronics are current-limiting the inrush current during power up, resulting in the "buzzing".

⚠ **CAUTION: Be sure to add coolant as the coolant lines and Laser Head fill up. Failure to do so may result in running the reservoir dry and damaging the pump.**

4. Turn the key switch OFF to shut the pump off. Leave the system off for approximately 30 seconds to allow any trapped air to collect. Turn the key switch back ON and add coolant as required. Repeat this cycle several times to ensure that all the air has been purged from the coolant loop. The Laser Head can also be tilted up and down while the coolant is circulating to help purge any air pockets in the head. This procedure should be followed any time the Laser Head has been disconnected and reconnected, to ensure that all air has been purged from the Laser Head and coolant lines before laser operation.

5. Once the coolant level has stabilized at the proper level, replace the reservoir cap.

The system is now ready for full operation. Make sure all the preliminary steps have been taken prior to laser operation. This includes inspection for visual damage, checking the coolant level, properly connecting all cables, and taking all necessary laser safety precautions.

CHAPTER 4

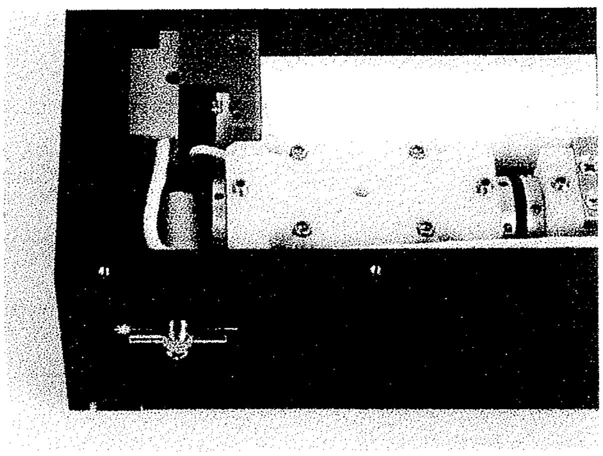
LASER OPERATION

The laser system has undergone extensive testing to verify its conformance to the specifications prior to delivery. It has been designed so that a field service engineer is not required for installation.

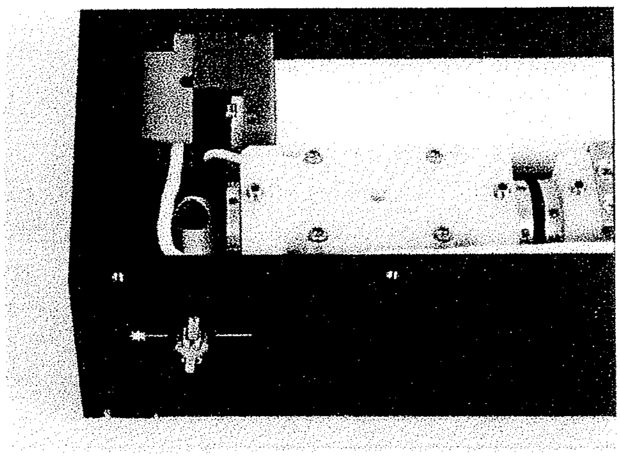
Once the laser system has been set up as outlined in the previous chapter, it is ready to operate. Turn the Key Switch ON. After approximately 10 seconds, the laser is initialized and ready for operator control. See Appendix I for factory preset operating configurations.

Manual Shutter Operation

The Ultra utilizes a manual shutter, located on the side of the laser head (see Figure 9). Lasing action cannot take place with this shutter closed. To open the manual shutter, position the shutter handle such that it is horizontal and aligned with the etched line on the Laser Head. The shutter is closed with the handle pin in the vertical position. See Figure 9.



a) Shutter OPEN – laser light emitted.



b) Shutter CLOSED – no laser light emitted.

Figure 9: Manual Shutter Positions

ICE Front Panel Control

Control Description

(See Figure 3 for a view of the ICE front panel)

1. *Power Key Switch:* This switch applies AC MAINS power to the ICE. The power indicator, located directly above the Key Switch, illuminates to indicate that AC power is ON. The key is not removable in the ON position. During power-up, all indicators and displays are illuminated momentarily to identify possible faulty LED's.

2. *Energy UP and Energy DOWN Keys:* These keys change the flashlamp pump energy. The Up Arrow Key increases pump energy and the Down Arrow Key decreases pump energy. The vertical bar graph adjacent to the energy control keys indicates the relative pump energy setting, with the top LED on the bar graph representing maximum laser output energy and the bottom LED representing approximate laser threshold. The bar graph displays in "dot mode" (single LED illuminated) when the laser is not energized (high voltage disabled). It displays in "bar graph mode" when a run command is issued and high voltage is enabled.

3. *PRF Up and PRF Down Keys:* These keys are used to change the flashlamp pulse repetition frequency (PRF). The frequencies available are 1, 2, 5, 10 and 20Hz. The selected PRF is displayed on a 2 digit, 7 segment LED display located between the keys. A PRF selection of "00" indicates that the ICE is in external trigger mode. The PRF selection keys are also used to change the Q-Switch divide by rate. See Q-Switch Key description. If "L0" is displayed on the 2 digit display, front panel control has been locked out via RS-232. See CHAPTER 5 for details.

4. *Q-Switch Key:* This key toggles the Q-Switch ON or OFF as well as selects the Q-Switch "fire-every" mode. Toggling the Q-Switch ON and OFF is done by momentarily pressing the Q-Switch key . The Q-Switch LED illuminates when the Q-Switch is activated. If the Q-Switch Key is held down for more than 2 seconds, the 2 digit display changes to display the Q-Switch "fire-every" frequency (Divide By *N* feature). By pressing the PRF UP or PRF DOWN arrow keys while holding down the Q-Switch key, the Q-Switch "fire-every" rate can either be incremented or decremented. For example, to run the flashlamp at 20 Hz and lase at 1 Hz , set the PRF to 20 Hz and the Q-Switch "fire-every" to 20. This setup fires the Q-Switch once for every twenty flashlamp shots. The Q-Switch key and LED are only valid for internal Q-Switch control.

5. *Laser Fire Key:* This key toggles the high voltage ON or OFF. To run the laser, momentarily press the Fire key. The Run LED will illuminate to indicate that high voltage is active and the laser flashlamp will flash at the selected PRF. To stop the laser, press the Fire key again to disable high voltage. In this mode the Stop LED will illuminate and the Run LED will extinguish.

6. *Save Configuration Key:* Pressing this key saves the current configuration. Each time the Ultra is powered ON, it initiates into the last stored configuration. To save a specific configuration, momentarily press the Save Config key. "SC" is displayed for several seconds on the 2 digit PRF display while the system configuration is being stored. The Save Config Key is only active with the laser off (HV disabled).

7. *Emergency Stop Switch:* This large red button, located on the front of the Ultra ICE, disconnects the AC Mains to the system. This button should be used only in an emergency when it is necessary to quickly shut down the laser system. The normal operating position is with the button out. Depressing the stop button disables the system. Twisting the cap clock-wise, as indicated, resets the switch.

Status Indicators

1. *Fault Indicator:* This LED illuminates to indicate that a system interlock has been opened. The Ultra is equipped with the following interlocks: coolant flow, coolant temperature, ICE front cover, External I/O cable, and remote interlock. Laser operation will be inhibited as long as an interlock fault is present. Once the interlock fault is corrected, Laser Fire must be selected to activate the laser. The laser will not begin firing on its own after a fault correction. Glitch capture circuitry has been incorporated to ensure a fault is captured even if it is for a very short period of time.

2. *Simmer Indicator:* This LED is illuminated when the flashlamp is simmering. Incorporating feedback from the flashlamp simmer current, this LED is used as a system diagnostic indicator.

3. *Fire Indicator:* This LED indicates that laser light is potentially being emitted from the Laser Head. The Fire LED flashes at the Q-Switch PRF when the Q-Switch is enabled and the flashlamp is flashing. This indicator is only valid for internal Q-Switch control.

ICE Back Panel Control and I/O

(See for a view of the ICE Back Panel. CHAPTER 8 contains detailed interface requirements.)

1. *Remote Run:* This input BNC connector is used to remotely run/stop the Ultra. Shorting this connector turns the laser ON, and opening it turns the laser OFF. The Remote Run BNC operates in conjunction with the front panel Laser Fire key. Pressing the Fire key even though the Remote Run BNC is shorted will stop the laser. To remotely start the laser again, the BNC must be opened and then closed again. When using this control connector, use only an isolated switch closure to avoid system ground loops.

2. *Remote Interlock (Remote Intlk):* This interlock BNC is provided in accordance with CDRH requirements and must be shorted for the laser to operate. The laser system has been shipped with a shorting connector already in place. The Remote Interlock can be connected to lab door interlocks or other system interlocks for safety. When using this interlock connector, use only an isolated switch closure, such as a relay, to avoid system ground loops.

3. *External Q-Switch Input (Ext Q-Sw):* This BNC connector allows the user to inject an external Q-Switch trigger. This can be used to more accurately control the firing of the laser and thus significantly reduce timing jitter. The Q-Sw Trig slide switch, described below, must be in the "I" position to use this BNC. The Q-Switch key, Q-Switch LED and Fire LED on the front panel are not valid when the External Q-Switch input is utilized.

Note: If Ext Q-Sw mode is used see Appendix I or contact Big Sky Laser Technologies' Customer Service Department to determine the optimum Q-Switch delay from flashlamp trigger and the required rod lensing delay to avoid unstable laser performance during the first few laser shots. Typical Q-Switch delay is 135ms, with respect to Lamp Sync.

CAUTION: When in external Q-Switch mode, the user has direct access to the Q-Switch driver trigger input. The Q-Switch driver in the laser head can be triggered even if the laser is not running.

4. *External Trigger Input (Ext Trig):* This BNC connector is used to externally trigger the Ultra laser system. The PRF display on the front panel must be set to "00" to be in external trigger mode.

5. *High Voltage Divided by 100 Output (HV/100):* This BNC outputs an analog voltage proportional to the charge voltage on the PFN Capacitor, divided by 100.

6. *Q-Switch Sync. (Q-Sw Sync):* This BNC provides a pulse, which is coincident with the Q-switch trigger. This output can be used to synchronize external equipment to the laser output.

7. *Lamp Sync:* This BNC provides a pulse which is coincident with the flashlamp discharge. This output can be used to pre-trigger or synchronize external equipment.

8. *RS-232 Communications Connector (RS-232):* See CHAPTER 5 for serial interface specification.

9. *Lamp Shot Counter:* This LCD display shows the number of shots on the laser flashlamp since the last time the counter was reset. The button next to the display resets the counter.

10. *High Voltage Test Switch (HV Test):* This switch is used for system diagnostics. Setting the switch to "I" displays a sample of the HV feedback on the front panel energy bar graph. Under normal conditions this switch should be left in the "0" position.

11. *External Q-Switch Switch (Q-Sw Trig):* This switch selects the source of the Q-Switch trigger. When in the "0" position, the Q-Switch trigger is internally generated. Setting the switch to "I" requires that the operator provide the Q-Switch trigger source.

12. *E-MAX Adjust:* Rotating this control knob CCW increases the Q-Switch delay, resulting in lower laser output energy without significantly effecting beam quality. Rotating the knob fully CW provides maximum laser output energy for a given energy setting on the front control panel.

13. *Laser Head Input/Output Connector (Laser Head I/O):* This D-Type connector provides the electrical interface to the laser head.

14. *Input Power Connector:* The AC power input connector is a standard IEC 320 power input integrated into a high performance Line Filter. The back panel label indicates the required AC Mains voltage configuration (either 115 VAC, 50/60 Hz, or 230 VAC, 50/60 Hz).

15. *Input Power Fuse*: The input power fuse is type 3AG, Slo-Blo, and is rated as indicated on the panel.

Long Pulse Mode

The Ultra laser system can be operated in a quasi-long pulse mode by Q-Switching the laser coincident with the flashlamp discharge. Running in this mode will produce approximately 80% of the 1064 nm laser output energy produced in Q-Switched mode. Long pulse mode should only be used for 1064 nm lasers, since the peak output energy densities are not high enough for efficient conversion of the harmonic wavelengths. Follow the instructions below to operate long pulse.

1. Set the External Q-Switch slide switch to the "1" position.

2. Jumper the Lamp Sync output to the Q-Switch Input using a BNC cable.

Precautions and Notes on Laser Operation

⚠ **CAUTION: Below is a list of guidelines, which apply to all Big Sky Laser Technologies' laser systems. These guidelines should be followed whenever possible to avoid laser damage.**

1. Operate the laser in a dust-free environment and keep the Laser Head covered when not in use. This protects the output window against dust and particulate.

2. The Laser Head is sealed with careful attention to use of low outgassing materials. Silicone and similar sealing, bonding or insulating materials should not be used in close proximity to the Laser Head since these substances will outgas and could contaminate the output window, causing laser damage.

3. Avoid back reflections. Back reflections of even a small percentage of the output energy can promote damage to optical components in the Laser Head. For example, an uncoated convex lens or a glass disk calorimeter will reflect about 4% of the incident energy. While the reflection may seem harmless, it can perturb the resonator operation to the extent that the near field beam intensity profile is degraded and may promote optical damage. It may also affect the resonator holdoff, which can cause prelasing and catastrophic optical damage. In some cases, even anti-reflection coated glass optics reflect enough energy to promote damage to laser optics. It is best to use only quality optics coated for the operating wavelength.

CAUTION: To avoid laser damage, minimize back reflections of the output beam. When reflections are unavoidable, direct them away from the optical axis of the system by canting the optics off-axis. Failure to do so can cause laser damage and void the warranty.

CHAPTER 5

RS-232 COMMUNICATIONS

Serial Interface Specifications

The Ultra's digitally-controlled power supply provides an RS-232 interface for remote control of the operating parameters of the power supply. All aspects of the laser operation can be accessed through the RS-232. The ICE can also be set to lock out front panel key control and avoid conflict with RS-232 communications.

Communication is set at 9600 baud, 8 bits, parity = none, and 1 stop bit. The Ultra uses only Tx and Rx for its communications. No hardware handshaking is utilized.

Command Syntax

All power supply commands have the following syntax:

$name ##CR

Where:	$	indicates a command follows.
	name	is the **command** name. For clarity, commands are not abbreviated; but only the first four characters must be sent. No spaces are allowed between the $ and the name.
	##	is an unsigned, integer associated with name (**command value**). A space must be inserted between name and ##.
	CR	Carriage Return (0Dh).

Commands are not processed until the Carriage Return is sent. If an error is made and identified prior to sending the Carriage Return, sending a new $ will reset the input buffer and allow a corrected command to be sent.

Software Handshaking

The Ultra power supply has several mechanisms to help software handshaking. These are as follows:

ECHO #	Turns echoing ON or OFF. With echoing ON, the power supply will echo back all characters except the "$". The CR, Carriage Return, is echoed followed by LF (Line Feed). With echo OFF, no characters are echoed. "0" turns echoing OFF, and "1" turns echoing ON.

Regardless of the echo status stated above, the following is a list of 2 character responses that will be echoed from each command that is issued.

OK	If the command has been recognized and carried out **successfully.**
?1	If the **command** itself is not recognized.
?2	If the **command value** is out-of-range.

Unidentified commands and most out-of-range conditions result in the power supply ignoring the command. Only one command can be processed per message. Commands are not processed until the Carriage Return is sent. If an error is made and identified prior to sending the Carriage Return, sending a new $ will reset the input buffer and allow a corrected command to be sent.

Querying ICE Status

To determine the current value of any parameter, the syntax is:

$name ?CR

Where ? replaces ##

This will return an integer followed by a Carriage Return. A "1" indicates the queried item is in the ON state and a "0" indicates OFF. The "STATUS" command can be used to check the current state of all internal interlocks. The responses to the "STATUS ?" command are as follows:

Response (Decimal)	Interlock Description
00	All interlocks satisfied
01	Coolant over temperature
02	Remote Interlock connector not shorted
04	Coolant flow low
08	Cables not connected or cover not secured.

Command Set

The following is a summary of the Ultra command set.

Command	Valid Range	Description
FIRE	01	Fires laser (High Voltage ON and lamp simmered)
STOP	00	Shuts off laser (High Voltage OFF)
MODE	01 - 03	01 = Continuous 02 = Burst 03 = External Trigger
LPRF	01, 02, 05, 10, 20	Lamp PRF (Lamp Pulse Repetition Frequency)
LAMP	00 - 01	00 = Stop lamp flashing 01 = Start lamp flashing
QSWITCH	00 - 01	00 = Q-Switch OFF 01 = Q-Switch ON
QFREQ	01 - 99	Q-Switch Fire-every
QDLY	00 - 99	Q-Switch turn-on delay in number of shots
EPFN	01 - 20	PFN Lamp voltage (corresponds to front panel bargraph display)
BURST	00 - 99	Number of burst pulses
STATUS	?	Interlock status - query only
SAVE	01	Save current configuration
KEYPAD	00 - 01	00 = Front Panel unlocked 01 = Front Panel locked out
ECHO	00 - 01	00 = Echo OFF 01 = Echo ON
VERSION	01	Returns software revision

Programming Notes

The easiest way to control laser operation over RS-232 is to set up all of the laser parameters through the front panel and then use only the $FIRE command to start lasing. All of these parameters can be stored for a given configuration by pressing the *Save Config* key on the front panel at any time except when the laser is running. The ICE boots into the configuration that was last saved or selected. Reinitializing the system is not required, even if the unit is disconnected from main power, since the ICE stores all the parameters in nonvolatile memory.

If the user wishes to change laser parameters remotely, the following steps outline the proper procedure.
Note: Steps 1-5 can be done in any order.

1. Use the $MODE command to set up the type of triggering that will be used.
2. Use the $LPRFcommand to set the lamp pulse repetition frequency.
3. Use the $EPFN command to set the pump energy. Refer to the efficiency data supplied with the laser in Appendix I to get the desired output energy.
4. Use the $QFREQ to get the desired laser output rate and the $QSWITCH command to enable the Q-Switch.
5. Use the $FIRE command to enable the high voltage and start lasing. The laser will operate according to all of the parameters previously set up.
6. To stop lasing, issue the $STOP command to disable the high voltage and lamp triggering. Resume lasing by issuing the $FIRE command.

9 Pin to 25 Pin D-Sub Correlation (For Reference Only)

Pin # DE-9	Pin # DB-25	Signal Name	Pin # DE-9	Pin # DB-25	Signal Name
1	8	DCD	6	6	DSR
2	3	RX	7	4	RT
3	2	TX	8	5	CTS
4	20	DTR	9	22	RI
5	7	GND			

CHAPTER 6

MAINTENANCE

Maintaining the Cooling System

CAUTION: The following is a list of items that should be checked periodically to maintain the cooling system. Inadequate cooling system maintenance could result in coolant contamination and/or system damage.

1. Circulate coolant through the system for at least 30 minutes every month when the laser is not in use. Turning the Key Switch ON will turn the coolant pump motor on and circulate the coolant.

2. Inspect the water level in the reservoir through the inspection slot on the rear panel. Keep the coolant level in the reservoir between the Max and Min marks at all times.

Coolant Replacement Procedure

CAUTION: Coolant should be replaced every three months. Failure to do so could result in system damage or laser performance degradation. The coolant change procedure is as follows:

1. Hold the Laser Head higher than the ICE with the coolant ports tilted slightly downward. Disconnect the left (blue) quick-disconnect coolant line on the Laser Head. The water in the Laser Head will be siphoned out into the reservoir. When the liquid stops draining out of the Laser Head, disconnect the remaining coolant line.

2. Tilt the Laser Head to pour the coolant out into a catch basin. Gently blow dry nitrogen through the left (blue) coolant connector on the Laser Head to empty any remaining coolant.

3. To drain the coolant lines, detach the coolant hoses from the back of the ICE. Hold the end of the coolant hoses (with coolant change connectors installed in the stainless steel connectors) in a catch basin. Press the white plastic part that protrudes from the end of the plastic connectors. When depressing this part, do not cover the entire end of this connector, for it will not allow the coolant to drain from the lines.

4. To drain the plumbing in the ICE, remove the reservoir cap and attach the connectors provided with the Accessories Kit to the cooling lines. Place the blue-colored hose into a catch basin and turn the ICE Key Switch to ON. Allow the pump to run only as long as coolant continues to flow into the catch basin.

CAUTION: Do not run the pump motor dry for an extended period of time, as this will cause permanent damage.

5. Replace the reservoir cap and screw it on tightly. Lay the ICE on the left side (when viewed from the front). Blow dry nitrogen into the red-colored coolant line until no more water exits the blue coolant line. Next, lay the ICE on the right side and blow dry nitrogen into the blue-colored coolant line (with the red-colored line in the catch basin) until no more water exits the ICE. Any residual coolant left in the cooling system after following this procedure is not a concern.

6. Inspect the discarded coolant for clarity. The coolant should be very clear and free from contaminants. There should be no organic contaminants (such as algae) or large particles in the waste coolant. Black particulate is typically a sign of pump wear. Green color may be a sign of organic contamination. All organic contaminants need to be removed from the coolant loop prior to operating the laser. Please consult Big Sky Laser Technologies if you suspect organically contaminated coolant.

7. To refill the cooling system, reconnect the coolant lines between the Laser Head and ICE.

8. Fill the reservoir. Tilt the entire ICE to the left (when viewed from the front) at a 30-45° angle. Air should bubble out of the lower fitting inside the reservoir with the ICE in this position. Tapping lightly on the side of the ICE will assist in breaking any internal air-locks that may have formed in the plumbing between the reservoir and the pump. When the bubbles cease, the pump is primed. Turn the Key Switch ON and add coolant until the reservoir remains 3/4 full with the pump running. Do not overfill the reservoir. It is important to leave room for coolant expansion in the reservoir. It will be necessary to add coolant as the head and coolant lines fill. Circulate water through the Laser Head for approx. 5 minutes, or until no more bubbles flow through the coolant lines. Switching the ICE ON and OFF several times (waiting approx. 30 seconds after turning off each time to allow air to collect) will aid in removing air trapped in the lines.

Using Ethylene Glycol Coolant

For operation below 5°C, a mixture of 50% ethylene glycol and 50% distilled water by volume should be used as the coolant. If you replace the coolant, use only high purity, reagent grade ethylene glycol. Follow the above procedure to drain the coolant and replace it with the 50/50 mix.

Draining the System for Transport

⚠ **CAUTION: If your system has been supplied with distilled water, it must be COMPLETELY drained before transporting, since the coolant could freeze and cause damage to the Laser Head or cooling unit.**

9. Hold the Laser Head higher than the ICE with the coolant ports tilted slightly downward. Disconnect the left (blue) quick-disconnect coolant line on the Laser Head. The water in the Laser Head will be siphoned out into the reservoir. When the liquid stops draining out of the Laser Head, disconnect the remaining coolant line.

10. Tilt the Laser Head to pour the coolant out into a catch basin. Gently blow dry nitrogen through the left (blue) coolant connector on the Laser Head to empty any remaining coolant.

11. To drain the plumbing in the ICE, remove the reservoir cap and attach the connectors provided with the Accessories Kit to the cooling lines. Place the blue-colored hose into a catch basin and turn the ICE Key Switch to ON. Allow the pump to run only as long as coolant continues to flow into the catch basin.

⚠ **CAUTION: Do not run the pump motor dry for an extended period of time, as this will cause permanent damage.**

Replace the reservoir cap and screw it on tightly. Lay the ICE on the left side (when viewed from the front). Blow dry nitrogen into the red-colored coolant line until no more water exits the blue coolant line. Next, lay the ICE on the right side and blow dry nitrogen into the blue-colored coolant line (with the red-colored line in the catch basin) until no more water exits the ICE. Any residual coolant left in the cooling system after following this procedure is not a concern.

12. **To drain the coolant lines, detach the coolant hoses from the back of the ICE. Hold the end of the coolant hoses (with coolant change connectors installed in the stainless steel connectors) in a catch basin. Press the white plastic part that protrudes from the end of the plastic connectors. When depressing this part, do not cover the entire end of this connector, for it will not allow the coolant to drain from the lines.**

Flashlamp Replacement

The only periodic maintenance action required in the Laser Head is flashlamp replacement. For optimal performance, the flashlamp should be replaced approximately every 30 million shots. Increasing input energy to maintain the output energy to the original level, as gradual lamp degradation takes place, is acceptable and normal. If the shot counter on the back panel of the ICE is used to track lamp life, reset the counter after replacing the flashlamp.

Handle the flashlamp only with talc-free, rubber finger cots. Refer to Figure 10 and Figure 11.

Lamp Removal

CAUTION: Make sure the PFN is discharged, the Laser Controller Key Switch is OFF and the coolant is completely removed from the Laser Head before removing or replacing the flashlamp. Failure to do so will void the warranty, flood the Laser Head with coolant, and may result in personal injury.

CAUTION: Keep the Laser Head in a horizontal orientation throughout the lamp change process! See item 3 below.

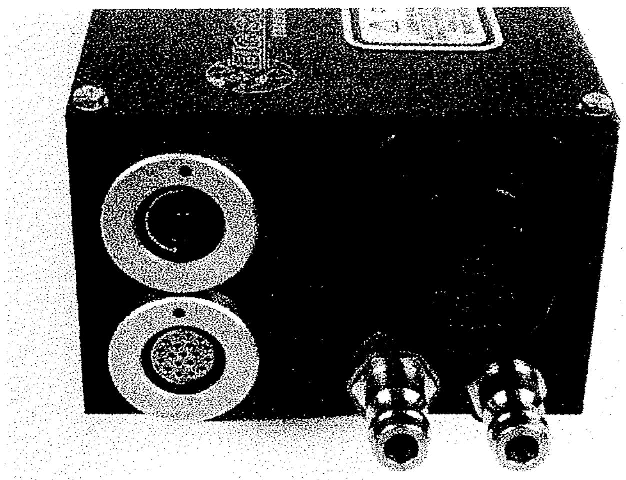
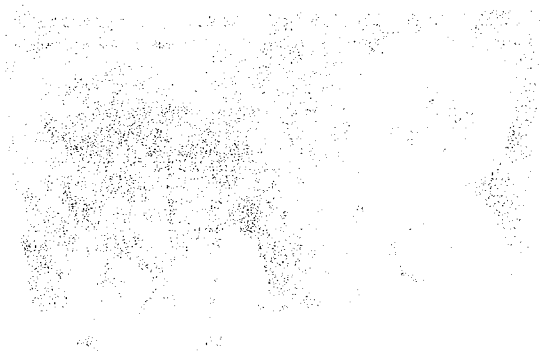


Figure 10: Lamp Access Cover

1. Disconnect the electrical cables and remove the coolant from the Laser Head following steps 1 & 2 of the Coolant Replacement Procedure.



2. With the Laser Head placed flat on its mounting feet, remove the lamp access cover, shown in Figure 10, from the Laser Head by pushing and rotating counterclockwise. Removal of the cover will reveal the plastic lamp insertion tool. (See Figure 11).

3. With the Laser head still placed flat on its mounting feet, firmly pull the brown plastic lamp insertion tool outward. The lamp can be difficult to break loose from the o-rings that seal the coolant; however, pulling firmly should release the lamp.

CAUTION: IT IS VERY IMPORTANT TO PULL STRAIGHT AND EVENLY TO AVOID BREAKING THE LAMP! Keep the laser head in a horizontal orientation with the lamp removed. If tilted, coolant left in the pump cavity will drain into the laser cavity permanently damaging laser components.

4. Remove the retaining clip and lamp insertion tool from the lamp.

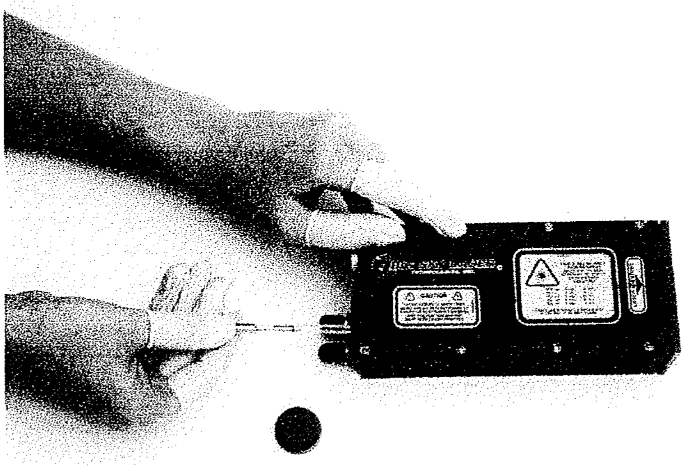


Figure 11: Flashlamp Replacement

<u>**Lamp Replacement**</u>

1. Clean the new lamp with methanol or acetone.

2. Install the lamp insertion tool and retainer clip onto the lamp.

3. Very slightly dampen the new lamp with distilled water so that it slides easily through the O-rings inside the Laser Head. Touching your finger cot in a single drop of water and then wetting the lamp envelope works well.

4. Manually slide the lamp into the laser. Do not tilt the laser head during installation of the flashlamp. You will feel a positive contact when the lamp is properly installed. The lamp will "bottom out" solidly when completely installed. If you are unsure as to whether the lamp is fully seated, pull the lamp back out approximately 1/2" and reseat.

CAUTION: Operation of the pump with a flashlamp that is not fully seated will flood the Laser Head and void the warranty, causing permanent laser damage. If there is any doubt about this lamp insertion process, please call Big Sky Laser Technologies' Customer Service Department.

5. Replace the lamp access cover by pushing and rotating clockwise, making sure that the sealing O-ring is properly installed between the lamp access cover and the Laser Head. Purge the Laser Head with dry nitrogen as described in the following paragraphs.

Nitrogen Purge

The Laser Head has been factory purged with UHP (Ultra High Purity) dry nitrogen to prevent condensation on the laser optics. If any cover or access screw is removed for any reason, the head should be purged again with UHP nitrogen.

1. Remove the two nitrogen purge/seal screws on the side of the Laser Head. (See Figure 9).

2. Connect 5 psi dry nitrogen to one seal screw hole, using the Schrader valve and #4-40 screw adapter supplied in the Accessories Kit. Flow UHP (Ultra High Purity) dry Nitrogen through the laser head for 5-10 minutes. Replace the screw in the purge hole used as the exit port for the dry Nitrogen. Remove the 4-40 screw adapter and Schrader valve from the laser head. Reinstall the purge/seal screw in the remaining open hole.

CHAPTER 7

TROUBLE-SHOOTING

The Laser electronics is designed to control the laser and warn the user of problems that may occur. The microprocessor-based system monitors the laser system and automatically shuts down if a fault occurs. Software limits have been factory selected to protect the laser system against electrical and optical damage.

Interlocks

There are five interlocks, both hardware and software controlled, which if opened will not allow the laser to operate until corrected. If any of the interlocks are not satisfied, the fault light will be illuminated.

1. *Remote Interlock:* Located on the back panel of the ICE. The contacts on this connector must be shorted to close the interlock. Check that the shorting connector is in place or that the user interlock cabling is properly shorting these contacts.

2. *Flow Interlock:* This interlock ensures that coolant is flowing through the Laser Head. The flow switch is a magnetic switch that is located in the coolant loop. If a coolant interlock fault occurs, verify the coolant flow is proper by checking for coolant turbulence in the reservoir. Also check for pinched cooling lines or other flow obstructions. A pump motor failure will be evident by touching the ICE near the bottom and noting lack of vibration.

3. *Temperature Interlock:* This interlock ensures that the coolant temperature does not exceed an acceptable level. The sensor is located on the heat exchanger inside the ICE. This switch will open if coolant temperature exceeds 150°F.

4. *Cover Interlock:* Located behind the ICE front cover, these dual, redundant switches ensure that the laser cannot be operated with the ICE cover removed.

5. *External I/O Cable Interlock:* The cable between the ICE and Laser Head is interlocked to ensure that high voltage cannot be enabled if the cable is not properly or completely installed. This interlock is in series with the cover interlock.

No Laser Output

1. *Check Fault Light:* Refer to the above paragraph if the fault light is illuminated.

2. *Check Cables:* With the prime power OFF and unplugged, check all electrical connections between the Laser Head and the ICE. Make sure all connections are secured. If any of the cables are not installed properly, the system will not function.

3. *Check Shutter Position:* The shutter is manually controlled and is located on the side of the laser head. When the shutter handle is horizontal, the shutter is open.

4. *Check Pump Energy Setting:* Refer to the efficiency data supplied in Appendix I and make sure the pump energy is not set below the lasing threshold. Correct if necessary.

5. *Check Q-Switch Setup:* Verify that the Q-Switch is enabled and that the Q-Switch "fire-every" is setup properly. The Q-Switch LED should be illuminated and the Fire LED should be flashing at the Q-Switch PRF. Verify that the External Q-Switch slide switch is in the "0" position. If External Q-Switch control is being used, verify that the switch is in the "1" position, the external trigger is connected and that it is adequate to drive the 50Ω input.

6. *Check E-MAX Adjustment:* Verify that the E-MAX adjustment knob on the ICE back panel is fully CW. Rotating the knob fully CCW will push the Q-Switch delay out past the fluorescent life time of the laser rod, resulting in low or no output energy.

Energy is Low

1. *Flashlamp Degradation:* If output energy is slightly below normal level, it may suggest gradual lamp degradation. These characteristics are normal over time and with a large shot accumulation (>30 million). The pump energy can be increased to compensate for lamp degradation. However, excessive input energy (voltage) to the lamp must be avoided since prelasing and optics damage may result. If significant lamp degradation is suspected, replace the flashlamp as detailed in the previous chapter.

2. *Coolant Degradation:* Operating the laser system with contaminated coolant can adversely effect energy. Inspect the coolant for clarity. The coolant should be very clear and free from contaminants. There should be no large particulate or organic contaminants in the coolant. Black particulate is a sign of pump wear. Green color may be a sign of organic substances growing in the cooling system. If contaminated coolant is suspected, the cooling system must be purged and properly cleaned prior to operating the laser. Please consult Big Sky Laser Technologies for instructions on how to clean your cooling system if you suspect organically contaminated coolant.

3. *Incorrect Q-Switch Delay:* Check that the Q-Switch delay is set to 135µs with respect to the flashlamp. Using an oscilloscope, connect channel 1 to the Lamp Sync BNC and channel 2 to the Q-Switch Sync BNC. Triggering the scope on channel 1, verify that the delay from the rising edge of the Lamp Sync to the rising edge of the Q-Switch Sync is approximately 135µs. If the delay is longer than 135µs, the laser output will be attenuated. Verify that the E-MAX adjustment knob on the ICE back panel is rotated fully CW.

4. *Resonator Misaligned:* If beam quality has degraded, it may suggest that the resonator needs realignment. Contact Big Sky Laser Technologies for more details.

Lamp Does Not Flash

1. *Simmer Problem:* If the flashlamp does not flash, it may be an indication that the lamp will not simmer or is difficult to simmer. Check to see that the simmer indicator is illuminated when high voltage is enabled. If it is not, either ionized, or contaminated coolant, or a degraded flashlamp may be the cause. Coolant should indicate a resistivity of 1 MΩ/cm or greater for proper operation. If coolant resistivity is less than1 MΩ/cm, replace the coolant. If the lamp still does not simmer replace the flashlamp. Refer to CHAPTER 6 for both procedures.

2. *PRF Setting:* Another possible cause of the flashlamp not flashing is that the PRF setting is set for external mode and the external trigger is either not connected or is not adequate to drive the 50Ω input. Set the PRF setting for internal PRF control (1, 2, 5, 10 or 20 Hz) and check to see if the flashlamp will flash in this mode.

3. *Charger Latch-up:* If the ICE makes a squealing or hissing sound when the high voltage is enabled, and the simmer LED is illuminated but the flashlamp does not flash, **disable the high voltage immediately**. A component inside the ICE has most likely failed and the high voltage charger is attempting to charge into a short circuit. If the ICE is operated in this mode for longer than a few seconds additional electronics damage may occur.

⚠ **CAUTION: Do not continue to run the laser system if you suspect Charger Latch-up. Permanent damage to the ICE high voltage charging electronics will result if operated in this mode.**

Misc. ICE Problems

1. *Front Panel Keys don't respond:* Check if the front panel is locked out. The PRF display will indicate "L0" if the ICE is in this mode. See CHAPTER 5 to disable the lock out feature.

2. *Energy Control Keys do not respond:* Check that the HV Test Switch is in the "0" position. If it is in the "1" position, the bar graph display will only display the actual high voltage feedback. Since the high voltage is not enabled, the display will remain blank, even though the keys are actually adjusting the high voltage setpoint.

3. *Energy bar graph display does not adjust up to the top LED:* Check that the HV Test Switch is in the "0" position. If it is in the "1" position the bar graph display will only display the actual high voltage feedback when the high voltage is enabled. The high voltage feedback is not scaled for the full range of the bar graph display.

Contact Big Sky Laser Technologies for any repair actions necessary beyond those described in this manual. Attempts to adjust, repair or replace any portion of the laser system may cause additional problems and void the warranty. See CHAPTER 9.

CHAPTER 8

SPECIFICATIONS

Integrated Cooler and Electronics Specifications

Mechanical Specifications:

Chassis Dimensions	7.5"W x 14"H x 14"D (nominal).
Weight	Laser Head: 2.5 lbs. ICE: 32 lbs. (with coolant).

Input Electrical Specifications:

Prime Power	115 VAC ± 10%, 50/60 Hz.
	230 VAC ± 10%, 50/60 Hz.
	400 Watts maximum.

Environmental Specifications:

Storage Temperature	5 to +50°C (Distilled Water).
	-30 to +60°C (EGW).
Operating Temperature	10 to +40°C (Distilled Water).
	-10 to +50°C (EGW).

ICE Electrical Interface

1. Connector Name: RS-232
   Connector Type: D-Sub, DE-9S

PIN	SIGNAL NAME	DESCRIPTION
1	DCD	Data Carrier Detect. Not Used.
6	DSR	Data Set Ready. Not Used.
2	RX	Receive Data.
7	RTS	Request to Send. Not Used.
3	TX	Transmit Data.
8	CTS	Clear to Send. Not Used.
4	DTR	Data Terminal Ready. Not Used.
9	RI	Ring Indicator. Not Used.
5	Gnd	Signal Ground.

NOTE: A pin-to-pin (straight-through) cable should be used to connect to the RS-232 port. A null modem cable should not be used. If a 9-to-25 pin adapter is used, ensure that it is a straight-through adapter.

2. Connector Name: LASER HEAD I/O
Connector Type: D-Sub, Multi-pin 13W3S (DB-25 Shell Size)

PIN	SIGNAL NAME	DESCRIPTION
1	Laser Intlk (+)	Laser Interlock. Must be tied to Pin 6 to close.
6	Laser Intlk (-)	Laser Interlock. Must be tied to Pin 1 to close.
3	+24 VDC	+24 VDC at 300 mA.
9	+24V Rtn	Return for +24V.
7	Q-SW Trig	Q-Switch trigger output. ~+15V, 100µs pulse into 50Ω.
2	Q-SW +15 VDC	+15 VDC at 100 mA.
8	Q-SW +15V Rtn	Return for +15V.
5	Simmer Trigger	-250V pulse_{NOM} to ionize laser flashlamp.
10	Sim Trigger Rtn	Signal return.
4	Reserved	Reserved for BSLT use.
A3	Lamp (+)	High voltage to laser flashlamp. ~120µs pulse, 1000V at 300A .
A2	Lamp (-)	High voltage return.
A1	Safety Gnd	Ground.

3. Connector Name: REMOTE RUN
Connector Type: BNC

PIN	SIGNAL NAME	DESCRIPTION
C	Remote Run	+5 VDC thru 10K pull-up resistor. Short to Run, Open to Stop.
SH	Remote Run Rtn	Signal return.

4. Connector Name: REMOTE INTLK
Connector Type: BNC

PIN	SIGNAL NAME	DESCRIPTION
C	Remote Intlk (+)	+15 VDC thru 10K pull-up resistor. Short to Shield to Close.
SH	Remote Intlk (-)	Signal return.

5. Connector Name: EXT Q-SW
Connector Type: BNC

PIN	SIGNAL NAME	DESCRIPTION
C	External Q-Switch In	External Q-Switch trigger input, +5 VDC, 100µs, into 50Ω.
SH	External Q-Sw Rtn	Signal return.

6. Connector Name: EXT TRIG
Connector Type: BNC

PIN	SIGNAL NAME	DESCRIPTION
C	External Trigger	External lamp trigger input, +5 VDC, 100µs, into 50Ω.
SH	External Trig Rtn	Signal return.

7. Connector Name: HV/100
Connector Type: BNC

PIN	SIGNAL NAME	DESCRIPTION
C	HV/100	Test point. Provides PFN capacitor sample voltage/100.
SH	HV/100 Rtn	Signal return.

8. Connector Name: Q-SW SYNC
Connector Type: BNC

PIN	SIGNAL NAME	DESCRIPTION
C	Q-Sw Sync	Test point. +5 VDC sync pulse output, 100µs, 50Ω drive.
SH	Q-Sw Sync Rtn	Signal return.

9. Connector Name: Lamp SYNC
Connector Type: BNC

PIN	SIGNAL NAME	DESCRIPTION
C	Lamp Sync	Test point. +5 VDC sync pulse output, 100µs, 50Ω drive.
SH	Lamp Sync Rtn	Signal return.

10. Connector Name: Mains AC INPUT
Connector Type: IEC 320

PIN	SIGNAL NAME	DESCRIPTION
1	AC L1	115/230 VAC, 50/60 Hz.
2	AC L2/N	115/230 VAC, 50/60 Hz.
3	Safety Gnd	Safety ground.

Laser Head Interface

1. Connector Name: LASER I/O
   Connector Type: Fischer, DEE104A092

PIN	SIGNAL NAME	DESCRIPTION
1	Laser Intlk (+)	Laser Interlock. Tied to Pin 2.
2	Laser Intlk (-)	Laser Interlock. Tied to Pin 1.
11	Reserved	No connection.
3	Reserved	No connection.
14	+24 VDC	+24 VDC at 300 mA for harmonic generator oven.
16	+24V Rtn	Return for +24V.
15	Reserved	No connection.
6	Temp FB #1	Temperature feedback from harmonic generator, test point.
17	Temp FB Rtn	Temperature feedback signal return.
7	Reserved	No connection.
19	Q-Sw +15 VDC	+15 VDC at 100 mA to Q-Switch driver.
8	Q-Sw +15V Rtn	Return for +15V and Q-Switch trigger.
18	Q-SW Trig	Q-Switch trigger input to Q-Switch driver.
9	Simmer Trigger	Flashlamp start pulse to trigger transformer.
10	Sim Trigger Rtn	Signal return.
4	Reserved	No connection.
5	Reserved	No connection.
12	Reserved	No connection.
13	Reserved	No connection.

2. Connector Name: HV INPUT
   Connector Type: Fischer, DEE104A087

PIN	SIGNAL NAME	DESCRIPTION
1	Lamp (+)	High voltage to laser flashlamp. ~120µs pulse, 1000V at 300A.
2	Lamp (-)	High voltage return.
3	PFN Intlk (+)	High voltage interlock. Tied to Pin 4.
4	PFN Intlk (-)	High voltage interlock. Tied to Pin 3.

Laser Timing:

Figure 12 shows a typical timing diagram for the Ultra Laser system. The delay from Q-Switch Sync to Laser output is shown for 1064 nm at 50 mJ. Decreasing the pump energy or increasing the Q-Switch delay will result in an increase in the delay from Q-Switch Sync to Laser output. This is due to reduced gain in the resonator, resulting in longer pulse buildup time.

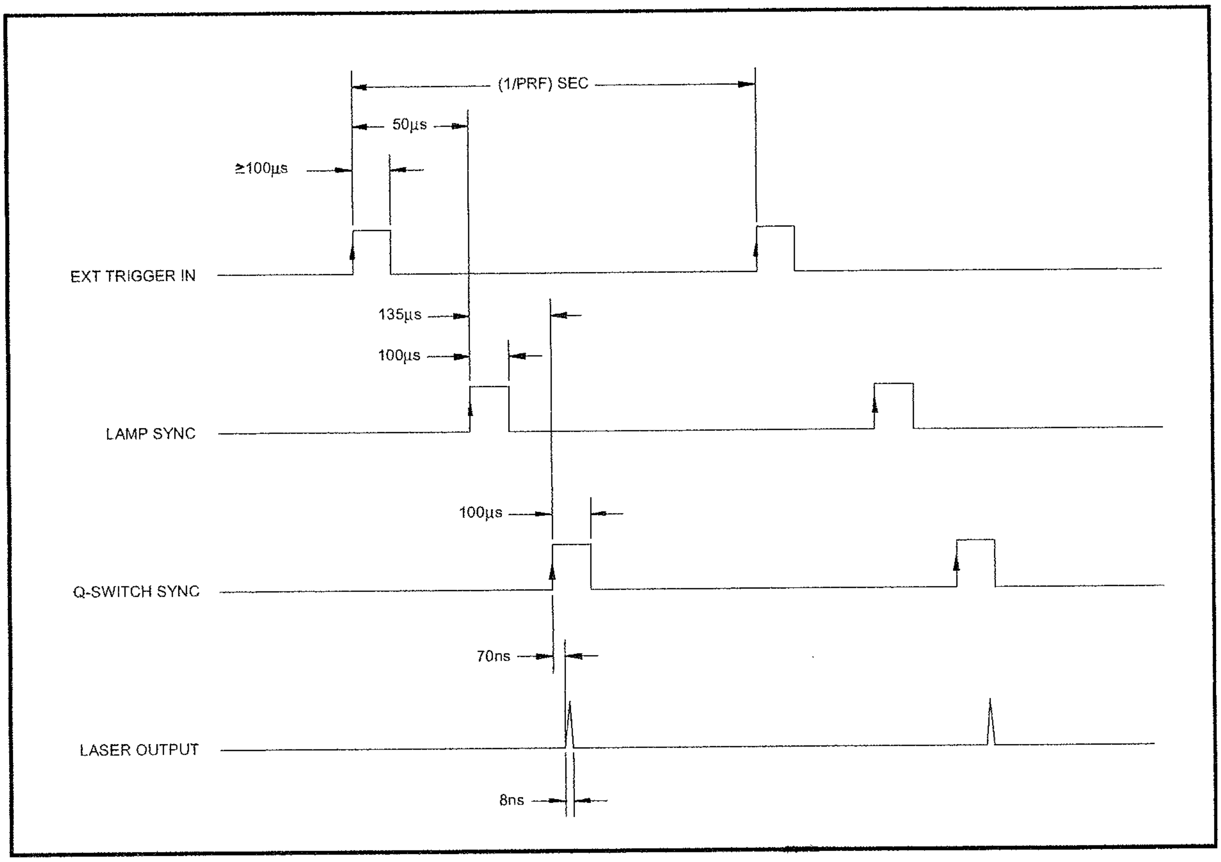
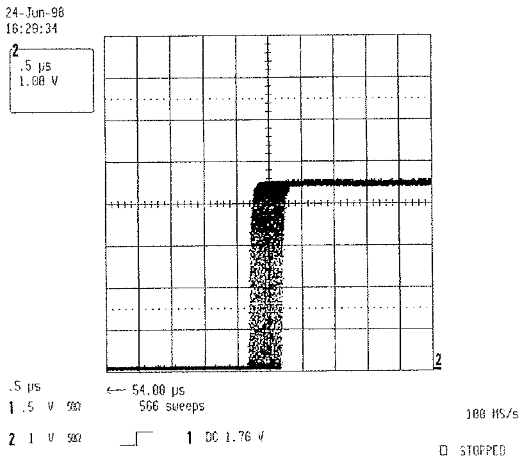


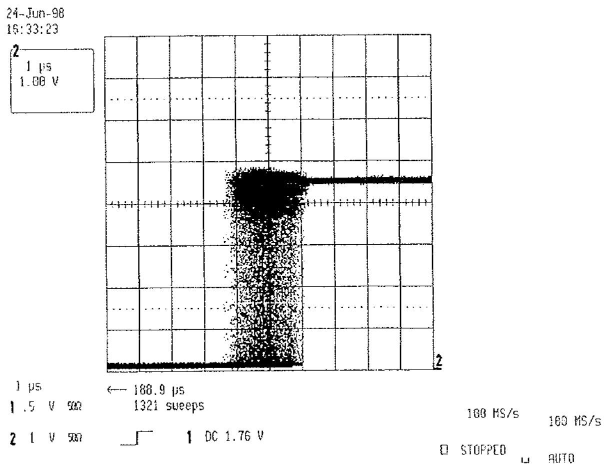
Figure 12: Typical Timing Diagram

Delay and Jitter Measurements:

Actual timing and jitter waveforms are shown in the following figures. Unless otherwise specified, all waveforms were recorded at 1064 nm, 50 mJ out, 20 Hz. Q-Switch delay was set at 135 μs past Lamp Sync. The energy in Figure 16 was set at 25 mJ by decreasing the lamp pump energy. The energy in Figure 17 was set at 15 mJ by returning the energy adjustment back to 50 mJ and then changing the Q-Switch delay using the E-Max Adjustment from 135 μs to 260 μs.



Lamp Sync Jitter



Q-Switch Sync Jitter

Figure 13: Sync Jitter with respect to External Trigger In

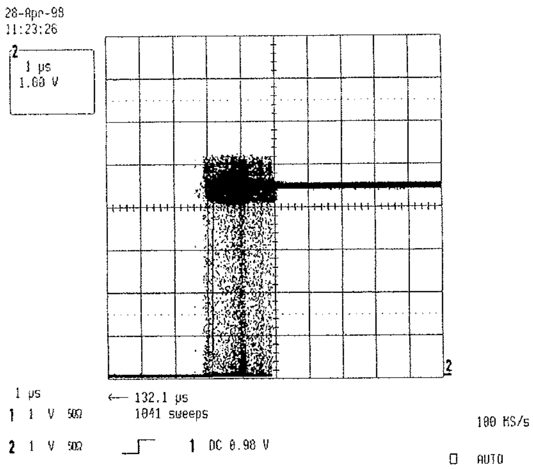
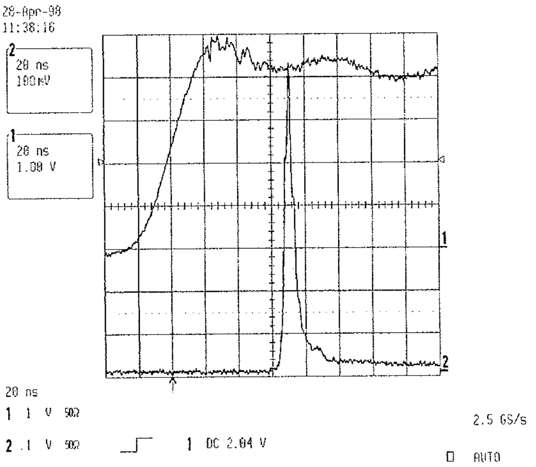
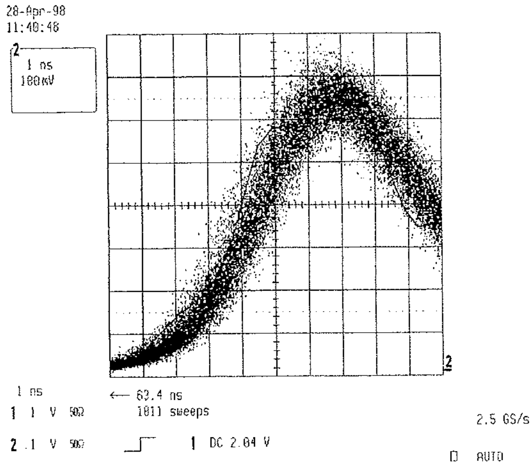


Figure 14: Q-Switch Sync Jitter with respect to Lamp Sync



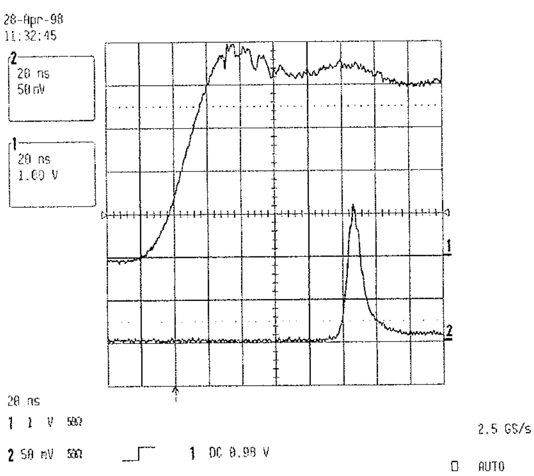
CH1: Q-Switch Sync CH2: Light Out

DELAY



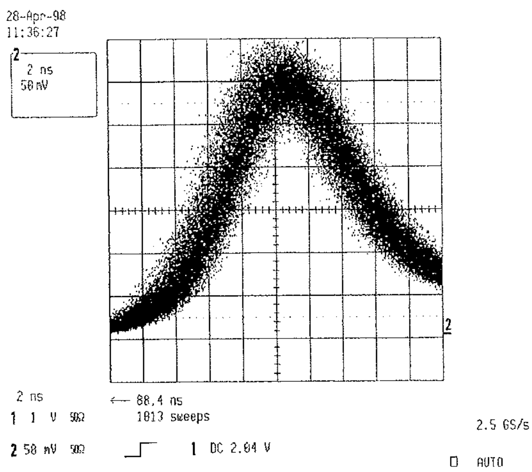
JITTER

Figure 15: Jitter, Q-Switch Sync to Light Out @ 50mJ



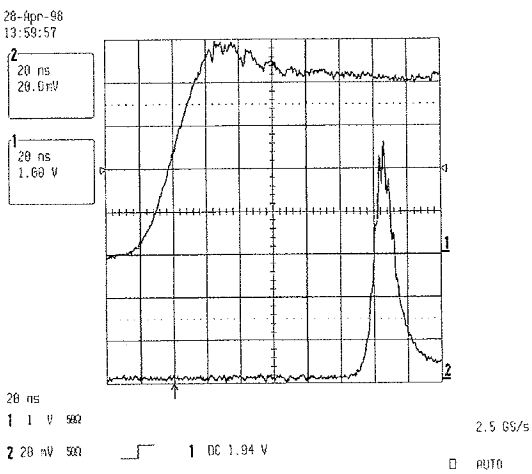
CH1: Q-Switch Sync CH2: Light Out

DELAY



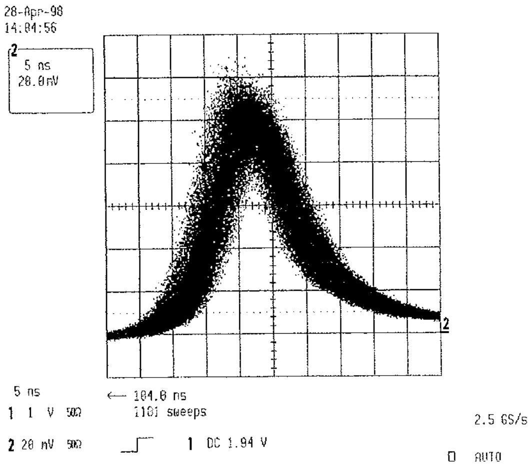
JITTER

Figure 16: Jitter, Q-Switch Sync to Light Out @ 25 mJ



CH1: Q-Switch Sync   CH2: Light Out

DELAY



JITTER

Figure 17: Jitter, Q-Switch Sync to Light Out @ 15 mJ

CHAPTER 9

CUSTOMER SERVICE

We at Big Sky Laser Technologies, Inc. are proud of our specialty laser systems. Our manufacturing and quality control processes emphasize consistency, stability, ruggedness, reliability and performance. We continually strive to make our laser systems more reliable and to provide superior customer support.

Should there be problems with the operation of your laser system, please call Big Sky Laser Technologies customer service hotline toll-free at 1-800-914-8216. We will do our best to get your system fully operational as quickly as possible.

Warranty

Big Sky Laser Technologies, Inc. warrants the lasers it manufactures and produces to be free from defects in materials and workmanship for one year following the date of shipment. Laser optics are warranted for 90 days following the date of shipment provided that operating instructions are properly followed. This warranty is limited to the original purchaser of the laser and is not transferable.

During the one year warranty period, we will repair or replace, at our option, any defective products or parts at no additional charge, provided that the product is returned, shipping prepaid, to Big Sky Laser Technologies, 601 Haggerty Lane, Suite C, Bozeman, MT 59715. All replaced parts and products become the property of Big Sky Laser Technologies.

This warranty does NOT extend to any lasers which have been damaged as a result of accident, misuse, abuse (such as use of incorrect input voltages, improper or insufficient ventilation, faulty lamp replacement, failure to follow the operating instructions provided by Big Sky Laser Technologies, or other contingencies beyond our control), or as a result of service or modification by anyone other than Big Sky Laser Technologies.

Feedback

We welcome your feedback in regard to the use and performance of our laser system. Product improvements and refinements come about from these contacts, continually improve our product reliability, performance and customer satisfaction. Our toll free number is 1-800-2BIGSKY.