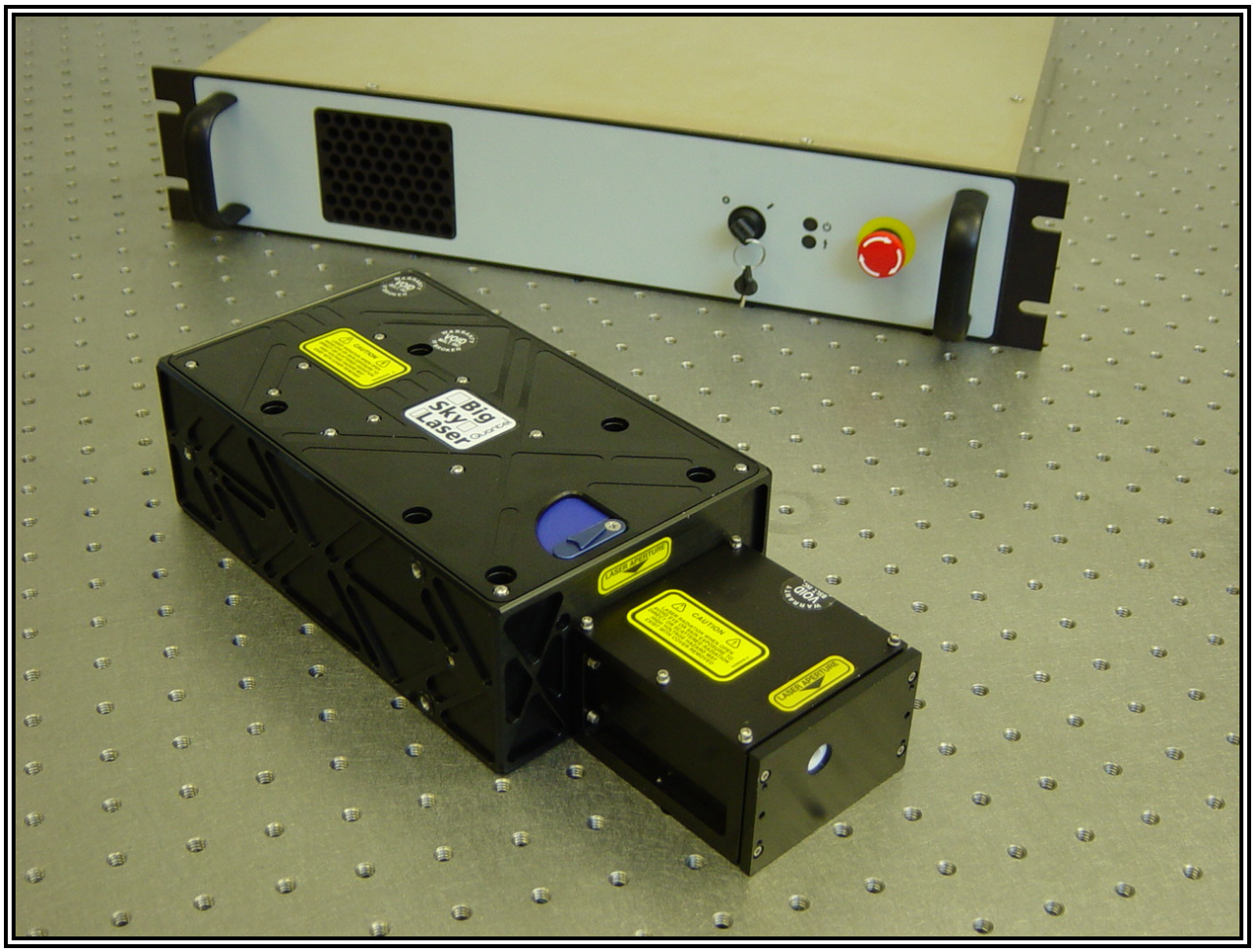

User's Manual

CENTURION
Diode Pumped
Nd:YAG Laser System

DOC00060 Revision G
June 2013

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PREFACE

This User's Manual contains the technical information needed to properly operate and maintain Quantel USA's Centurion Series diode-pumped Nd:YAG laser system. It provides instructions for set-up and installation, operation, service, preventative maintenance, and troubleshooting (fault-isolation). The laser system consists of two major subassemblies: (1) the Compact Laser Head (with optional nonlinear optics and add-on modules), and (2) the Laser Controller.

The laser system is truly "turn-key" and has been shipped fully functional. No adjustments are necessary to operate the laser. The cable interconnects are keyed for simplicity of installation. Hardware interlock and safety features are included in the Laser Controller 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 Laser Controller. The maximum ratings indicated on the system labels exceed the normal operating parameters. Please refer to the Data Summary Sheet for specific information pertaining to your system.

The laser system produces laser radiation, which is hazardous to eyes and skin, can burn and cause fires, and can vaporize substances. Chapter 2 contains essential safety information about these hazards.

NOTE: As of January 1st, 2008 "Big Sky Laser Technologies" underwent a name change to "Quantel USA". We are currently in the process of updating our manuals. Please note that some of the images in this manual do not reflect this change.

CHAPTER 1 *SYSTEM OVERVIEW*

Block Diagram

Figure 1-1 shows the laser system block diagram which consists of the Centurion Laser Head, Laser Controller, optional Air-Cooling Unit, and host computer (user supplied).

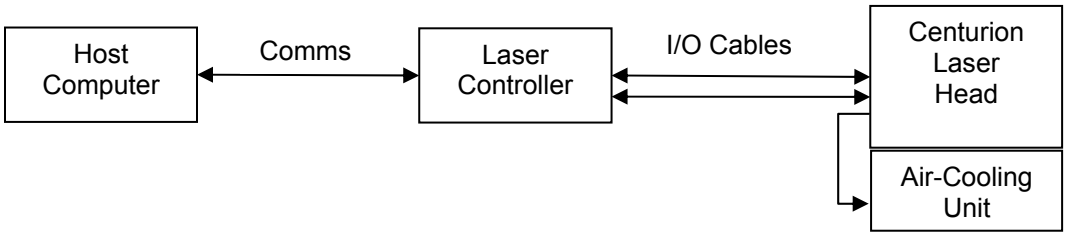


Figure 1-1: System Block Diagram

Since laser action is relatively inefficient, it generates more heat than light, even for a diode-pumped laser system. The laser normally uses a finned heat sink with cooling fans to keep the Laser Head cool. The Laser Controller provides the power to operate the laser diodes, which pump the laser rod. It also provides system timing, synchronization, controls and safety interlocks. Some electronic assemblies, such as the diode driver, thermo-electric coolers (TEC's) and Q-switch driver, are within the Laser Head. The Laser Controller requires a host computer 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 driving quasi-CW laser diode arrays (tuned to 808nm wavelength) which are optically coupled to a Nd:YAG laser rod, the diode optical output 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 230 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 occurs when 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 consists 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 Laser Controller is to provide the charging supply for the capacitors in the diode array driver, located in the Laser Head. This electrical energy is subsequently discharged through the diode array by use of a low-voltage switching network which supplies a constant current. The Laser Controller also provides other key functions including timing and control, diode and Q-Switch trigger, system status and safety features (time delays and interlocks).

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

The Laser Head

Figure 1-2 below shows the Centurion Laser Head with an optional non-linear optics module attached and without the air-cooling unit. Consult Chapter 3 for detailed schematics of the size, location of mounting holes, and alternate mounting configurations.

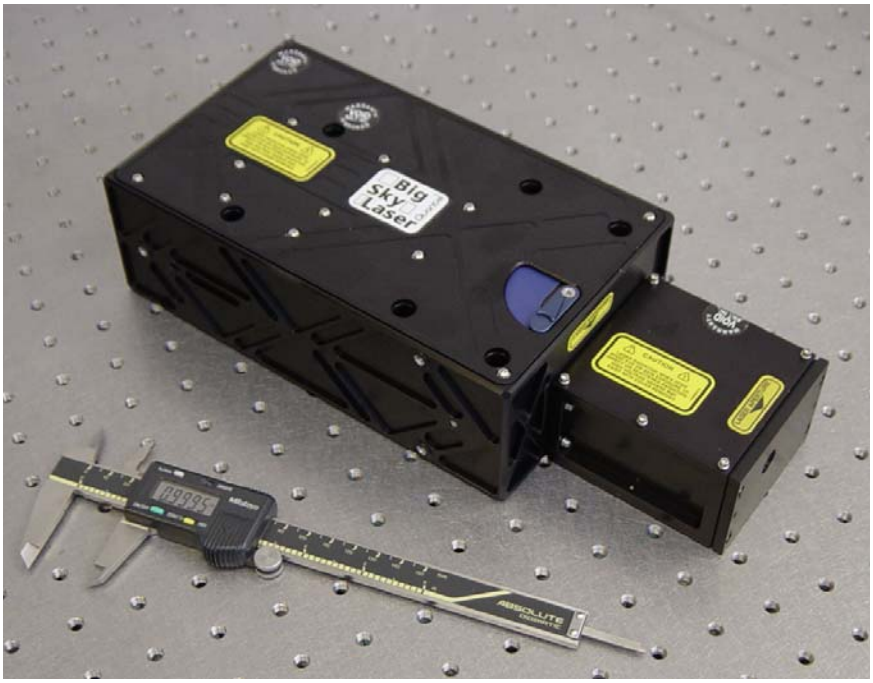


Figure 1-2: Centurion Laser Head

The Laser Controller

The Laser Controller consists of a mountable 2U 19" rack unit. The unit must be computer controlled through one of the serial communications ports (RS-232 or RS-422). The air-cooling system is automatically powered up when the system prime power is turned on via the Key Switch. Temperature interlocks prevent laser operation without adequate cooling and during over-temperature conditions. Figure 1-3 shows this assembly.

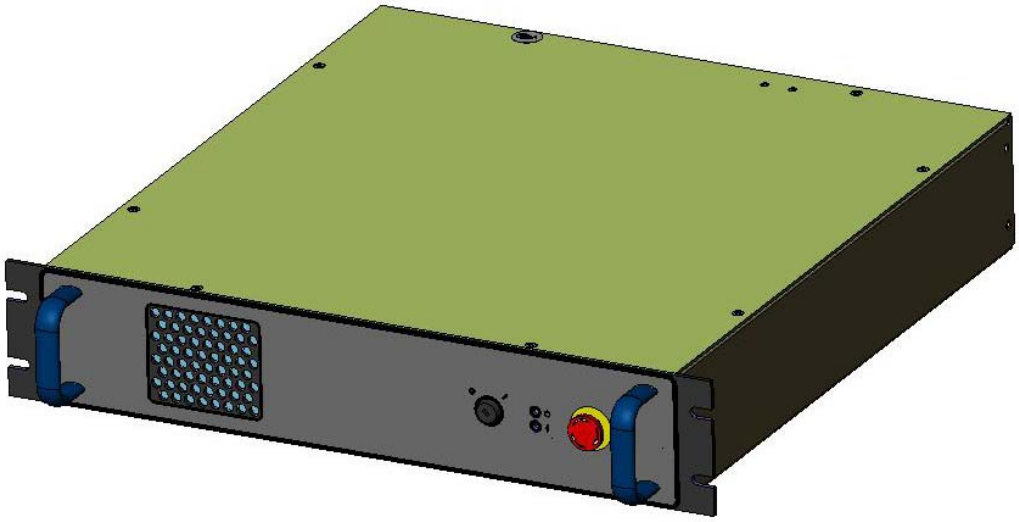


Figure 1-3: Laser Controller

The Laser Controller connects directly to the Laser Head, to prime power, and to the host computer. It contains all of the electronics necessary to operate the Laser Head. It also contains the interface electronics for system control. It is intended for use as an OEM control unit, with the laser functions being controlled via the RS-232 (or RS-422) interface via the host computer. The various functions available over the serial communications include pulse repetition frequency (PRF) control, Q-Switch enable, save configuration, pump energy control, and various status indicators. See Chapter 4 for detailed information on the laser electronics control interface.

Laser Head Cooling

Figure 1-4 shows the Laser Head with the Air-Cooling Unit attached. The air-cooling unit attaches to the thermal interface plate on the bottom of the Laser Head using eight (8) #6-32 socket head cap screws.

Figure 1-4: Laser Head with Air-Cooling Unit

Alternatively, the Laser Head can be attached to a user-supplied heat sink in lieu of the air-cooled heat sink. The user supplied heat sink must be capable of dissipating 150 watts of heat without exceeding 65° Celsius at the interface plate, when operating at full power. Reduced power operation will require less dissipation. The recommended screws used to mount the laser in this manner are #8-32 or M4.

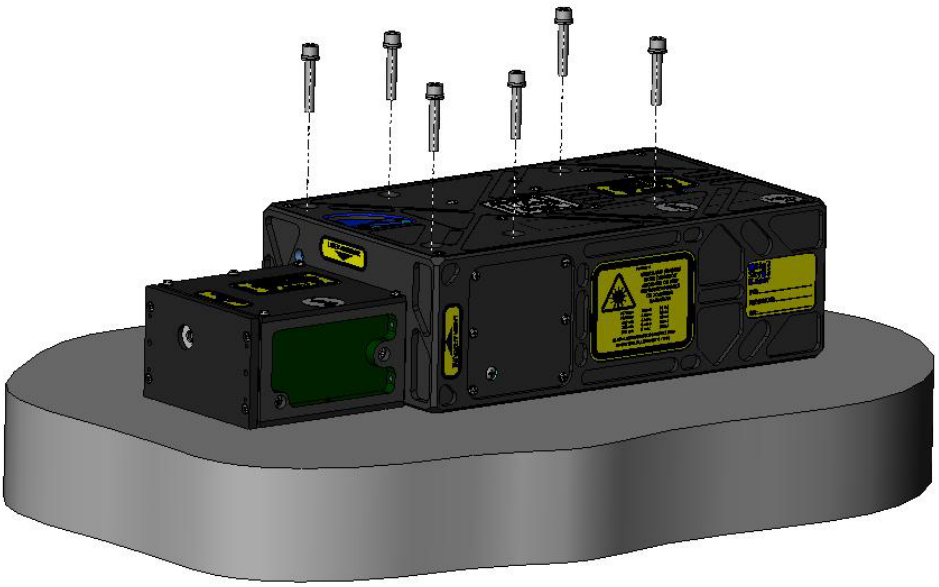


Figure 1-5: User-supplied heat sink

Wavelength Options

The Centurion can be configured to output many different wavelengths including 1064nm, 532nm, 355nm, 266nm, or 1574nm laser radiation. Several add-on wavelength separation modules are available. For the harmonic generation, there is a short oven warm-up time of less than 10 minutes when the system is initialized. If any of the ovens have not achieved their operating temperature of approximately 65°C, then the conversion to the harmonic will be severely affected.

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

Second Harmonic Generation (SHG)

The Centurion uses a temperature-controlled type II KTP (or type I LBO) doubler inside a nonlinear optics module to generate 532nm radiation. When the system is initialized, there is a short oven warm-up time of less than 10 minutes. If the oven is below the normal operating temperature of approximately 65°C, the 532nm output energy will be below the specified level.

Wavelength separation can be obtained by installing a dichroic module after the doubler module. Without the dichroic assembly, both the 1064nm and 532nm laser light exit the Laser Head through the same output aperture. With the dichroic module, the 532nm beam exits from the right aperture when viewed from the front of the Laser Head. The residual 1064nm laser radiation may be either internally absorbed or emitted from the left aperture.

Relative to the thermal interface plate, the output polarization of the 532nm laser light is vertical (perpendicular) when using KTP or horizontal when using LBO. The polarization of the residual 1064nm light is elliptical when using KTP, and vertical when using LBO.

Third Harmonic Generation (THG)

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

Wavelength separation can be obtained by installing a dichroic module beyond the tripler module. Without the dichroic assembly, the 1064nm, 532nm and 355nm laser radiation exit the Laser Head through the same output aperture. With the dichroic module, the 355nm beam exits from the right aperture when viewed from the front of the Laser Head while the residual 1064nm and 532nm laser radiation may be either internally absorbed, or emitted from the left aperture.

Nominally, the output polarization of the 355nm laser radiation is vertical and the residual 532nm radiation is horizontal. The residual 1064nm radiation is elliptical when using KTP and vertical when using LBO. All polarization directions are relative to the thermal interface plate.

Fourth Harmonic Generation (FHG)

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

Wavelength separation can be obtained by installing a dichroic module beyond the quadrupler module. Without the dichroic module, the 1064nm, 532nm and 266nm laser radiation exit the Laser Head through the same output aperture. With the dichroic module the 266nm beam exits from the right aperture, when viewed from the front of the Laser Head, while the residual 1064nm and 532nm laser radiation may be either internally absorbed or emitted from the left aperture.

Depending on the module configuration, the nominal output polarization of the 266nm is vertical for the LBO configuration and the 532nm is horizontal. The residual 1064nm radiation is elliptical for a KTP configuration or vertical for a LBO configuration. All polarization directions are relative to the thermal interface plate.

1.57 µm KTP OPO Module

The KTP OPO module is used to convert incident 1064nm radiation to more eye-safe mid-IR radiation, near 1.57 microns. The output polarization is horizontal (parallel) to the thermal interface plate. The standard OPO unit is not wavelength controllable and there is no temperature or mechanical adjustment required. The warm up time is the same as the 1064nm configuration.

CHAPTER 2 SAFETY

Safety Summary

This product complies with FDA performance standards for laser products, except for deviations pursuant to Laser Notice 50, dated June 24, 2007. This product also complies with EN61010-1 and IEC 61010-1 and IEC 60825-1. Do not install substitute parts or perform any unauthorized modifications to the product. Return the product to Quantel USA for service or repair to ensure that all safety features are maintained.

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

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 Centurion 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. 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 only 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.

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.

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 International Electrotechnical Commission (IEC) requirements. This laser product complies with Title 21 of the United States Code of Federal Regulations, 1040.10, as applicable, and with IEC 60825-1:2007-03, 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 Laser Controller.

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.

4. Verify that the Emission Indicators illuminate when the laser is capable of generating radiation. The Emission Indicators are located on the Laser Head (under the shutter switch), and on the front panel of the Laser Controller.

Electrical Safety

HIGH VOLTAGE

High Voltage Precautions for Safety

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

Consult with Quantel USA's 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 action is required, it is recommended that you contact Quantel USA 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. “Compliance Guide for Laser Products”
   HHS Publication FDA 86-8260
   U.S. Department of Health and Human Services
   FDA
   Center for Devices and Radiological Health
   Rockville, Maryland 20857 USA
   Phone: (240) 276-3332

3. "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

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

5. “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 Centurion laser system. These labels are installed at the factory and should not be removed by the user. If for any reason a label is removed, obscured or damaged, please contact Quantel USA for a replacement.

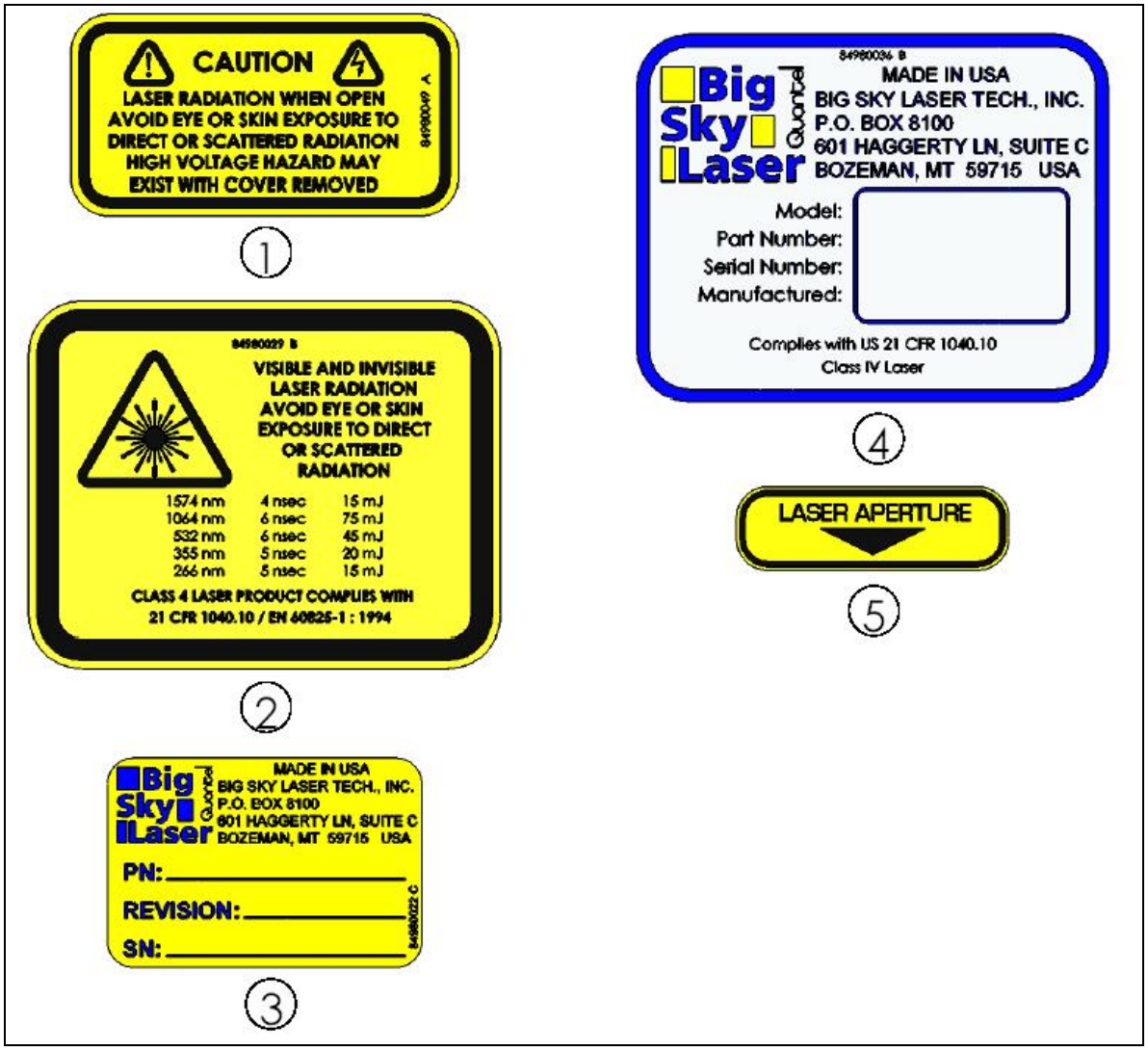


Figure 2-1: Safety Labels

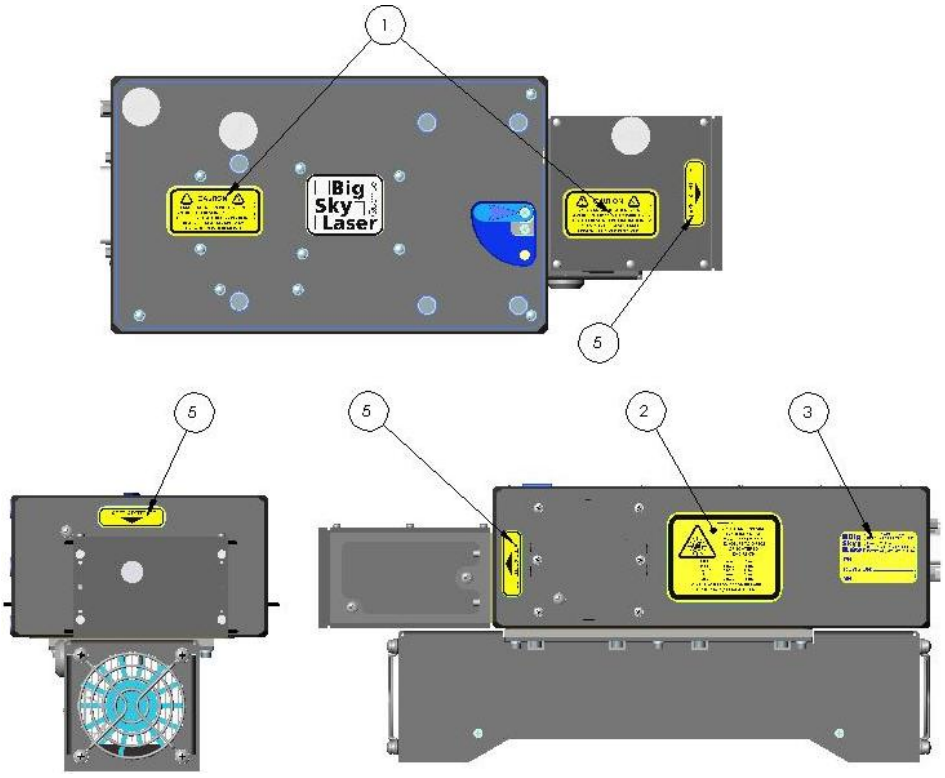


Figure 2-2: Laser Head Safety Label Locations

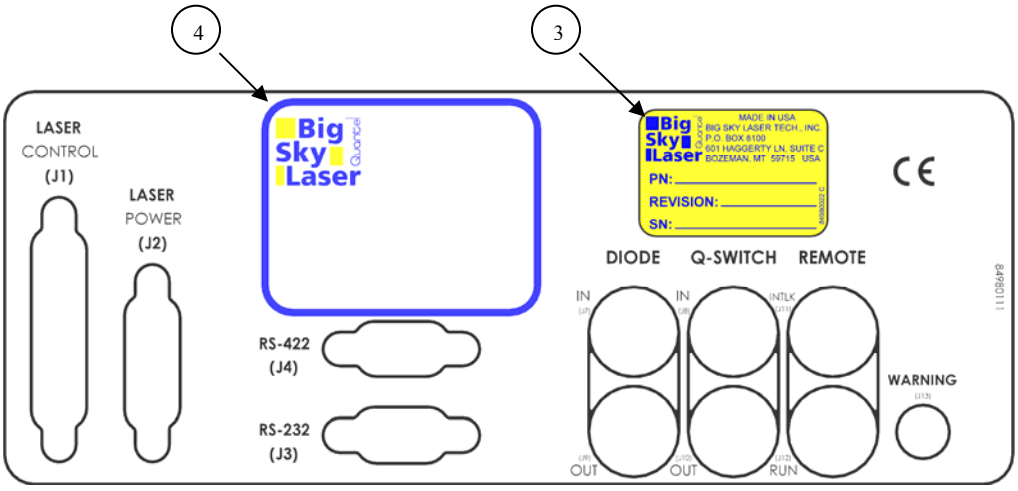


Figure 2-3: Laser Controller Product Label

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 Quantel USA. We will do whatever possible to quickly get the laser system fully operational.

It is recommended that the shipping container be kept for any future shipping purposes, such as the unit requiring repair or maintenance services. If a damage claim has been filed, the container should be provided to prove shipping damage.

The laser system is a “turn key” system, designed so that a field service engineer is not required for system installation, start-up or operation. 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 laser system before thoroughly reading the installation and operation instructions. 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. Do not connect the Laser Controller to main power until you make sure the Key Switch is in the OFF position.

System Inventory

The laser system consists of the items listed below. Verify that all items are present in the shipping container. If there are any discrepancies, contact Quantel USA immediately.

1. Centurion Laser Head
2. Laser Controller
3. One Pair External I/O Cables (one D15 and one D25)
4. Power Cord
5. 2 Keys
6. Accessory Kit
7. Application Specific Hardware [1]

NOTES

1. Refer to Quantel USA Quotation for included Application Specific Hardware

Laser Installation

The Laser Head can be mounted several different ways:

1. The laser can be mounted using a user-supplied heat sink as shown in Figure 3-1. Six (6) #8-32 x 1in. or M4 x 25mm socket head cap screws are used to affix the laser to a properly sized heat sink, with a hole configuration as shown in Figure 3-2. The six screws are inserted straight down through the laser. Reference dowel pins (1/8" or M3) can be used to accurately locate the laser.

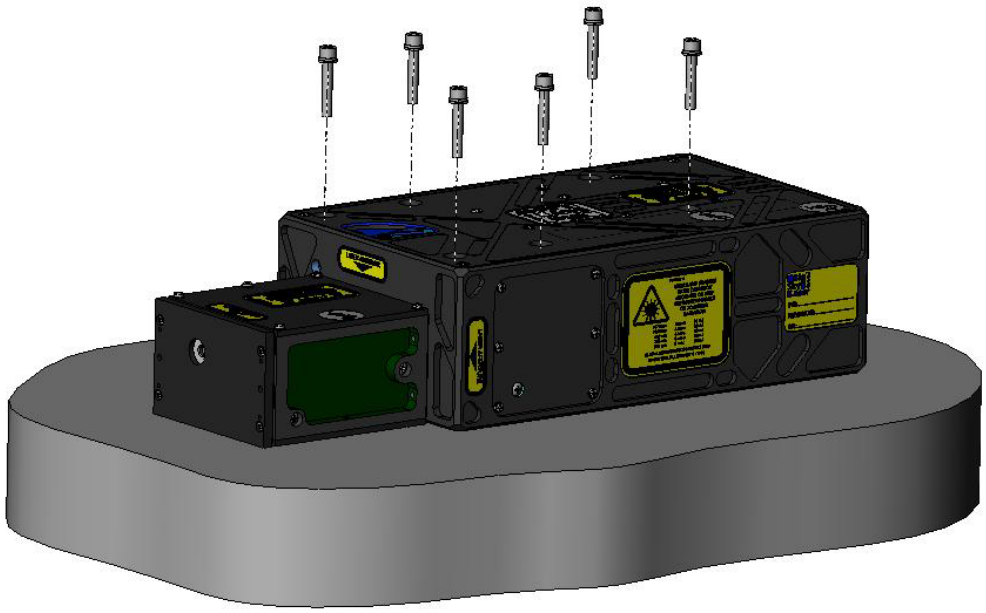


Figure 3-1: User-Supplied Heat Sink

Mounting with this configuration requires the surface flatness of the surface to be 0.001". The heat sink must be capable of removing up to 150 watts of heat while not exceeding 65°C when running at full duty cycle operation. If running at a reduced duty cycle, the capacity of the heat sink can be reduced accordingly. Refer to figure 3-2 for reference dimensions. The use of silicon heat sink compound is **NOT** recommended between the heat sink and the laser.

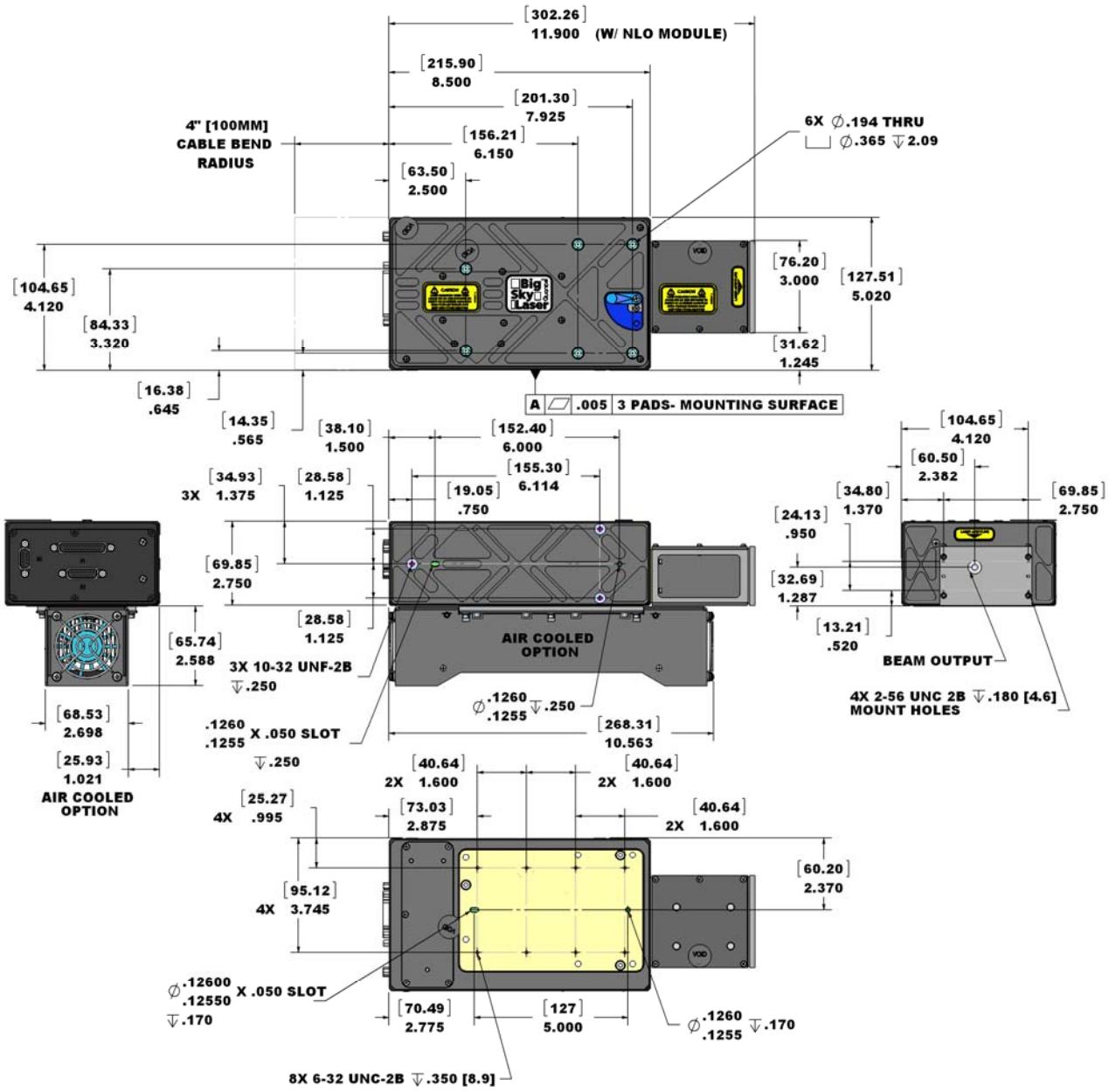


Figure 3-2: Laser Head Mounting Reference Geometry

2. When using the air-cooled heat sink, the laser can be mounted using three (3) #10-32 UNC screws as shown in Figure 3-3. These screws need to come through the mounting plate and screw directly into the Laser Head. Two (2) 1/8 in. or M3 dowel pins can be used for accurately locating the laser. An optional mounting plate is available which will allow mounting on a conventional optical table with #¼-20 or M6 mounting holes. The Quantel USA part number for the mounting plate is 16008311.

Figure 3-3: Mounting Through Optional Mounting Plate

The optional mounting plate is shown in Figure 3-3. However, any suitable surface plate geometry is acceptable. The surface needs to be flat to prevent the optical structure from misaligning. Refer to Figure 3-2 for reference dimensions.

3. Connect the External I/O cables to the Laser Head and Laser Controller. If using the air-cooled option, connect the 9-pin connector from the fan shroud to J3 (24VDC) on the Laser Head. All connectors are unique to ensure proper connection. Be sure to tighten the jackscrews on the connectors to ensure that the connectors are fully seated.

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

5. Verify that the Emergency Stop switch is in the OUT position. Rotate the switch clock-wise (in the direction of the arrows) to disengage.

6. Attach the host computer system to the Laser Controller using either the RS-232 or RS-422 connector.

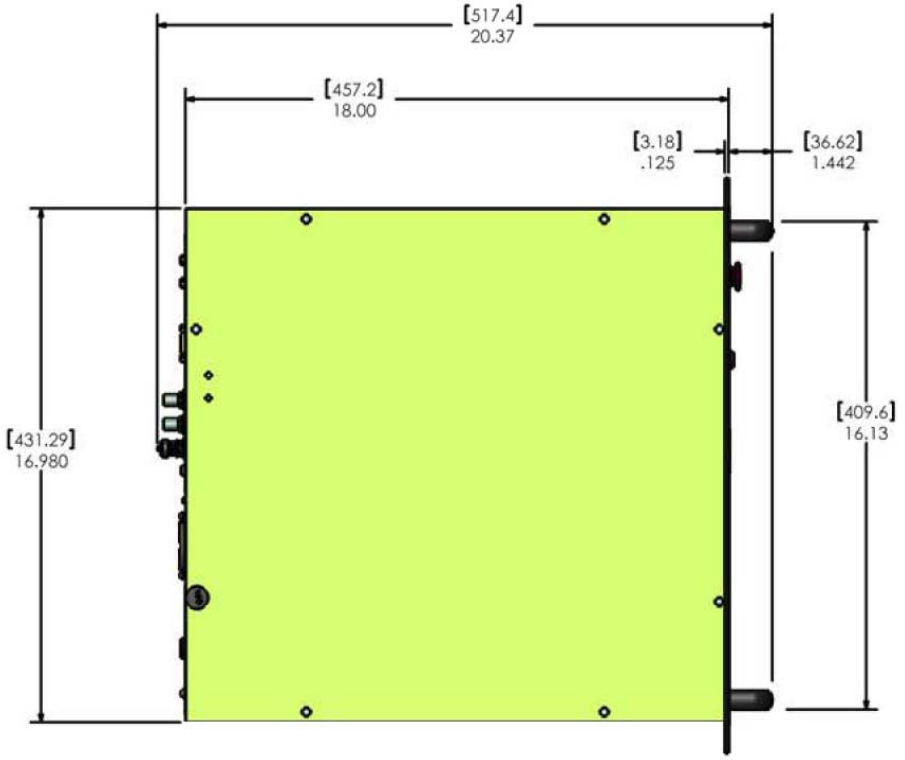
7. Ensure that the REMOTE INTERLOCK BNC connector and REMOTE RUN BNC connector are shorted. The laser system has been shipped with these shorting connectors already in place. The remote interlock can be connected to lab door interlocks or other system interlocks for safety. Refer to Chapter 8 for a detailed description of the electrical interface for these connectors.

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

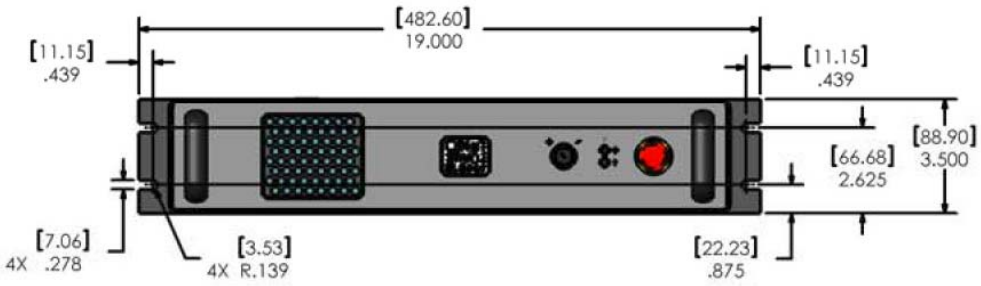
8. Connect the system to prime power, using the supplied power cord.

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

CAUTION: Ensure that the main power outlet that the Centurion Laser Controller connects to is properly grounded. Poor ground quality could result in exposure to electrical shock.



a) Laser Controller (Top View)



b) Laser Controller (Front View)

Figure 3-4: Laser Controller Dimensions

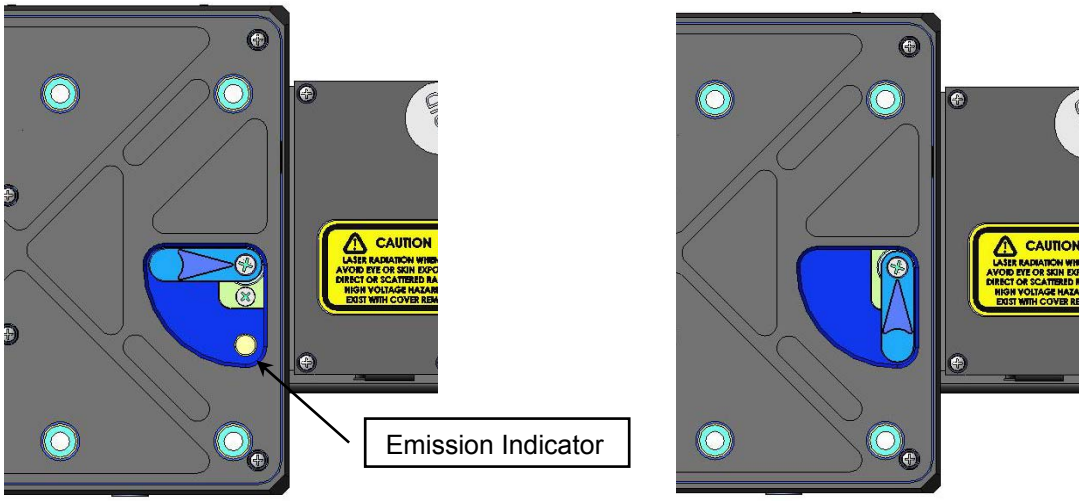
CHAPTER 4 LASER OPERATION

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. The Centurion Laser System can only be operated and controlled via a serial computer connection (RS-232 or RS-422). Turn the Key Switch ON. After approximately 10 seconds, the laser is initialized and ready for operator control. The Laser Controller will produce an audible BEEP whenever it changes state. The operational states, as defined in Chapter 5, are Sleep, Standby, and Fire. See Summary Data Sheets included with your laser for factory preset operating configurations.

Manual Shutter Operation

The Centurion utilizes a manual shutter, located on the side of the Laser Head (see Figure 4-1). Lasing action cannot take place with this shutter closed. To open the manual shutter, position the shutter handle so that it is horizontal. The shutter is closed with the handle pin in the vertical position. See Figure 4-1.



a) Shutter OPEN – laser light emitted

b) Shutter CLOSED – Lasing Inhibited

Figure 4-1: Manual Shutter Positions

The Emission Indicator LED located underneath the shutter handle indicates the operating mode of the laser. If this light is continuously illuminated, it is in STANDBY mode. If it is pulsing (2 Hz), the laser is in FIRE mode, and it should be assumed that laser light is being emitted. The shutter handle will completely cover this LED when the shutter is closed.

If the shutter is physically in the OPEN position, it should be assumed that the laser is capable of lasing, regardless of the status of the Emission Indicator.

Laser Head Connectors

Figure 4-2 shows the connector locations on the back of the Centurion Laser Head.

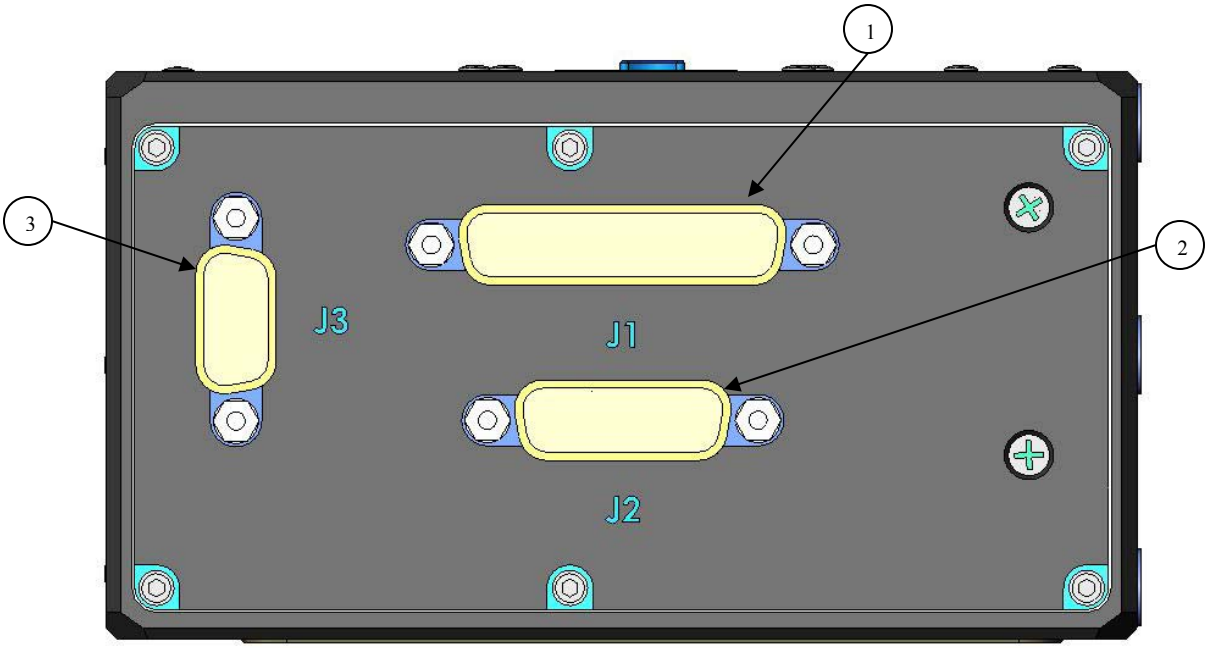


Figure 4-2: Laser Head Connector Locations

Connectors

1. *Laser Head Control Connector (J1 – Laser Control):* This D-25 connector provides the electrical control interface to the Laser Head.

2. *Laser Head Power (J2- Laser Power):* This D-15 connector provides the electrical power interface to the Laser Head.

3. *Air-Cooling Fan Power (J3 – Auxiliary):* This D-9 connector supplies +24 VDC power to the air-cooling fan shroud.

Laser Controller Front Panel

See Figure 4-3 for a view of the Laser Controller front panel

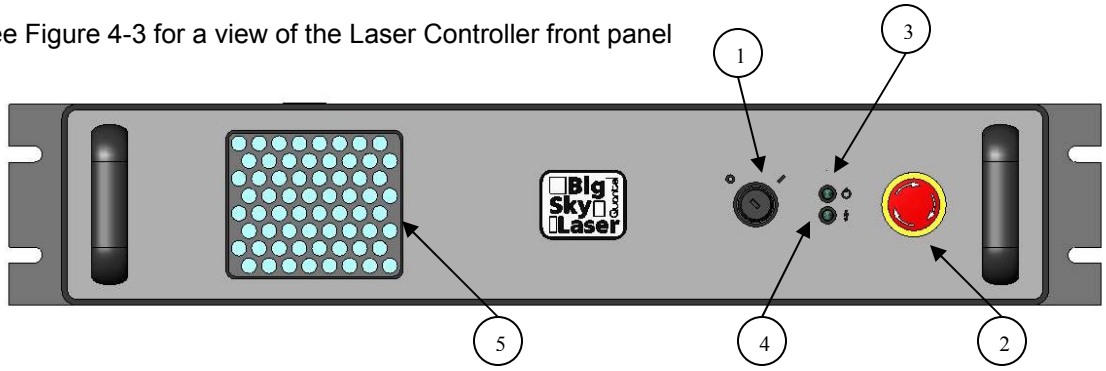


Figure 4-3: Laser Controller Front Panel

Switches

1. *Power Key Switch:* This switch applies AC main power to the controller. The power indicator, the upper LED located directly to the right of the Key Switch, illuminates to indicate that AC power is ON. The key is not removable in the ON position.

2. *Emergency Stop Button:* This large red button, located on the front of the Centurion Laser Controller, disconnects the AC main power to the system. This button should be used only in an emergency when it is necessary to quickly shut down the laser system. The button protrudes during normal operation. Depressing the stop button disables the system. Twisting the button clock-wise and allowing it to push outward as indicated by the white arrows resets the switch.

Status Indicators

3. *Power Indicator:* This LED (described above) illuminates to indicate that AC main power has been applied to the system.

4. *Emission Indicator:* This LED (located immediately under the Power Indicator LED) indicates that the system is in STANDBY mode or that laser light is potentially being emitted from the Laser Head (FIRE mode). When the laser is in STANDBY mode, this LED will be continuously illuminated. When the LED flashes (~2Hz), the laser is in the FIRE mode, the Q-Switch is enabled, and the diodes are pulsing.

Miscellaneous

5. *Air Inlet:* The Laser Controller is force convection cooled via an internal fan. Do not block the air inlet during laser operation.

Laser Controller Back Panel

See figure 4-4 for a view of the Laser Controller back panel. Chapter 8 contains detailed interface requirements.

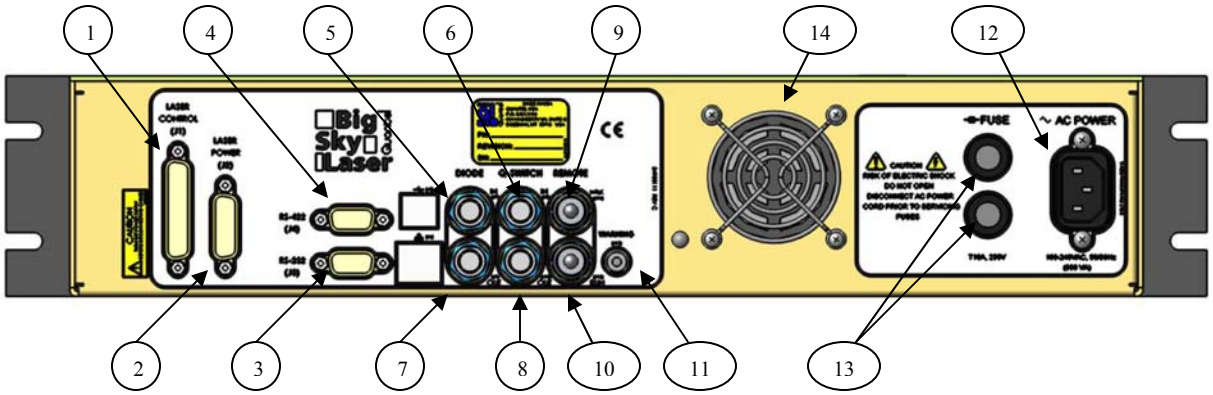


Figure 4-4: Laser Controller Back Panel

Connectors

1. *Laser Head Control Connector (J1 – Laser Control):* This D-25 connector provides the electrical control interface to the Laser Head.

2. *Laser Head Power (J2- Laser Power):* This D-15 connector provides the electrical power to the Laser Head.

3. *RS-232 Communications Connector (J3 - RS-232):* This D-9 connector provides the serial communications to the Laser Controller from the host computer. See Chapter 5 for serial interface specification.

4. *RS-422 Communications Connector (J4 - RS-422):* This D-9 connector provides differential serial communications to the Laser Controller from the host computer. See Chapter 5 for serial interface specification

5. *Diode In (J7 - Ext Trig):* This BNC connector is used to externally trigger the Centurion laser system. The Laser Controller must be set to external trigger mode (see Chapter 5) to be in external trigger mode.

6. *Q-Switch In (J8 - 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.

   Note: If External Q-Switch Trigger mode is used, see the Data Summary Sheet or contact Quantel USA's Customer Service Department to determine the optimum Q-Switch delay from diode trigger and the required rod lensing delay to avoid unstable laser performance during the first few laser shots. A typical Q-Switch delay is *10-15µs* with respect to Diode Out (Diode Sync falling edge).

7. *Diode Out (J9 - Diode Sync):* This BNC provides a sync pulse with the same timing as the diode current. This output can be used to pre-trigger or synchronize external equipment.

8. *QS Out (J10 - Q-Sw Sync):* This BNC provides a sync pulse coincident with the Q-switch trigger. This output can be used to synchronize external equipment to the laser output.

9. *Remote Interlock (J11 - 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.

10. *Remote Run (J12):* This input BNC connector is used to remotely gate the Diode and Q-Switch Triggers ON/OFF. When the BNC is shorted, the triggers are enabled. Opening the connection disables the triggers. This BNC can also be software configured as a general purpose input to perform customer specific requirements. Contact Quantel USA for more details. Use only an isolated switch closure to avoid system ground loops. The Laser Controller has been shipped with a shorting connector already in place.

11. *Warning (J13):* This output is coincident with the laser Emission Indicators on the Laser Head and the Laser Controller front panel. It is designed to drive an external device, such as a Laser Warning Lamp at the entrance to a laser lab.

Power Input

12. *AC Mains Power Line Input:* This industry standard IEC 60320 power inlet provides the electrical power input to the Laser Controller. Refer to Chapter 8 for the electrical specifications and power requirements.

13. *AC Mains Power Fuses:* System AC power fuses disconnect the Laser Controller from the AC Mains in the event of an electrical fault inside the unit. The Laser Controller operates on universal input power as defined in Chapter 8. Fusing both AC lines ensures safe operation with all AC Mains circuits worldwide.

CAUTION: The Type of replacement fuse is printed on the label next to the fuse holders. Use only the specified fuse type and rating. Failure to do so could result in equipment damage or personal injury. Disconnect the power cord before servicing.

Miscellaneous

14. *Air Exhaust:* Laser Controller cooling air is exhausted out of the back of the enclosure. Ensure that this vent is not blocked during laser operation.

Long Pulse Mode

The Centurion laser system can be operated in a quasi-long pulse mode by Q-Switching the laser in advance of the diode current. Running in this mode will produce approximately 80% of the 1064nm laser output energy produced in the Q-Switched mode. Long pulse mode should only be used for 1064nm lasers, since the peak output energy densities are not high enough for efficient conversion of the harmonic wavelengths. Operation in this mode is done by issuing a software command.

Precautions and Notes on Laser Operation

CAUTION: Below is a list of guidelines, which apply to all Quantel USA's 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 to protect the output window.

2. The Laser Head is sealed with careful attention to the use of low out-gassing materials. Silicone and similar sealing, bonding or insulating materials should not be used in close proximity to the Laser Head. 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 inside 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 upset 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 pre-lasing and catastrophic optical damage. In some cases, even anti-reflection-coated glass optics reflect enough energy to promote damage to laser optics. 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.

CHAPTER 5 COMMUNICATIONS PROTOCOL

Serial Interface Specifications

This chapter provides a complete description of the communications protocol between the host computer and the Laser Controller. The protocol is described, and all commands and acknowledgements are defined. All aspects of the laser operation are accessed through this protocol.

The Laser Controller must acknowledge each communications packet it receives. If the command is not valid or recognized, then it will respond appropriately and ignore the erroneous command.

Only the host initiates communications. Any change of state due to an interlock, warning, or not-ready alert shall be latched in the Laser Controller until it has been queried at least once from the host.

Physical Layer

The communications media between the host and the Laser Controller is full duplex RS-232 or RS-422, communicating at 57600 baud, 1 start bit, 8 data bits, parity configurable (see Operational Commands Summary Table), 1 stop bit and no flow control.

General Format Overview

The Laser Controller protocol is an ASCII protocol. Where appropriate, 2 ASCII characters shall be used to represent a byte, expressed in Hexadecimal format.

The basic command structure adheres to the following syntax:

$name data<CR>

Where: $ is the attention command indicating a command follows

"**name**" is the command name. Commands are not abbreviated, but only the first 5 characters are used. No spaces are allowed between the $ and the name.

"data" is the value associated with **name**. Each command dictates the type of data acceptable (string, integer, floating point). A space must be inserted between name and data. Certain commands are stand-alone and do not require a data input.

<CR> indicates the end of the command packet (command terminator – carriage return).

Commands are not processed until the command terminator is received. If an error is made and identified prior to sending the command terminator, sending a new "**$"** will reset the input buffer and allow a new command to be sent. The "*backspace*" function is not a valid editing tool to correct an error in the command.

The Laser Controller has various mechanisms to assist in software handshaking.

$ECHO # Turns echoing **ON** (#=1) or **OFF** (#=0). With echoing **ON**, the Laser Controller will echo back all characters it receives. The **<CR>** is echoed followed by **LF** (Line Feed). With echo **OFF** (0), no characters are echoed.

Regardless of the echo status above, the Laser Controller will always respond to any complete command it receives with one of the following acknowledgement packets:

$name data the command was recognized, determined to be valid, and carried out successfully.

$Bad Command the command itself was not recognized.

$Bad Value the command was recognized, but the data value was not valid due to being out of range or of the incorrect type.

A non-identified command or not-valid value results in the Laser Controller simply ignoring the command. In general, only one command can be processed per message. Some special commands can accept a Hex value representing multiple simultaneous commands.

The current value of any valid command can be queried by the following syntax:

$name ?<CR>

The data value is simply replaced by a "**?**"

The response will be of the expected form

$name data

Where the data is the current value

When a command is of a binary type (ON or OFF), a value of "1" represents ON or TRUE, while a value of "0" represents OFF or FALSE.

Two levels of commands are available. In the lower level are the operational commands allowing the user to change the modes of the laser and basic functionality commands. In the upper level are the BIT (Built-In-Test) factory settings commands where the values can only be adjusted by authorized personnel. Access to these commands requires the user to first send a password to the Laser Controller.

Firmware updates to the controller software or FPGA are in binary form. An application for applying updates is supplied with the laser.

Byte Order

If necessary, Hex bytes can be used to represent integers. Each multiple byte integer value defined within the protocol is transmitted in network byte order (Big Endian) with the high byte first and the low byte second.

Response Timeout

The host computer can expect an Acknowledgement Packet from the Laser Controller within 5 seconds. An exception to this is the File Transfer messages. Operations occurring on files, which are stored in flash memory, can take more than 30 seconds to complete.

Packet Retries

If the host computer does not receive an Acknowledgement Packet from the Laser Controller within the timeout period, the host computer should retransmit the message.

Floating Point

The command dictates the type of data accepted by the Laser Controller. Floating point data may be used.

Packet Data

There are two general types of communication packets defined within the Laser Controller communications framework. These packets are Command Packets and Acknowledgement Packets.

Command Packet

A Command Packet is any packet sent from the host computer to the Laser Controller.

As described previously, a Command Packet merely consists of the command NAME and DATA. The format of the DATA is completely dependent on the command.

Acknowledgement Packet

An Acknowledgement Packet is any packet sent from the Laser Controller to the host computer. An Acknowledgement Packet is sent after every Command Packet the Laser Controller receives.

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Laser Modes

Operational States

The laser has three main operational states. The Laser Controller produces an audible BEEP whenever there is a state change.

SLEEP The Laser Controller boots up in this mode upon power ON. Communications with the host computer are enabled and any installed non-linear crystals are thermally regulated.

STANDBY When put in standby mode, the Laser System enters a conditioning mode and prepares itself to be operated. The TEC and Diode power supplies are turned on. The Laser System is in a NOT-READY state until certain conditions are met. When these conditions are met, the Laser Controller enters a READY state and the third operational state becomes available.

FIRE In this mode, lasing operation can commence as long as the diodes and the Q-Switch driver have been enabled. If any parameters (i.e. temperatures) fall outside of certain acceptable ranges, a NOT-READY condition will force the laser out of FIRE mode to either STANDBY or SLEEP (depending on the problem) to protect itself from any possible damage. If there is no risk to the laser, but something is not within optimum range, the laser will issue a WARNING to notify the user of the issue, but shall remain in FIRE mode.

Configuration States

Various configurable states are available to the user. These states tell the Laser Controller to enable or disable the diodes and the Q-Switch, if the laser is in Q-Switched or Long Pulse mode, and if the associated triggers are to be generated internally or supplied externally.

State Byte (SB)

The STATE command can be utilized to change multiple laser parameters and modes by sending a single byte to the Laser Controller. It is necessary to decode this byte using the following table to determine the complete laser mode. The State Byte configuration can also be queried by sending the STATE command without any data.

NOTE: Both STANDBY and FIRE cannot be authorized at the same time, therefore they are mutually exclusive. If bits D6 and D7 are set to "1" in the STATE command, they will remain "0", but all other bit configurations will be updated.

The State Byte has the following structure D7 D6 D5 D4 D3 D2 D1 D0 (where D7 is the MSb and D0 is the LSb). The Laser Controller will respond to/with 2 ASCII characters to represent this single byte.

State Byte Definition

Bit	Description	State	
		1	0
D7	Fire	Authorized	Prohibited
D6	Standby	Authorized	Prohibited
D5	Q-Switch Mode	Q-Switched	Long Pulse
D4	Diode Trigger Source	External	Internal
D3	Q-Switch Trigger Source	External	Internal
D2	Diodes Enabled	Authorized	Prohibited
D1	Q-Switch Enabled	Authorized	Prohibited
D0	Reserved	No Action	No Action

Binary To Hexadecimal Conversion Chart (256 Combinations)

BINARY BYTE (MSb → LSb)	HEX BYTE	BINARY BYTE (MSb → LSb)	HEX BYTE
0000 0000	00	0001 0000	10
0000 0001	01	0001 0001	11
0000 0010	02	0001 0010	12
0000 0011	03	0001 0011	13
0000 0100	04	↓	↓
0000 0101	05	0011 1111	3F
0000 0110	06	0100 0000	40
0000 0111	07	0100 0001	41
0000 1000	08	↓	↓
0000 1001	09	0111 1110	7E
0000 1010	0A	0111 1111	7F
0000 1011	0B	1000 0000	80
0000 1100	0C	1000 0001	81
0000 1101	0D	↓	↓
0000 1110	0E	1111 1110	FE
0000 1111	0F	1111 1111	FF

Happy Bytes (HB)

In a completely analogous fashion to the STATE BYTE, HAPPY BYTES can be decoded to determine the status of various interlocks, or to identify the source of any problem the Laser Controller has detected. Generally speaking, a value of “0” means that the subsystem in question is happy and a value of “1” indicates a problem.

Beyond the standard hardware interlocks, there exist two levels of severity for unhappy subsystems. If the subsystem is not within ideal operating range, but there is no threat to the laser, the laser will enter a WARNING state but continue to operate in its current mode. If a subsystem is so far away from its ideal operating range that it represents a risk to the system, or if a subsystem malfunctions in a way that prevents the laser from being able to operate, the laser will enter a NOT-READY state. Depending on the cause, the laser will now be in either SLEEP or STANDBY mode, but never FIRE mode.

HB1 is the global byte that defines the severity of the issue (00 indicates all is well). HB2 depicts the subsystems responsible for a WARNING mode. HB3 depicts the subsystems responsible for a NOT-READY state HB4 describes the status of the various hardware interlocks. Note: These are not mutually exclusive. For example, a subsystem problem can cause both a WARNING and a NOT-READY report (i.e. temperature).

If a WARNING, NOT-READY, or INTERLOCK causes a status change, this cause is latched until it has been reported via a "**STATUS ?**" command.

Happy Bytes Definitions

Name	Bit	Description	State	
			1	0
HB1 (GLOBAL)	D7	Reserved		OK
	D6	Reserved		OK
	D5	Reserved		OK
	D4	Reserved		OK
	D3	Reserved		OK
	D2	INTERLOCK bit is set (HB4)	Interlock Fault	OK
	D1	NOT-READY bit is set (HB3)	Not-Ready	OK
	D0	WARNING bit is set (HB2)	Warning	OK
HB2 (WARNING)	D7	Reserved		OK
	D6	Reserved		OK
	D5	Reserved		OK
	D4	Remote Run BNC	Triggers Disabled	OK
	D3	Diode Trigger Frequency too high	Warning	OK
	D2	Specified temperature is in WARNING range	*See Temperature Table*	
	D1			
	D0			
HB3 (NOT-READY)	D7	Reserved		OK
	D6	Self-Test (can't find sensors or EEPROM)	I2C Fault	OK
	D5	Emergency Over-temperature	Temp Fault	OK
	D4	Diode Power Supply Status	Diode P/S Fault	OK
	D3	TEC Power Supply Status	TEC P/S Fault	OK
	D2	Specified temperature in NOT-READY range	*See Temperature Table*	
	D1			
	D0			
HB4 (INTERLOCK)	D7	J1 Connector Interlock	J1 Disconnected	OK
	D6	J2 Connector Interlock	J2 Disconnected	OK
	D5	Remote Interlock	Remote Intlk Open	OK
	D4	Emergency Stop Interlock	E-Stop Open	OK
	D3	Laser Controller Cover Interlock	Cover Open	OK
	D2	Coolant Flow (*Available when HB4 D0 = 1)*	Low Coolant Flow	OK
	D1	Coolant Level (*Available when HB4 D0 = 1)*	Low Coolant Level	OK
	D0	Cooler Connector Interlock *(Factory Option)*	Cooler Installed	Off

Up to four temperature sensors are monitored. If there is a temperature WARNING or NOT-READY bit set, the following table depicts how to decode bits D0 – D2 of HB2 or HB3 to determine which temperature is out of range:

Temperature Table

D2	D1	D0	Description	Hardware Address
1	0	0	Temperature #4 - SPARE	(10)
0	1	1	Temperature #3– Interface Plate	(11)
0	1	0	Temperature #2 – Dump Resistor	(01)
0	0	1	Temperature #1– Pumphead	(00)
0	0	0	No temperature warning	

Operational Commands

The laser is controlled using the following discrete commands utilizing a serial communications program such as Windows Hyper Terminal. If the Data Range field is grayed out, no data input is required. A single "**?**" in the Data Range field indicates that the command is a query only.

Operational Commands Summary

Name	Data Range/Query	Description
BURST(1)	0 – 2 / ?	Burst Mode: 0 = disabled; 1 = QS only; 2 = QS and Diodes
BSTOF(1)	0 – 65535 / ?	Burst Mode: Number of "OFF" pulses. If set to 0, then laser drops back to standby after number of "ON" pulses
BSTON(1)	0 – 65535 / ?	Burst Mode: Number of "ON" pulses
CVERS	?	Query Controller Firmware Version Number
D0PW(1)	10 – MAXPW(2) / ?	Diode PulseWidth Ramp: Initial diode pulsewidth (1 µsec resolution)
DFREQ(3)	1 – MAXREP(4) / ?	Internal diode trigger frequency (1 µsec resolution)
DIODE	0 – 1 / ?	Diode Trigger Gate: 0 = Diodes OFF; 1 = Diodes Enabled
DPW	10 – MAXPW(2) / ?	Diode current pulsewidth (1 µsec resolution)
DPTC(1)	Floating Point(5) / ?	Diode PulseWidth Ramp: Time to get to final pulsewidth (sec)
DRAMP(1)	0 – 1 / ?	Diode PulseWidth Ramp: 0 = Ramp function Disabled; 1 = Ramp function Enabled
DTRIG(3)	0 – 1 / ?	Diode Trigger Source: 0 = Internal; 1 = External
FIRE		Attempt to enter FIRE mode
FVERS	?	Query FPGA Firmware Version Number
HOURS(6)	?	Query Time-On Counter (10 msec resolution)
HVERS	?	Query Hardware Version Number
PASSWORD	*Authorized Only*	Enter Factory settings Mode
QD0PW(1)	0 – 400 / ?	Q-Switch Delay Ramp: Initial Q-Switch delay (1 µsec resolution)
QDTC(1)	Floating Point(5) / ?	Q-Switch Delay Ramp: Time to get to final Q-Switch delay (sec)
QRAMP(1)	0 – 1 / ?	Q-Switch Delay Ramp: 0 = Ramp function Disabled; 1 = Ramp function Enabled
QSBLANK(1)	0 – 1 / ?	Q-Switch Blanking: 0 = Blanking Disabled; 1 = Blanking Enabled.
QSBLS(1)	0-65535 / ?	Q-Switch Blanking: Number of shots to blank when enabled.
QSDELAY	0 – 400 / ?	Delay from rising edge of Diode trigger to Q-Switch trigger (µsec)
QSDIV(1)	0 – 255 / ?	Q-Switch Trigger Divide-By: Fire Q-Switch every # of diode pulses
QSON	0 – 1 / ?	Q-Switch Trigger Gate: 0 = Q-Sw OFF; 1 = Q-Sw Enabled
QSTRIG	0 – 1 / ?	Q-Switch Trigger Source: 0 = Internal; 1 = External
QSWITCH(1)	0 – 1 / ?	Q-Switch Mode: 0 = Long Pulse; 1 = Q-Switched
RECALL(1)	1 – 4 / ?	Recall operational Configuration 1 – 4 (*4 = factory default*)
RS232(1)	*<peripheral command>*(7)	Pass through serial commands to laser head peripherals. Refer to peripheral communications protocol.
SAVE(1)	1 – 3 / ?	Save operational Configuration
SERIAL	?	Query Laser Head Serial Number
SHOT	?	Query Diode Shot Counter (1 shot resolution)
STANDBY		Attempt to enter STANDBY mode
STATE(8)	*<state byte>*	Change multiple configuration parameters simultaneously
STATUS(9)	?	Retrieve State Byte and Happy Bytes
STOP		Return the laser to SLEEP mode
TEMPS(10)	?	Query all temperatures. Values are reported in 1/10th Deg. C
USHOT	0 / ?	User controlled shot counter: 0 = Reset
PARITY	0 – 1 / ?	Sets Communication Parity (1 = EVEN *default*, 0= NONE) – Requires save configuration and power cycle.

NOTES: (1) Described in more detail in Operational Command Definitions Section.
(2) MAXPW is a factory setting. This value limits the diode pulsewidth. The value of MAXPW can be queried using the standard protocol ($MAXPW ?<cr>).
(3) If the diode trigger source is selected as External, the maximum external trigger frequency is limited by the internal trigger frequency DFREQ, which in turn is limited by the maximum frequency factory setting MAXREP. An external frequency that exceeds the frequency limit will result in pulse selection (i.e. If the external frequency is 200 Hz and the frequency limit is 50 Hz, every 4^{th} pulse will be allowed).
(4) MAXREP is a factory setting. This value limits the diode pulse frequency. The value of MAXREP can be queried using the standard protocol ($MAXREP ?<cr>).
(5) Floating Point indicates that the data value is a number between 1 and 255, inclusive, with a maximum of 6 numerical characters. Examples of Valid formats: 1; 1.002, 10.2356, 128.525, etc.
(6) HOURS reports the On-Time of the Laser System in 10 millisecond increments. Example: 1 hour would be reported as 360000.
(7) <*Peripheral Command*> is defined by the peripheral protocol document. For example, if the peripheral is a motorized variable attenuator (MVAT), the data stream that follows the RS232 command is defined by the communications protocol for the MVAT.
(8) To query status of STATE Byte, send command without data and without "?". Sending a "?" will be interpreted as an ASCII character and change the STATE.
(9) STATUS format is SB AA BB CC DD, where SB is the State Byte, AA is Happy Byte 1, BB is Happy Byte 2, CC is Happy Byte 3, and DD is Happy Byte 4.
(10) Temperatures are reported in order XXX YYY ZZZ, where XXX is the pump head, YYY is the Dump Resistor, and ZZZ is the Interface Plate. Reported temperature is in $1/10^{th}$ degrees C. Example: 451 is 45.1^{0}C.

Operational Command Definitions

Due to the complexity of certain operational commands, more detail is required to describe the functionality.

BURST MODE

Burst Mode Select {$BURST #<cr>}: The laser has a burst or scan mode defined by the number of "ON" and "OFF" pulses in a pulse sequence. A value of 0 turns this mode off. A value of 1 leaves the diodes firing continuously and applies the burst parameters to the Q-Switch only. A value of 2 applies the burst parameters to the diodes and the Q-Switch. If Burst Mode is activated, it works with both internal and external trigger sources.

Burst Mode ON Pulses {$BSTON #<cr>}: This parameter selects the number of sequential trigger pulses in a pulse train that are sent to the laser head.

Burst Mode OFF Pulses {$BSTOF #<cr>}: This parameter selects the number of sequentially skipped trigger pulses in a pulse train. A special case exists when the parameter BSTOF is set to 0. In this case, the laser operates in a true burst mode. After the number of "ON" pulses is met, the laser drops back to STANDBY mode. The cycle begins anew when a new FIRE command is given. True single-shot operation can be attained in this manner. If this parameter is not 0, then the laser operates in a scan mode where it cycles ON and OFF continuously.

Example: Set BURST to 1; Set BSTON to 1 pulse; Set BSTOF to 9 pulses. The diodes will trigger at the set operating frequency as defined by DFREQ. The laser will Q-Switch on the first pulse, wait 9 pulses, and repeat the cycle indefinitely until stopped.

DIODE PULSEWIDTH RAMP

Diode Ramp Enable {$DRAMP #<cr>}: In order to correct for any initial energy variation upon startup, it is possible to ramp the diode pulsewidth. Sending a value of 1 enables this feature. Once enabled, two additional parameters need to be defined to characterize the ramp. First, an initial pulsewidth value is set. Second, a time constant is entered which determines the rate at which the pulsewidth changes (in 1 µsec increments) from the initial setting to its final width as defined by the parameter DPW. If the diode trigger (internal or external) goes away for 1 second or more, the ramp is reinitiated when the trigger is once again provided. The system must transition into Fire Mode to initialize the ramp function. Simply sending a Fire Command while in Fire Mode will not reinitialize the ramp.

Starting Pulsewidth {$D0PW #<cr>}: This parameter sets the initial diode pulsewidth for the Diode Ramp function. Although the valid data range allows for a value of D0PW to be greater than DPW (up to MAXPW, where MAXPW is the factory maximum diode pulsewidth setting), there are limited scenarios in which ramping the diode pulsewidth inward will enhance laser performance.

Diode Ramp Time Constant {$DPTC #<cr>}: This parameter defines the time (in seconds) to ramp from the starting pulsewidth D0PW to the final optimized pulsewidth DPW.

CAUTION: If your laser system has been delivered with the Diode Ramp function enabled, do not change these parameters without consulting Quantel USA. Failure to do so could result in optical damage to the laser.

Q-SWITCH DELAY RAMP

Q-Switch Delay Ramp Enable {$QRAMP #<cr>}: This feature corrects for initial energy variations upon startup, similar to the diode ramp function. Q-Switch Delay Ramp is typically more effective, however, because of increased effective resolution. Sending a value of 1 activates the Q-Switch Delay Ramp function. Once enabled, two additional parameters need to be defined to characterize the ramp. First, an initial Q-Switch delay is set. Second, a time constant is entered which determines the rate at which the Q-Switch delay changes (in 1 µsec increments) from the initial setting to its final delay as defined by the parameter QSDELAY. If the internal Q-Switch trigger goes away for 1 second or more, the ramp is reinitiated when the trigger is once again provided (as in Burst Mode). Q-Switch Ramp is not valid for external Q-Switch trigger. The system must transition into Fire Mode to initialize the ramp function. Simply sending a Fire Command while in Fire Mode will not reinitialize the ramp.

Starting Q-Switch Delay {$QD0PW #<cr>}: This parameter sets the initial Q-Switch delay for the Q-Switch Delay Ramp function. The initial Q-Switch delay should be longer than the operational Q-Switch delay parameter QSDELAY. Although the valid data range allows for a value of QD0PW to be less than QSDELAY, this operational scenario should not be utilized since it does not enhance laser performance, and will likely result in the laser double-pulsing on the initial shots.

Q-Switch Delay Ramp Time Constant {$QDTC #<cr>}: This parameter defines the time (in seconds) to ramp from the starting Q-Switch delay QD0PW to the final optimized Q-Switch delay QSDELAY.

CAUTION: If your laser system has been delivered with the Q-Switch Delay Ramp function enabled, do not change these parameters without consulting Quantel USA. Failure to do so could result in optical damage to the laser.

Q-SWITCH BLANKING

Q-Switch Blanking Enable {$QSBLANK #<cr>}: This function inhibits Q-switching for a fixed number of shots when entering Fire Mode, to allow the laser rod to thermally stabilize. Sending a value of 1 enables Q-Switch blanking. A value of 0 disables blanking. The number of blanked Q-Switched shots is set by the QSBLS variable. Q-Switch Blanking parameters cannot be changed when in Standby or Fire Mode. Attempting to do so will force the system into Sleep Mode.

Q-Switch Blanking Shots {QSBLS #<cr>]: This parameter sets the number of pulses that the Q-Switch will be inhibited when entering Fire Mode, if Q-Switch Blanking is enabled. Valid values are 0 to 65535 shots. A value of zero effectively disables Q-Switch blanking.
.

CAUTION: If your laser system has been delivered with the Q-Switch Blanking function enabled, do not change these parameters without consulting Quantel USA. Failure to do so could result in optical damage to the laser.

Q-SWITCH TRIGGER DIVIDE-BY

Q-Switch Divide-By {$QSDIV #<cr>}: This command applies a divide-by function to the Q-Switch trigger with respect to the diode trigger. The Q-Switch trigger divide-by feature allows the laser to maintain constant thermal lensing by operating the laser diodes at a fixed frequency. The laser output frequency (Q-switch trigger frequency) is then selected by allowing every $\mathbf{n}^{th}$ Q-Switch trigger, where **n** is the variable QSDIV. Since all lasers are optimized at a specific operational frequency, this function is required if the user desires to reduce the operating frequency of their laser without effecting beam quality. This is especially important if the laser resonator design is “Unstable” (GRM).

For normal operation, leave this parameter at 1 to Q-Switch (lase) at the same pulse repetition frequency as the diodes. To fire at half the operating frequency, set QSDIV to 2. This will fire the Q-Switch every other shot. Setting the variable to 3 triggers the Q-Switch every 3^{rd} shot, and so on.

CAUTION: If you purchased an Unstable Laser System, operate the laser diodes only at the factory optimized frequency. To change the lasing frequency, use the Q-Switch Divide-By function. Changing the diode frequency can result in optical damage to the laser.

Q-SWITCH OPERATIONAL MODE

Q-Switch Mode {$QSWITCH #<cr>}: Two Q-Switch modes are available to the user. Normal Q-Switched operation is selected by setting this variable to 1. A low power, quasi-long pulse mode can be selected by setting this variable to 0. The long pulse mode adjusts the Q-Switch trigger timing so that the Q-Switch fires approximately 30 µseconds prior to the leading edge of the diode trigger. This effectively gates open the q-switch and allows the laser to operate in free-running (long pulse) mode. The low energy pulse train generated by the laser, when in long pulse mode, is ideal for aligning external optics.

OPERATIONAL CONFIGURATION

Save Configuration {$SAVE #<cr>}: 3 configurations are available for the user to store their current setup. These setups store most of the current values of the Operational Commands. When the Centurion is turned on, the values stored in configuration 1 will be used.

The saved parameters are:

Diode Pulse Width
Q-Switch Delay
Diode Trigger Mode (enabled/disabled, internal/external)
Q-Switch Trigger Mode (enabled/disabled, internal/external, q-switched/long pulse)
Internal Diode Trigger Frequency
Q-Switch Trigger Divide-by
Q-Switch Blanking
Diode Pulse Width Trigger Ramp Variables
Q-Switch Delay Ramp Variables
Burst Variables

Recall Configuration {$RECALL #<cr>}: 4 configurations are available for recall. The first 3 configurations can be modified, stored, and recalled by the user. The 4th configuration contains the factory default operational parameters. Recalling configuration 4 will return the laser to its original operational performance. Configuration 4 cannot be modified by the user.

SERIAL PERIPHERAL INTERFACE

Peripheral Communications {$RS232 #<cr>}: An internal serial port exists in the Centurion that can pass commands to a RS-232 controlled device connected to the laser head. This port is configurable so that it can accommodate a variety of devices. Its main purpose is to pass commands to a factory-installed MVAT (Motorized Variable Attenuator). The data packet that accompanies the RS232 command is simply relayed to the serial device. Any response from the device is appended to the acknowledgement response.

Timing

An external diode trigger has to be greater than 10 µsec wide for it to be validated as an intentional trigger and not noise. For stable operation, the external trigger pulsewidth must be between 50 and 900 µsec wide. Approximately 12 µsec after the rising edge of the external diode trigger, the internal diode trigger (and diode sync pulse) is generated. The rising edge of the internal diode trigger is considered to be t_0 and all delays are measured from this point. There is no pulsewidth validation for an external Q-Switch trigger, since the validation process will add unacceptable jitter to laser light out.

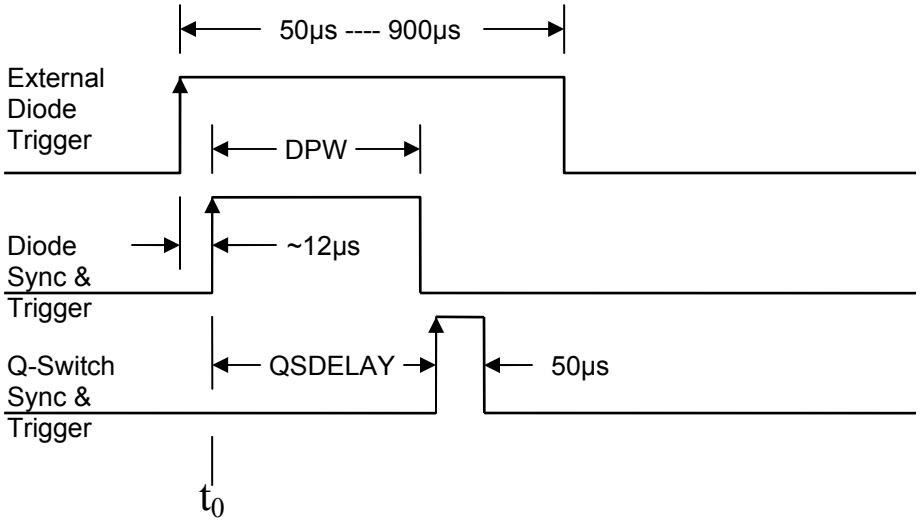

Figure 5-1: Typical Timing - Q-Switched Mode

The Internal trigger rate (DFREQ) cannot be set past the MaxRepRate limit. When running in external diode trigger mode, the maximum repetition rate is limited by the value of DFREQ. There is no frequency check to limit input frequency for external Q-Switch trigger.

Note: The diode current pulse width is dictated internally in the software with the DPW setting, not by the pulsewidth of the external diode trigger input.

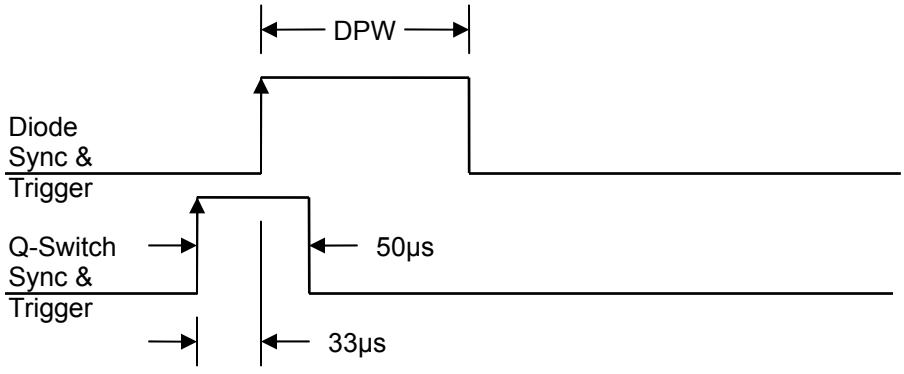

Figure 5-2: Typical Timing - Long Pulse (Internal Trigger Mode)

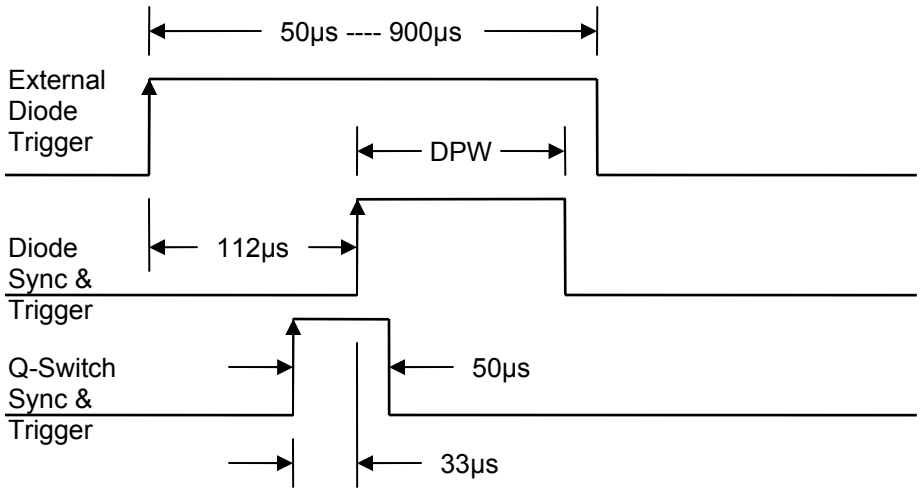

Figure 5-3: Typical Timing - Long Pulse (External Trigger Mode)

CHAPTER 6 MAINTENANCE

The Centurion Laser System has been designed to require a minimum amount of routine maintenance.

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, one on the desiccant pocket cover, and one on the front of the laser. (See Figure 6-1). Do not remove the desiccant pocket cover.

2. Connect 5 PSI dry nitrogen to seal screw hole in the desiccant cover, using the #4-40 purge adapter supplied in the Accessories Kit. Flow UHP 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 purge adapter from the desiccant pocket cover. Reinstall the purge/seal screw.

Desiccant Replacement

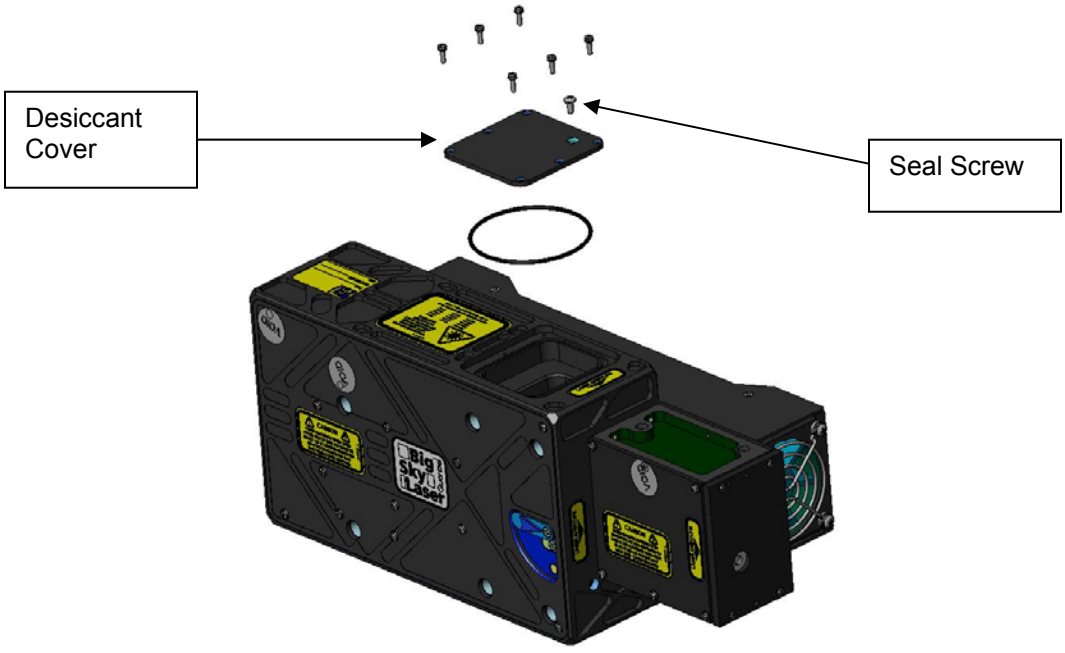

Figure 6-1: Desiccant Pocket

The desiccant should be replaced whenever any of the laser covers are removed for any reason, and approximately every six months, or more frequently when the laser is used in an especially humid environment.

The desiccant is a 1/6 unit molecular sieve class 100 clean room Tyvek™ bag. Desiccant can be purchased from Quantel USA (specify part number 72006020).

CHAPTER 7 TROUBLESHOOTING

The Laser Controller 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 or interlock event occurs. Software limits have been factory selected to protect the laser system against electrical and optical damage.

Interlocks

There are several hardware and/or software controlled interlocks. If any interlock is activated (opened), the laser will not operate until the interlock is closed. See the section on HAPPY BYTES located in Chapter 5 *HB4* for information on how to access the interlock faults via the serial communications.

1. *Remote Interlock and Remote Run BNC:* Located on the back panel of the Laser Controller. These connectors must be shorted to close the interlock and allow triggering respectively. Check that the shorting connectors are in place or that the user cabling is properly shorting these contacts.

2. *Emergency Stop Interlock:* This interlock is created when the Emergency Stop Button on the Laser Controller has been depressed. To reset this interlock, rotate the red mushroom cap clockwise to allow the button to return outward.

3. *Laser Controller Cover Interlock:* Located underneath the top cover, these dual redundant switches ensure that the laser cannot be operated with the Laser Controller top cover removed.

4. *External I/O Cable Interlocks:* The two cables (J1 and J2) between the Laser Controller and Laser Head are interlocked to ensure that power cannot be enabled if the cables are not properly or completely installed.

Faults

There are several fault conditions that prevent the laser from operating to protect it from damage. See section 5.6, HB3 for information on how to access these via the serial communications:

1. *Temperature Faults*: The Laser Head monitors three separate locations for temperature – the pumphead, the interface plate, and a dump resistor. Temperature faults are primarily triggered when the user-supplied heat sink is not adequate for the duty cycle or the ambient air temperature is excessive (air-cooling). Temperature faults also occur if the fan power connector disconnects from the back of the Laser Head.

2. *Emergency Overtemp*: This is a redundant sensor which will disable the laser in the event that internal communications are lost within the Laser Head and the above temperature fault is not triggered.

3. *Self-Test Fault*: This fault sets in the event of an internal communications failure.

4. *TEC/Diode Power Supply Fault*: This fault occurs in the laser pump head cooling system or Diode Driver Power Supply located inside the Laser Controller.

No Laser Output

1. *Check Fault and Interlock Conditions:* Refer to the previous paragraphs if the fault or interlock conditions exist.

2. *Check Cables:* With the prime power OFF and unplugged, check all electrical connections between the Laser Head and the Laser Controller. Make sure all connections are secure. Inspect the D-Sub connectors for bent pins. 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 top of the Laser Head. Refer to Figure 4-1 for information on the shutter position.

4. *Check Mode Setting:* Verify the laser is in FIRE mode.

5. *Check Timing Settings:* Refer to the data supplied in the Data Summary Sheet and make sure the Diode Pulse Width and Q-Switch Delay are set correctly. Correct if necessary.

6. *Check Trigger Settings:* Verify that the Diodes are enabled and set to the appropriate settings for your application (Internal/External Trigger)

7. *Check Q-Switch Settings:* Verify that the Q-Switch is enabled and that any Q-Switch divide-by is set up properly. The laser should be in Fire mode and the Emission Indicators on the Laser Head on Laser Controller should be flashing. If External Q-Switch control is being used, verify that the laser is set to external Q-Switch mode, the external trigger is connected, and that it is adequate to drive the 50Ω input.

Low Energy

1. *Incorrect Q-Switch Delay:* Check that the Q-Switch delay is set 10 to 15 μs longer than the diode pulse width. For example, if the diode pulse width is set to 120μs, the Q-Switch delay should be to 130 to 135 μs. Using an oscilloscope, connect channel 1 to the Diode-Out BNC and channel 2 to the Q-Switch-Out BNC. Triggering the scope on channel 1, verify that the delay from the falling edge of the Diode Out to the rising edge of the Q-Switch Out is approximately 10 to 15 μs. If this delay is longer than 15μs, the laser output will be attenuated.

2. *Resonator Misaligned:* If beam quality has degraded, it may suggest that the resonator needs to be realigned. Contact Quantel USA for more details.

Contact Quantel USA 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

Laser Head and Laser Controller Specifications

Mechanical Specifications

Laser Head Weight (Air-cooled, no NLO modules)	4.5 kilograms
19” Laser Controller Dimensions	19"W x 18”H x 3.5"D (nominal)
19” Laser Controller Weight	7 kilograms

Electrical Specifications

Prime Power	90-264 VAC, 47-63 Hz
	300 Watts maximum

Environmental Specifications

Storage Temperature	-20° to +75°C
Operating Temperature	5° to 35°C

Laser Controller Electrical Interface

1. Connector Name: Laser Control (to laser head J1)
   Connector Designator: J1
   Connector Type: D-Sub, DB-25S

2. Connector Name: Laser Power (to laser head J2)
   Connector Designator: J2
   Connector Type: D-Sub, DA-15S

3. Connector Name: RS-232 (EIA232)
   Connector Designator: J3
   Connector Type: D-Sub, DE-9S

PIN	SIGNAL NAME	DESCRIPTION
1	DCD	No Connection (Reserved)
6	DSR	No Connection (Reserved)
2	TxD	Laser Controller Transmit
7	RTS	Ready to Send
3	RxD	Laser Controller Receive
8	CTS	Clear to Send
4	DTR	No Connection (Reserved)
9	RI	No Connection (Reserved)
5	SGND	Signal Ground

4. Connector Name: RS-422
Connector Designator: J4
Connector Type: D-Sub, DE-9P

PIN	SIGNAL NAME	DESCRIPTION
1	TxD (+)	Laser Controller Transmit Plus
6	TxD (-)	Laser Controller Transmit Minus
2	RxD (+)	Laser Controller Receive Plus
7	RxD (-)	Laser Controller Receive Minus
3	SGND	Signal Ground
8	Spare	No Connection
4	Spare	No Connection
9	Spare	No Connection
5	Spare	No Connection

5. Connector Name: DIODE IN
Connector Designator: J7
Connector Type: BNC

PIN	SIGNAL NAME	DESCRIPTION
C	Ext Diode Trigger In	Diode Trigger Input; 5V nominal pulse, ~100µs wide, into 50Ω load.
SH	Ext Diode Trigger Rtn	Signal return

6. Connector Name: Q-SWITCH IN
Connector Designator: J8
Connector Type: BNC

PIN	SIGNAL NAME	DESCRIPTION
C	Ext Q-Sw Trigger In	Q-Switch Trigger Input; 5V nominal pulse, ~100µs wide, into 50Ω load.
SH	Ext Q-Sw Trigger Rtn	Signal return

7. Connector Name: DIODE OUT
Connector Designator: J9
Connector Type: BNC

PIN	SIGNAL NAME	DESCRIPTION
C	Diode Sync	Test Point. Diode Trigger Sync. 5V nominal pulse. 3V nominal into a 50Ω load.
SH	Diode Sync Rtn	Signal return

8. Connector Name: Q-SWITCH OUT
Connector Designator: J10
Connector Type: BNC

PIN	SIGNAL NAME	DESCRIPTION
C	Q-Switch Sync Out	Test Point. Q-Switch Trigger Sync. 5V nominal pulse. 3V nominal into a 50Ω load.
SH	Q-Switch Sync Rtn	Signal return

9. Connector Name: REMOTE INTLK
Connector Designator: J11
Connector Type: BNC

PIN	SIGNAL NAME	DESCRIPTION
C	Remote Interlock (+)	Short connector center contact to shield to satisfy interlock.
SH	Remote Interlock (-)	Signal return

10. Connector Name: REMOTE RUN
Connector Designator: J12
Connector Type: BNC

PIN	SIGNAL NAME	DESCRIPTION
C	Remote Run	Short to RUN, open to STOP
SH	Remote Run Rtn	Signal return

11. Connector Name: LASER WARNING
Connector Designator: J13
Connector Type: STEREO JACK

PIN	SIGNAL NAME	DESCRIPTION
1,2	Laser Warning (+)	Factory configurable Warning Indicator Output. Can be configured to directly drive an LED or to supply voltage to a relay. Relay voltage configuration levels are +24VDC, +12VDC, and +5VDC. Constant illumination when Diode Power is active. Flashes at 2Hz when lasing.
3,4	Laser Warning (-)	Factory configurable as signal return for LED illumination or as transistor switched return to control a relay.
5	Shield	Chassis connection

12. Connector Name: MAIN AC INPUT (MAINS)
Connector Type: IEC 60320

PIN	SIGNAL NAME	DESCRIPTION
1	AC L1	90-264 VAC, 47-63 Hz
2	AC L2/N	
3	Safety GND	Safety ground

Laser Head Interface

1. Connector Name: Laser Control (to laser controller J1)
   Connector Designator: J1
   Connector Type: D-Sub, DB-25P

2. Connector Name: Laser Power (to laser controller J2)
   Connector Designator: J2
   Connector Type: D-Sub, DA-15P

3. Connector Name: Auxiliary Power
   Connector Designator: J3
   Connector Type: D-Sub, DE-9S

PIN	SIGNAL NAME	DESCRIPTION
1	+24 VDC Aux	Air-cooling Fan Power, 500mA maximum
6	+24V Aux Rtn	Fan power return
2	+24 VDC Aux	Air-cooling Fan Power, 500mA maximum
7	+24V Aux Rtn	Fan power return
3	Spare	No Connection
8	Spare	No Connection
4	Spare	No Connection
5	Spare	No Connection
9	Spare	No Connection

Laser Timing

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.

Delay and Jitter Measurements

Actual timing and jitter waveforms are shown in the following figures.

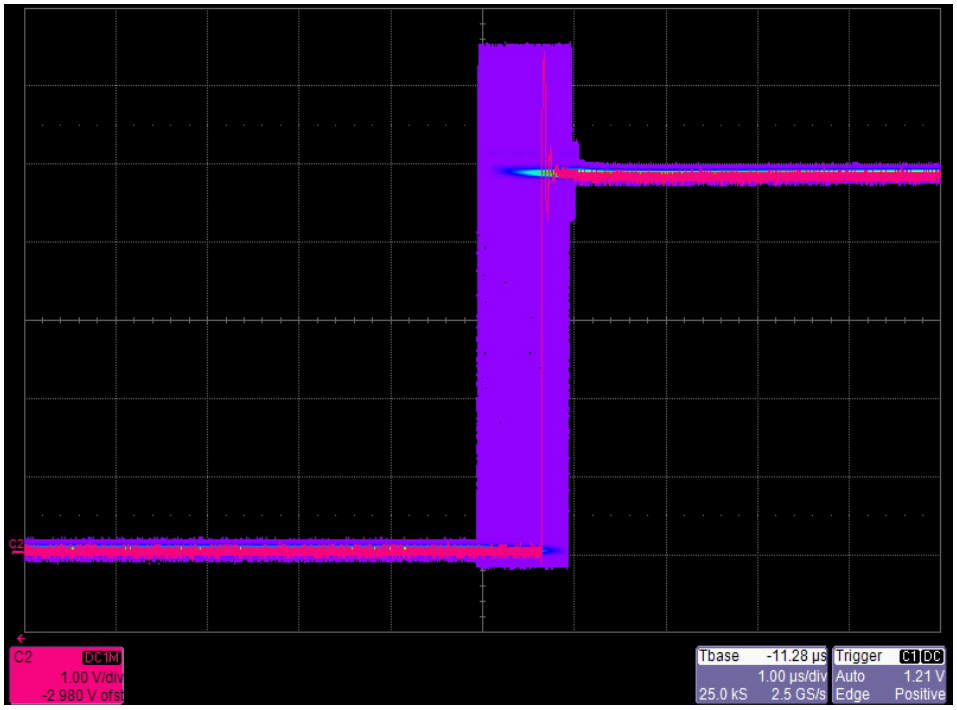

Figure 8-1: Diode/Q-Switch Sync Jitter with Respect to External Diode Trigger In

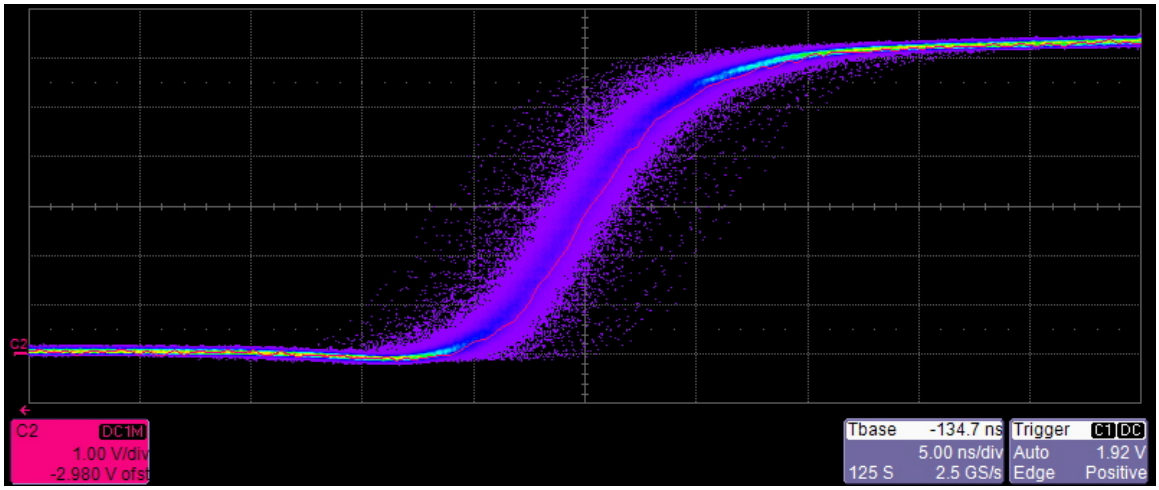

Figure 8-2: Q-Switch Sync Jitter with Respect to Q-Switch Trigger In

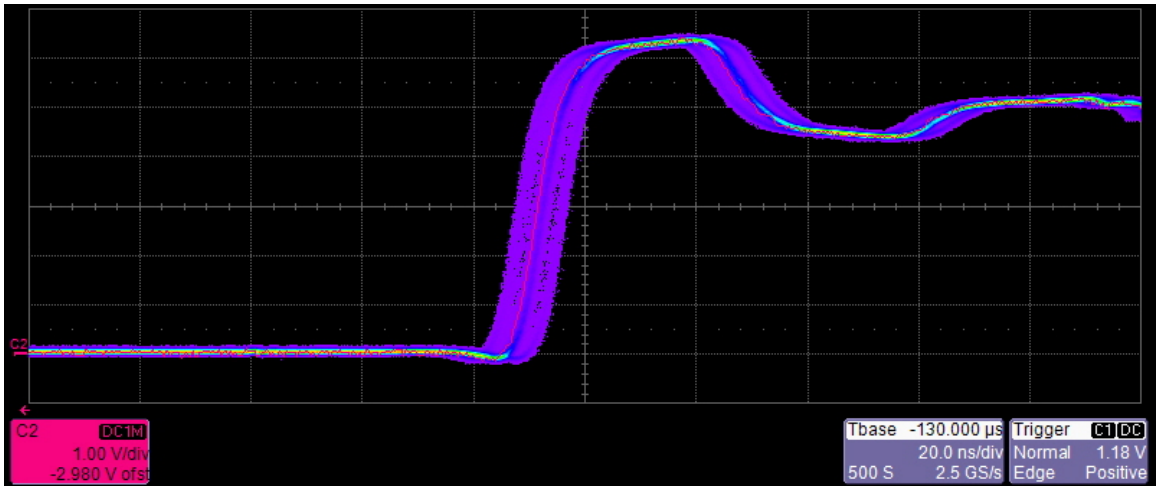

Figure 8-3: Q-Switch Sync Jitter with respect to Diode Sync

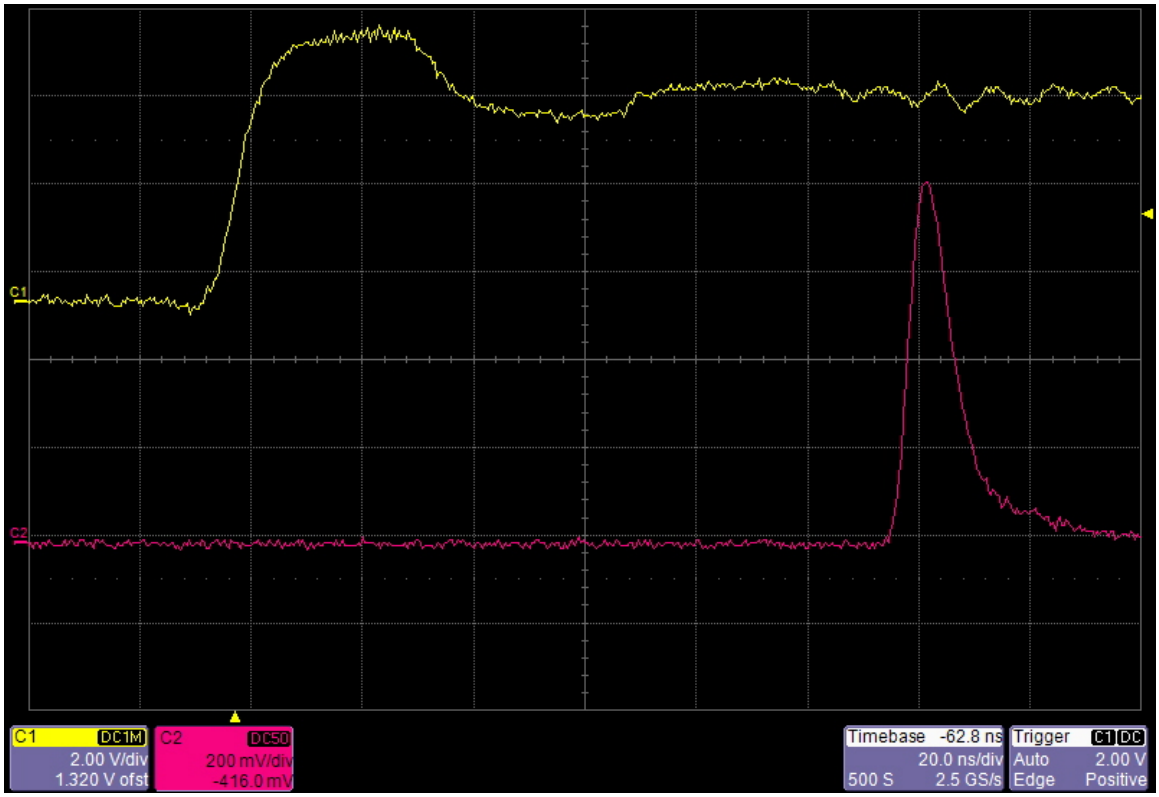

Figure 8-4: Q-Switch Sync to Light Out @ 30mJ (CH1; Sync, CH2; Light)

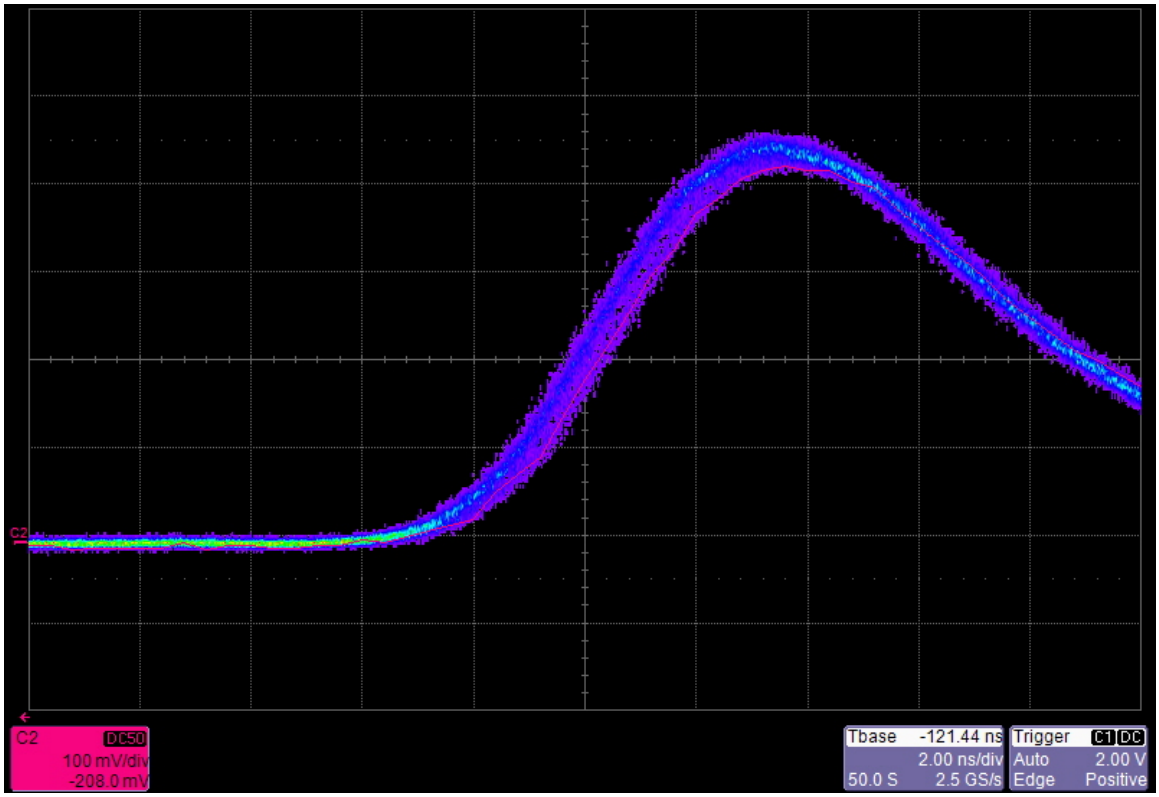

Figure 8-5: Light Out Jitter with respect to Q-Switch Sync

CHAPTER 9 CUSTOMER SERVICE

We at Quantel USA are proud of our specialty laser systems. Our manufacturing and quality control processes emphasize consistency, stability, ruggedness, reliability and performance. We strive to make our laser systems more reliable and to provide superior customer support.
Should there be problems with operation or failure of any kind, please call the Quantel USA customer service hotline toll-free at 1-800-914-8216. For international customers, please call our service center in France at 033-1-6929-1700. We will do our best to get your system fully operational as quickly as possible.

Warranty

(a) Quantel USA warrants the lasers it manufactures and produces to be free from defects in materials and workmanship for twelve (12) months following the date of shipment provided that all operating instructions are properly followed. 213nm optical components are warranted for 90 days following the date of shipment. Diodes are warranted for 1 billion shots or one year, whichever comes first. This warranty is limited to the original purchaser of the laser and is not transferable.

During the 12 months 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 Quantel USA, 601 Haggerty Lane, Suite C, Bozeman, MT 59715. All replaced parts and products become the property of Quantel USA.

(b) This warranty is the only warranty made by QUANTEL USA with respect to the goods delivered hereunder and no representative or person is authorized to bind QUANTEL USA for any obligations or liabilities beyond this warranty in connection with the sale of QUANTEL USA's goods.

(c) Remedies are available only if QUANTEL USA is notified in writing by Buyer promptly upon discovery of any defects and in any event within the warranty period for the individual goods, whereby Seller's examination of such goods discloses to QUANTEL USA's satisfaction that such defects actually exist and the goods have not been (i) repaired, worked on or altered by persons not authorized by QUANTEL USA so as, in QUANTEL USA's sole judgment to effect the stability, reliability or proper operation of such goods; (ii) subject to misuse, negligence, abuse or accident; or (iii) connected, installed, used or adjusted otherwise than in accordance with the instructions furnished by QUANTEL USA or normal usage.

(d) All goods that Buyer considers defective shall be returned, freight and insurance prepaid, to QUANTEL USA's office, as designated on the face hereof. QUANTEL USA shall not be liable for additional transportation costs arising from the goods having to be shipped to a location remote from the original one. Buyer shall obtain return authorization from QUANTEL USA before returning any goods. QUANTEL USA shall not bear responsibility for damage or loss to goods not properly prepared for transportation.

(e) If it is found QUANTEL USA’s goods have been returned without cause and are still serviceable, Buyer will be notified and the goods returned at Buyer's expense, freight collect. In addition, a charge for testing and examination and/or for reimbursement of shipment costs paid by QUANTEL USA under subsection (d) above, may, at QUANTEL USA's sole discretion, be made on goods so returned which such charges shall also be payable by the Buyer.

(f) The foregoing warranty is exclusive and in lieu of all other warranties whether written, oral or implied, including any warranty of merchantability or fitness for a particular purpose, and shall be the Buyer’s sole remedy and QUANTEL USA’s sole liability on contract or warrant or otherwise for the product.

(g) This warranty shall not apply in the event that the original device identification markings have been removed, defaced or altered, or if any parts have been substituted or modified without the express consent of QUANTEL USA.
(h) This warranty will not apply if the customer's general account at QUANTEL USA is delinquent in whole or in part.

QUANTEL USA's liability under, for breach of, or arising out of this agreement and/or sale will be limited to repair or replacement of any defective goods or a refund of the purchase price of the goods, at QUANTEL USA's sole discretion. In no event will QUANTEL USA be liable for costs of procurement of substituted goods by buyer, nor will QUANTEL USA be liable for any special, consequential, incidental or other damages (including without limitation loss of profit) whether or not QUANTEL USA has been advised of the possibility of such loss, however caused, whether for breach or repudiation of contract, breach of warranty, negligence or otherwise.

Feedback

We welcome your feedback in regard to your use and performance of the 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 (1-800-224-4759). For international customers, please call our service center in France at 033-1-6929-1700. You can also visit us online at http://www.quantel-laser.com.