

**Minilite<sup>TM</sup>**  
**Operation Manual**

**Continuum<sup>®</sup>**

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## Preface

The internationally recognized warning symbols shown here are used throughout the manual to alert the user of potential hazards when operating this laser.



### LASER RADIATION:

The radiation symbol is to alert the user to the danger of laser radiation when performing certain operations and when the danger of exposure is the greatest. It is also used when the optical hazards are present.



### DANGEROUS VOLTAGE:

The lightning or thunderbolt indicates the presence of high voltage which may pose a danger to the user or the equipment.



### CAUTION:

The exclamation point symbol is to draw attention to other potential hazards not included under the optical or electrical categories. The user should be aware of special care that needs to be taken when performing potentially hazardous procedures.



### WARNING! PERSONAL INJURY

The Safety section is placed as the first chapter of the manual to emphasize its importance and the need for everyone to read it before working with the laser.

The installation section includes a copy of the installation instructions for future reference. The site requirements are listed as is the initial installation process step by step.

The Operation section begins with the daily startup and shutdown procedures. The single shot operation is discussed here too. The LED status information and external control are explained. A description of the installation and removal of the harmonics is given in Chapter III.

Instructions for careful cleaning of optics, replacing flashlamps and replacing of cooling group filters are given in the Maintenance section.

The Troubleshooting chapter presents common problems that are encountered and ways to solve them in both the electronic and optical areas. It is here that the more complicated procedures such as eliminating free-running are discussed.

The Appendix lists the Continuum warranty and gives Service telephone and FAX numbers for further help. The Operator Notes gives the user a convenient place to keep maintenance records and other information.



## Préface

Les symboles de danger reconnus internationalement présentés ici sont utilisés tout au long du manuel pour avertir l'utilisateur des risques possibles lors de l'utilisation de ce laser.



Le symbole de radiation sert à avertir l'utilisateur du danger d'exposition à la radiation laser lors de l'exécution de certaines opérations et lorsque ce danger est le plus grand. Il est aussi utilisé en cas de risques optiques.



Le signe d'éclair indique la présence d'une haute tension qui peut représenter un danger pour l'utilisateur ou l'équipement.



Le point d'exclamation sert à attirer l'attention sur d'autres risques possibles non inclus dans les catégories optique et électrique. L'utilisateur devrait être conscient des mesures de protection particulières à prendre lors de l'exécution de procédures potentiellement dangereuses.



La section Sécurité est en tête du premier chapitre de ce manuel afin de souligner son importance et la nécessité incombant à chaque utilisateur de la lire avant de commencer à utiliser un laser.

La section Installation comprend une copie des instructions de montage pour future référence. Les exigences de site sont énumérées comme l'est le processus d'installation initial, étape par étape.

La section Fonctionnement commence avec les procédures de mise en route et mise en arrêt quotidiennes. Le fonctionnement en décharge unique est aussi expliqué dans cette section. Une description de la mise en place et de l'élimination des harmoniques commence dans la section III.

Des instructions pour un nettoyage soigneux des éléments optiques, pour le remplacement de la lampe éclair et des filtres du dispositif de refroidissement se trouvent dans la section Entretien.

Le chapitre Dépannage présente les problèmes couramment rencontrés et indique les mesures à prendre dans les domaines de l'électronique et de l'optique. C'est aussi dans ce chapitre que les procédures plus complexes telles que l'élimination du fonctionnement libre sont expliquées.

L'Annexe décrit la garantie Continuum et fournit les numéros de téléphone et de fax du service après-vente. Les Notes de l'Utilisateur offrent à l'utilisateur un endroit pratique pour conserver les rapports d'entretien et d'autres informations utiles.

## Vorwort

Die hier abgebildeten, international verständlichen Warnsymbole werden in der gesamten Anleitung dazu verwendet, den Benutzer auf mögliche Gefahrenquellen beim Laserbetrieb hinzuweisen.



Das Strahlungssymbol warnt den Benutzer vor gefährlicher Laserstrahlung bei bestimmten Betriebsverfahren und bei den stärksten Strahlengefährdungen. Es wird auch für optische Gefahrenquellen verwendet.



Das Blitzsymbol weist auf das Vorliegen von Hochspannung hin, die eine Gefährdung für Benutzer oder Gerät darstellt.



Das Ausrufezeichensymbol soll auf weitere Gefahren aufmerksam machen, die nicht unter die Kategorie Optik oder Elektrik fallen. Der Benutzer sollte auf besondere Maßnahmen achten, die bei evtl. gefährlichen Verfahren anzuwenden sind.



Das erste Kapitel dieser Anleitung ist der Sicherheitsabschnitt, da dieser äußerst wichtig ist und vor dem Betreiben des Lasers von jedem Benutzer gelesen werden sollte.

Der Abschnitt zur Installation enthält für den zukünftigen Bedarf ein Exemplar der Installationsanleitung. Hier sind sowohl die Standortanforderungen als auch eine schrittweise Erläuterung der Erstinbetriebnahme enthalten.

Der Abschnitt zum Betrieb beginnt mit der täglichen Einschalt- und Abschaltprozedur. Außerdem werden der Einzelpulsbetrieb behandelt und die Leuchtdioden-Statusinformationen und -Fehlermeldungen erläutert.

Anweisungen zur sorgfältigen Reinigung der Optik, zum Austauschen der Blitzlampen und der Filter der Kühlgruppe sind im Wartungsabschnitt enthalten.

Das Kapitel Fehlersuche und -behebung beschreibt bekannte Probleme (Elektronik und Optik), die auftreten können, sowie

Abhilfemaßnahmen. Hier werden auch kompliziertere Verfahren, wie das Verhindern von "Freischwingern", erörtert.

Der Anhang enthält die Continuum-Garantie sowie Service-Rufnummern und -Faxnummern, unter denen weitere Hilfestellung verfügbar ist. Unter "Benutzernotizen" kann der Benutzer bequem Wartungsdaten und sonstige Informationen aufbewahren.

## Introduction

This manual covers the entire Minilite™ family of products. These include:

- Standard Minilite laser system with Tower-style power supply
- Optional Rack mount power supply
- Optional harmonics generators
- Optional PIV configuration

Except where noted, the features and procedures described for the standard Minilite configuration apply to all optional configurations.

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## Chapter I Laser Safety Precautions

### A. Class IV Laser safety precautions

Continuum's Minilite Nd:YAG laser is a Class IV high power laser whose beam is, by definition, a safety and fire hazard. Take precautions to prevent accidental exposure to both direct and reflected beams.

Diffuse as well as specular beam reflections can cause severe eye and skin damage. The 1064 nm, 355 nm and 266 nm outputs of a Nd:YAG laser are invisible, making them even more dangerous. Infrared radiation passes easily through the cornea, which focuses it onto the retina, where it can cause instantaneous permanent damage or blindness. Even small doses from scattered radiation can be harmful.

**AVOID EYE AND SKIN EXPOSURE TO DIRECT OR SCATTERED RADIATION.**

### B. General safety rules



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#### WARNING!

If the equipment is used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired.

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- Locate the laser in a locked area with access only by authorized personnel. Mark the area with well-defined warning signs, making it off limits to unauthorized personnel.
- Provide interlocks for all doors.
- Shut off or place the laser in standby when not in use.
- Remove volatile substances in the lab, which the laser could ignite.
- Place a fire resistant background behind target areas.
- Coat surrounding work areas with a radiation absorbing material.

### C. Electrical safety rules



- Turn off all power before beginning maintenance or repair.
- Avoid the high voltages, which are present in the laser cavity and Power Supply whenever the Minilite is on.
- To prevent accidents due to electrical shock, care should be taken to be sure the capacitors are completely discharged and the power turned off before any maintenance or repairs are made to the system. Electric shock and burns resulting from input power or capacitor discharge can cause serious injury or death.

### D. Optical safety rules



- Eye safety is the greatest concern. This is a Class IV laser, the highest and most dangerous classification. Even a main beam reflection from a polished surface can cause severe and permanent eye damage. Never look at a beam or reflection directly.
- Always wear laser goggles appropriate for the wavelength and beam intensity generated.
- Do not wear or use any object that may reflect laser light such as a watch, ring, pen, reflecting tool, etc.
- Light the area around the laser so that the operator's pupils are constricted normally.
- Operate the laser without its covers only when adjusting it; replace and rebolt covers promptly.
- Always use the LOW ENERGY MODE when the laser head cover is off.
- Expand the beam wherever possible to reduce beam intensity.
- Close beam exit shutter when laser is not in use.
- Use an infrared detector or energy detector to verify that the laser beam is off before working in front of the laser.
- Set up experiments so the laser beam is not at eye level.
- Provide enclosures for beam paths whenever possible.
- Avoid blocking the output beam or its reflection with any part of the body.



## E. Safety features



### *Interlocks*

The Minilite has interlock switches which stop it from firing when the:

- Laser head (rod) temperature is too high
- Laser head cover is open
- Cooling water flow too is low
- External interlock (if installed) is open.

All interlocks must be OK before the Minilite will fire. If any of them or the external interlock is tripped, the yellow INTERLOCK LED will light and laser firing will stop; it must be reset (Chapter III) before the laser will fire again.

You may also wire your Minilite so that opening a door to the laser laboratory (or opening any other switch) shuts off the laser. To install an external interlock, see Chapter III.

### *Laser covers*

Covers protect against stray laser radiation from the Minilite. Interlocks prevent laser operation when they are open. Do not remove them or defeat the interlock.

### *Exit shutter*

The Minilite has an exit beam shutter located outside its housing. Closing the beam shutter merely prevents the beam from exiting; it does not shut down the laser.

## F. Government and industry safety regulations



Continuum strongly suggests that all its customers purchase a copy of the American National Standard for the Safe Use of Lasers (ANSI Z136.1-1993) in order to read and implement necessary precautions. The American National Standards Institute (ANSI), a member of the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC), issues this booklet. Write or call the publisher listed below for information on obtaining a copy of ANSI Z136.1-1986.

Continuum's user information complies with 21 CFR 1040.10 concerning laser safety.

### G. Additional safety references

Regulations of the Administration and Enforcement of the Radiation Control for Health and Safety Act, 1968. US Dept. of Health and Human Services, Public Health Service and FDA, April 1988.

Regulation JIS C 6802, May 1, 1991 (Japan, based on the section 1040.10 of 21 CFR regulation of the United States cited on the previous page)

American National Standard for the Safe Use of Lasers. Laser Institute of America, 1986.

Laser Safety Guide. Laser Institute of America, 1977.

A Guide for Control of Laser Hazards. American Conference of Governmental Industrial Hygienists, 1976.

EN61010-1.

Figure 1.1  
Minilite dimensions

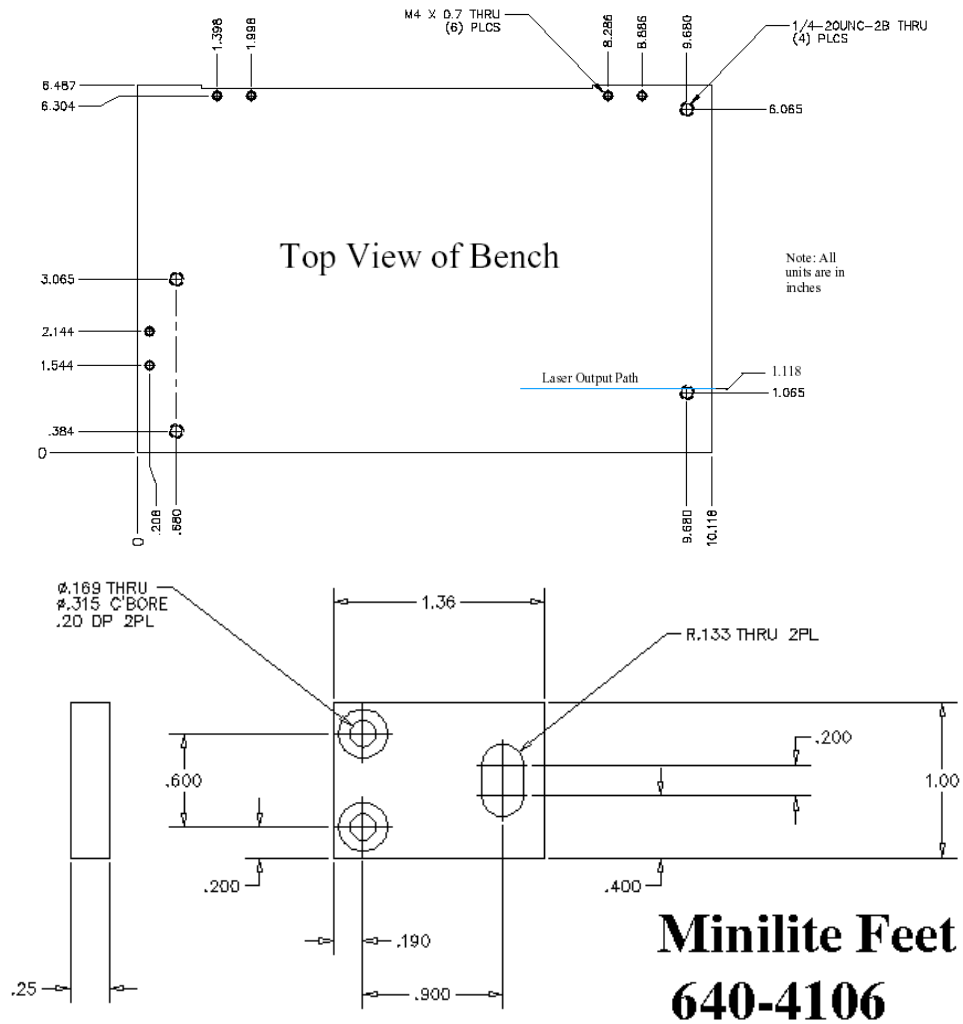
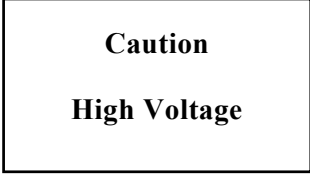




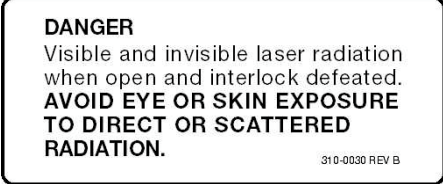



Figure 1.2  
Table of labels used

	Description	Image
A	High Voltage label	 <p>A rectangular white label with a black border. The text is centered and reads: <b>Caution</b> <b>High Voltage</b></p>
B	High Voltage cable label	 <p>An orange rectangular label with a black border. The text reads: <b>CAUTION: HIGH VOLTAGE</b> BEFORE WORKING ON THIS UNIT, -----SWITCH OFF POWER SUPPLY, -----DISCONNECT ALL PLUGS. 310-0028 Rev. B</p>
C	Laser aperture warning	 <p>A white rectangular label with a black border. The text reads: <b>AVOID EXPOSURE</b> VISIBLE AND INVISIBLE LASER RADIATION IS EMITTED FROM THIS APERTURE 310-0169 REV C</p>
D	Laser indicator	 <p>A white rectangular label with a black border. The text reads: <b>LASER A</b> 310-0209 rev B</p>
E	Laser indicator	 <p>A white rectangular label with a black border. The text reads: <b>LASER B</b> 310-0210 rev B</p>
F	Laser interlock warning	 <p>A white rectangular label with a black border. The text reads: <b>DANGER</b> Visible and invisible laser radiation when open and interlock defeated. <b>AVOID EYE OR SKIN EXPOSURE TO DIRECT OR SCATTERED RADIATION.</b> 310-0030 REV B</p>
G	CDRH Class IV label	 <p>A white rectangular label with a black border. It features a red starburst icon on the left. The text reads: <b>DANGER</b> VISIBLE AND INVISIBLE LASER RADIATION! AVOID EYE &amp; SKIN EXPOSURE TO DIRECT OR SCATTERED RADIATION! WAVELENGTH 1064nm, 100mJ 3ns WAVELENGTH 82nm, 50mJ 8ns WAVELENGTH 800nm, 20mJ 3ns WAVELENGTH 266nm, 20mJ 3ns 310-0152 REV E CLASS 4 LASER PRODUCT</p>

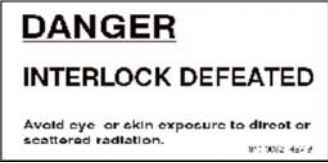
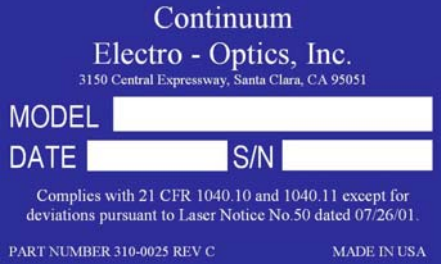
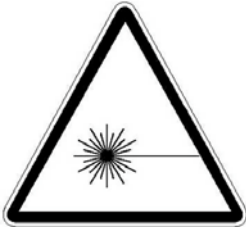
<p><b>H</b></p>	<p>Interlock defeated warning</p>	
<p><b>I</b></p>	<p>Serial number tag</p>	
<p><b>J</b></p>	<p>Laser Radiation symbol</p>	

Figure 1.3  
Label location diagram A

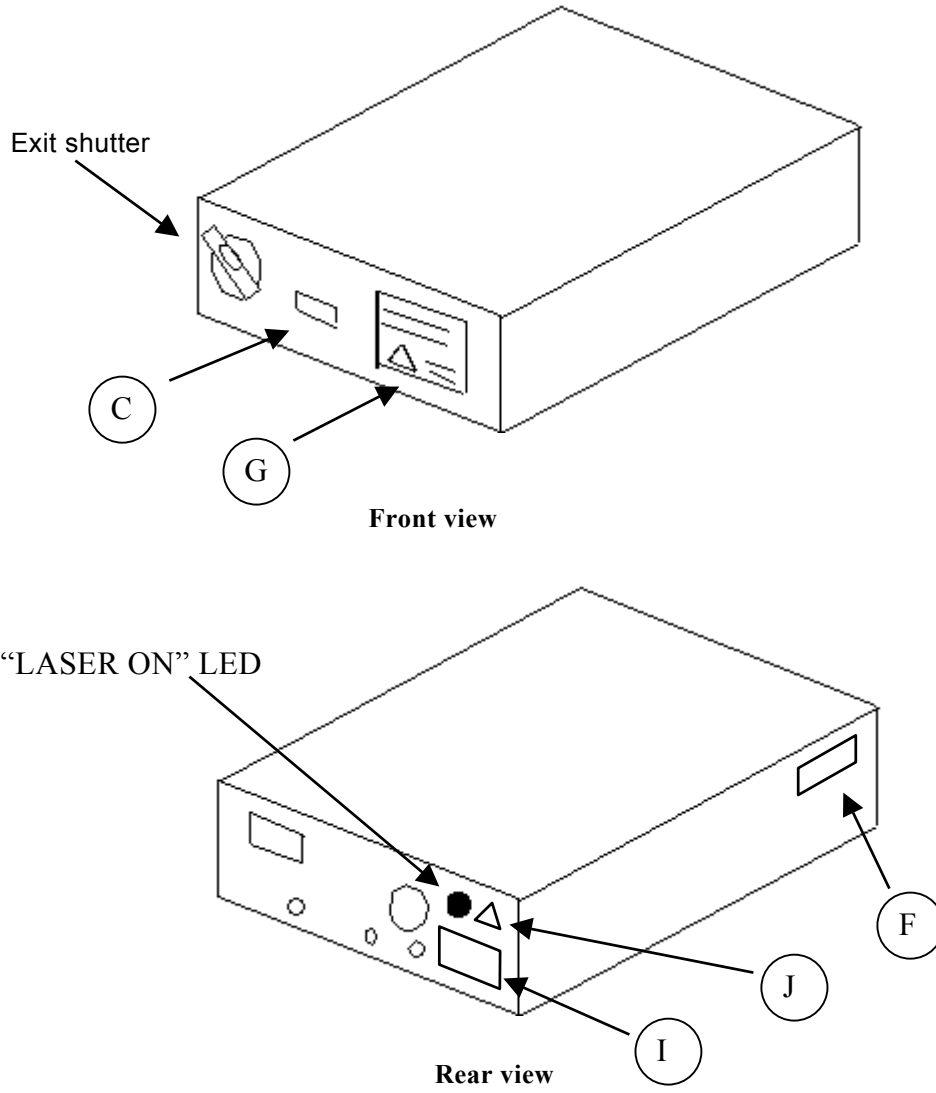


Figure 1.4  
Label location diagram B

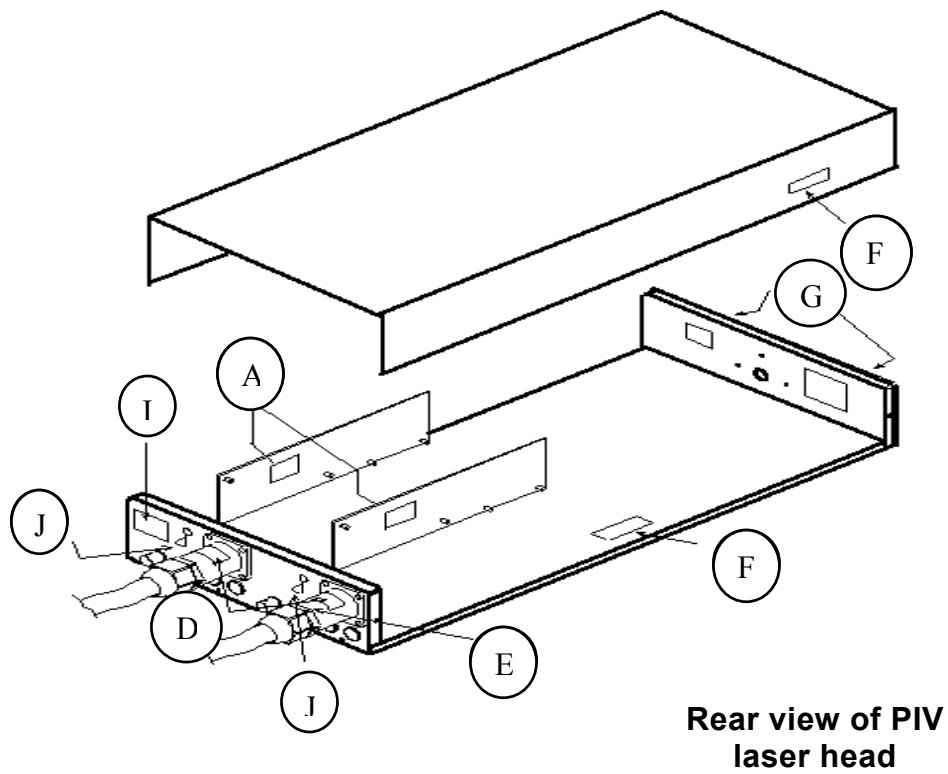
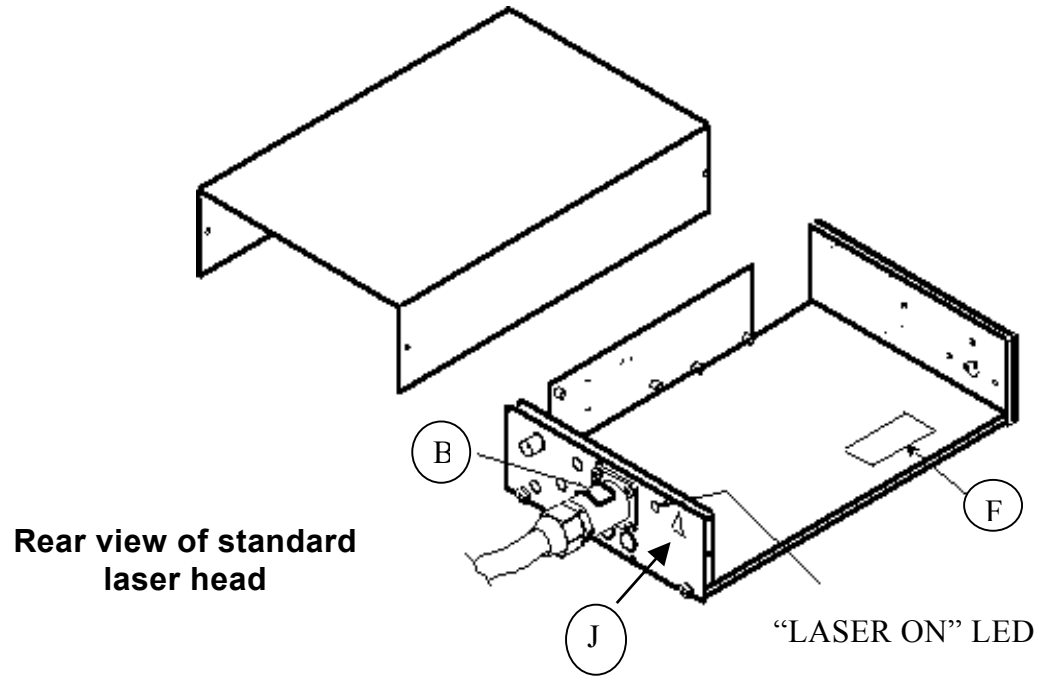
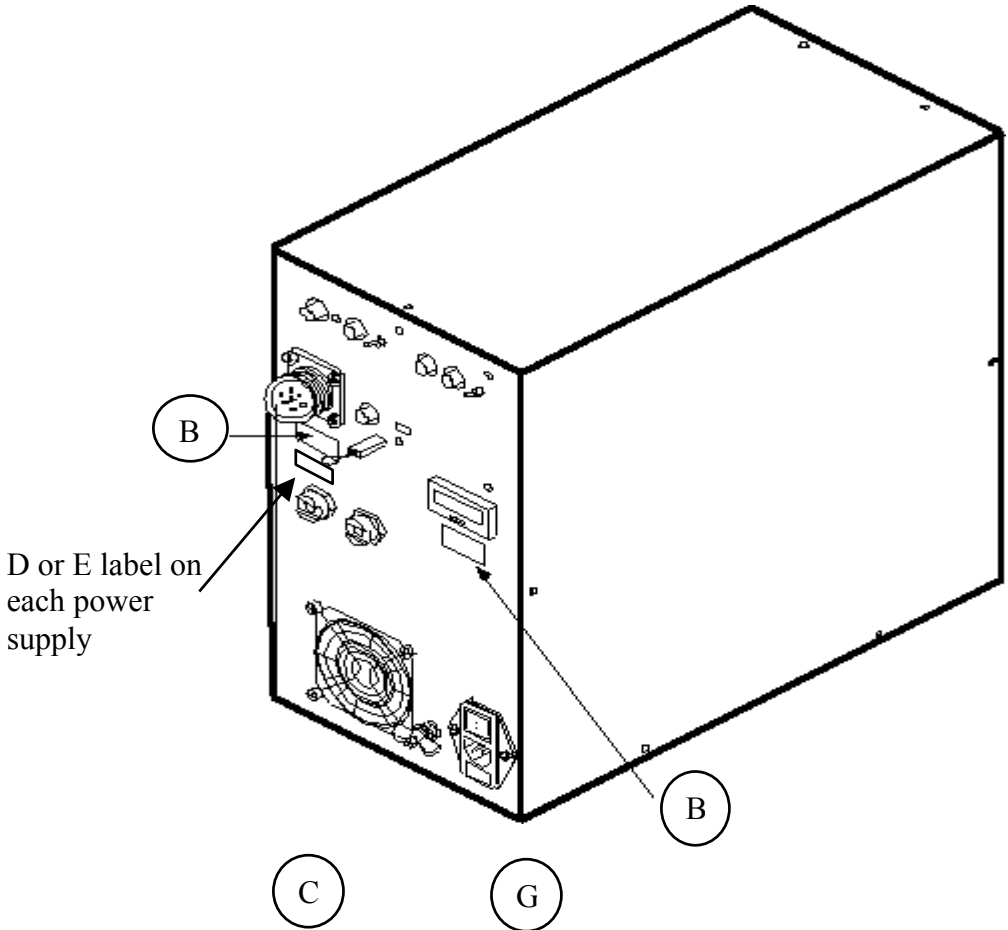


Figure 1.5  
Power Supply label location diagram C



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## Chapter II Installation

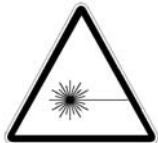


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**DANGER! High voltages and currents**

The laser head and Power Supply contain LETHAL VOLTAGES AND CURRENTS. Never operate the laser with the Power Supply cover removed

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**DANGER! Laser radiation**

Observe all Chapter I safety precautions, especially when the laser head cover is open. When it is open, operate the laser only in LOW ENERGY mode.

---

### A. Installation checklist

- 1) Prepare the site for the laser; refer to Chapter I safety rules.
- 2) Inspect the crates upon arrival for shipping damage and notify the shipper if any damage is visible.
- 3) Unpack the Minilite and check that all parts are present as listed in the Final Test Report. Notify Continuum customer service if any parts are missing. If any damage is found, notify both the shipper and Continuum Customer Service immediately.
- 4) Check all parts for shipping damage. Any shipping damage is the responsibility of the shipping company and buyer. Also open both laser covers and check for loose parts.
- 5) Set the equipment in place, considering all safety issues (Chapter I).
- 6) Attach the high voltage cable from the laser head onto the plug on the rear of the Power Supply.
- 7) Plug the BNC cable from the laser head into the Q-SW TRIGGER BNC connector to the right of the high voltage connector on the rear of power supply.

- 8) Use the CHASSIS GND wing nut to ground the power supply to the same ground used by other equipment associated with the laser.
- 9) Connect the two water lines to the Power Supply nipples. You may connect either water hose to the COOLING WATER IN line.
- 10) Fill the cooling water reservoir (see Chapter IV, Maintenance).
- 11) Remove any packing material around or under the cooling fans in the power supply, and replace the power supply cover.
- 12) Install an external interlock (optional). To install, wire a switch between the two pins of the 2-pin Molex connector plugged into the INTLK socket on the rear of the power supply. When this switch is open, the Minilite will not fire. Use switches and wiring rated at least 50 volts Vac at 0.1 A.



---

**Note:**

Short the Molex connector's two pins together and plug it into the INTLK socket when not using an external interlock.

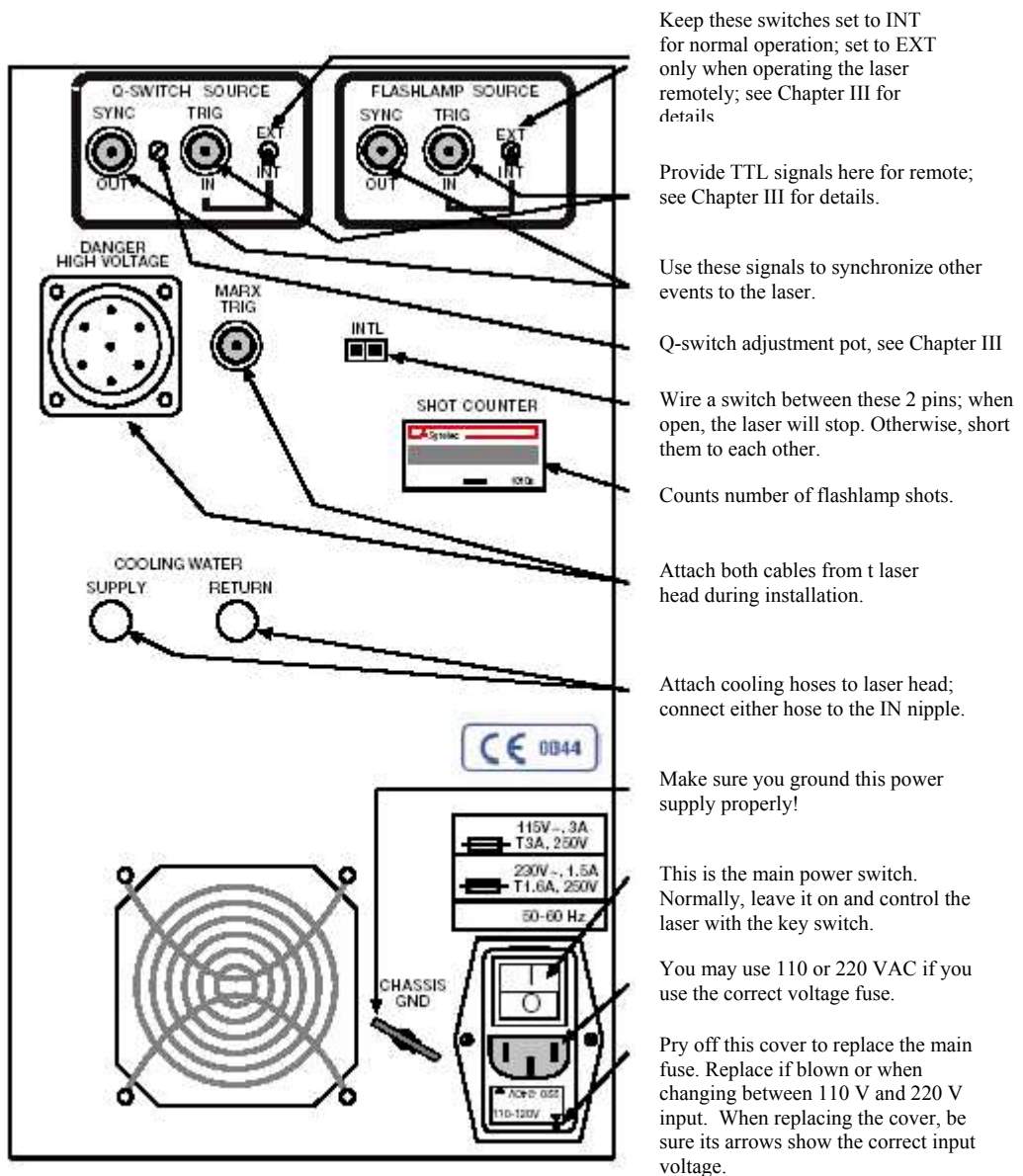
---

- 13) Verify that ACV selected corresponds to ACV you will provide.
  - If switching between 110 VAC and 220 VAC (single phase) operation, be sure to replace the line fuse, located at the bottom of the AC INPUT plug, just below the power plug on the rear of the Power Supply.
  - Check which fuse is installed by examining the arrows on the fuse holder cover plate. To replace, first pry off the cover plate. After installing the correct fuse, replace the cover plate making sure that it is oriented so that its arrow indicates the correct operating voltage. No other change is needed.
- 14) Connect Power Supply to AC power. The Minilite requires a single 15 amp outlet, 50 to 60 Hz.

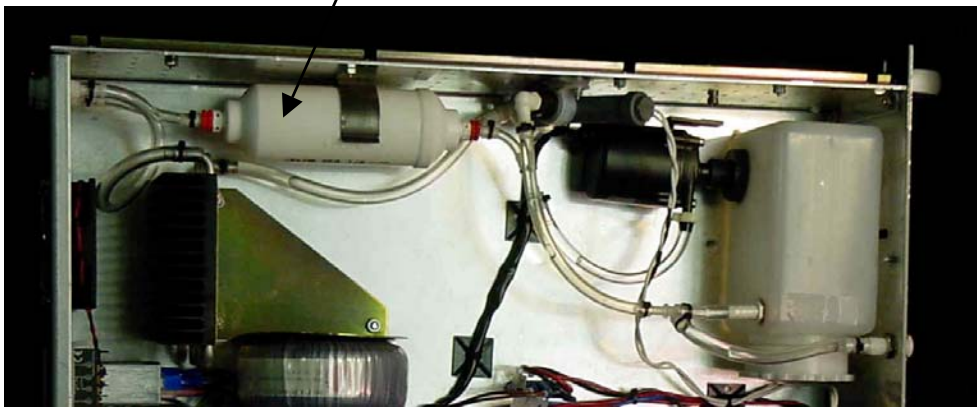
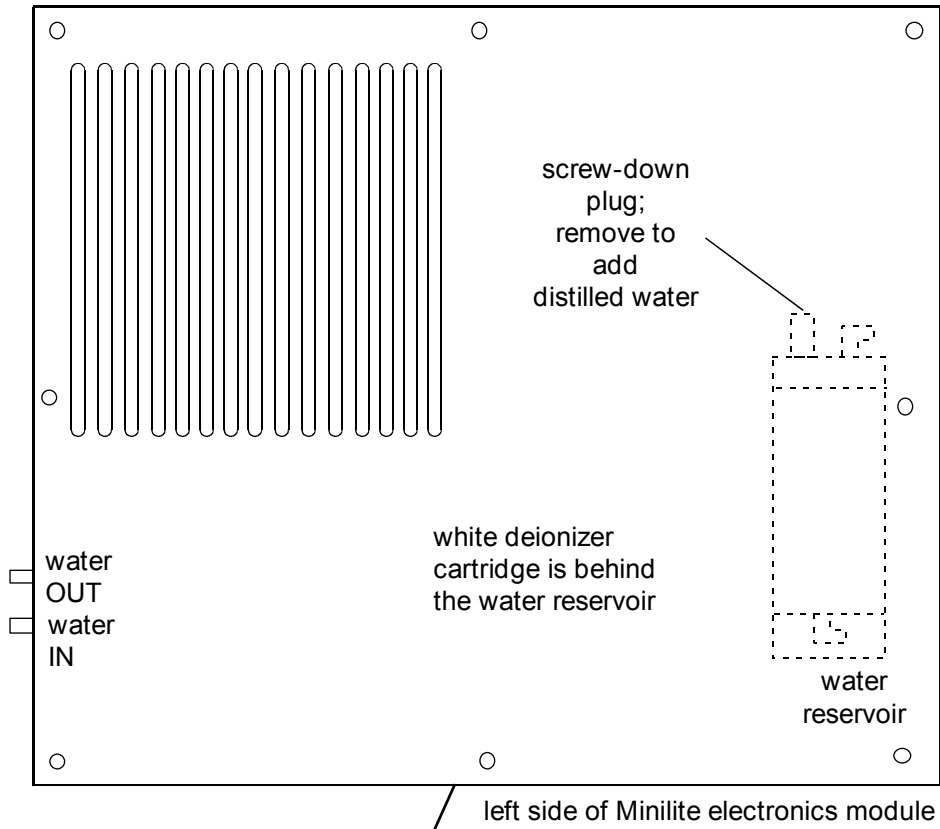
## B. Switching between 110 and 220 volt power

If switching between 110 Vac and 220 Vac (single phase) operation, be sure to replace the line fuse located at the bottom of the AC INPUT plug, just below the power plug on the rear of the Power Supply (Figure 2.1). Check which fuse is installed by examining the arrows on the fuse holder cover plate. To replace, first pry off the cover plate. After installing the correct fuse, replace the cover plate, oriented so its arrow indicates the correct operating voltage. No other change is needed.

Figure 2.1  
Rear View of Power Supply



**Figure 2.2 Cooling system, side view.**



Left side of rack mount power supply

## Chapter III Operation

### A. Startup

Start the laser only after completing the installation and understanding the laser safety chapter thoroughly. Be sure all covers are closed and the reservoir is filled with distilled water before starting. See also Figure 3.1.

1. Open the exit shutter on the front of the laser head.
2. Turn the AC power on; the red AC POWER ON LED on the front panel will light; see Figure 3.1.
3. Turn the key switch ON; the cooling fan and water pump will start, the yellow STOP LED will light, and the red LASER ON LED will light after blinking for eight seconds.
4. Push the LOW ENERGY MODE key; its yellow LED should light.
5. Use the UP and DOWN keys to choose a firing rate between 1 Hz and 15 Hz as shown by the REP RATE display.
6. Push the START button to start flashlamp and Q-switch firing; low power laser light will now exit the laser head. Verify the beam is correctly aligned after leaving the laser; the yellow Q-SWITCH LED will flash with each shot.
7. Switch to full energy mode by pressing the LOW ENERGY MODE button again.
8. To fire single shots, connect the single shot cable to the front panel BNC; now the Minilite fires 1 shot each time you press the cable's button. The flashlamp continues to fire at the current REP RATE; the single shot occurs at the next flash after the button is pushed.



---

**Note:**

Pushing the single shot button for several seconds will stop single shot operation and start lasing at the set REP RATE. Pushing it again returns the laser to single shot mode.

---

**B. Shutdown**

1. Push the STOP button (see Figure 3.1).
2. Close the exit shutter.
3. Turn the key switch to the OFF position. The laser is now off. You may also wish to turn off the AC POWER switch on the rear panel.
4. Remove the key to prevent unauthorized use.
5. If shutting down for more than 3 months, observe the Caution below.



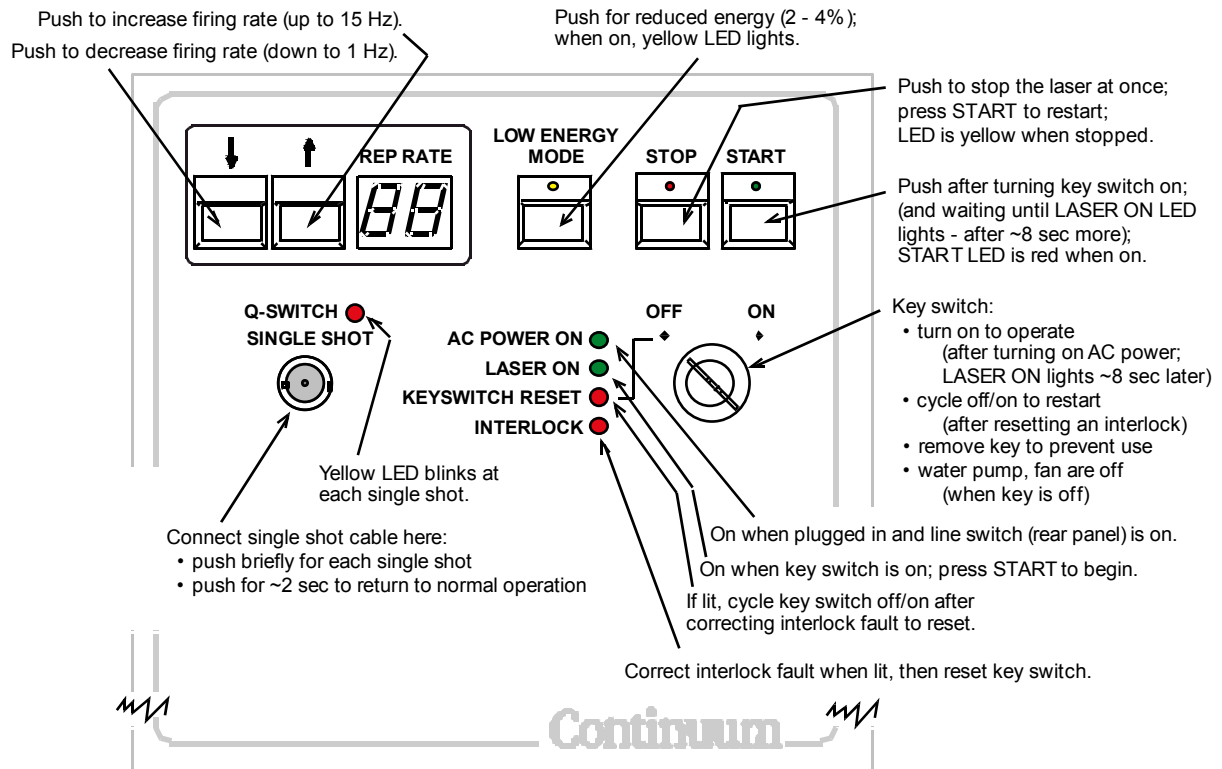
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**CAUTION!**

To prevent algae from growing in the cooling system, run the laser at least 15 minutes/week. If you will not use the laser for more than 3 months, Continuum suggests that you drain and flush the cooling system; Chapter IV has details.

---

**Figure 3.1**  
*Power supply front panel.*



## C. Operation

### *Firing single shots*

Pushing the button of the single shot cable, when it is attached to the front panel SINGLE SHOT BNC, switches to single shot mode. Each successive push fires a single shot. The flashlamps continue to fire at the current REP RATE with the cable attached, and each shot will occur during the next flashlamp cycle (see Figure 3.3). Keeping this button depressed for ~2 seconds will return the Minilite to normal firing mode.

***Low power operation***

When the LOW ENERGY MODE key (Figure 3.1) is on, the Minilite produces an output beam with 2-4% of normal power. Use this mode when steering the laser's output beam and when converting between different harmonic options.

***Energy Attenuator***

When the attenuator and its associated dielectric polarizer are installed, a lever projects through an opening in the top of the laser head, near the output port. Moving the lever allows beam energies between ~4% and 100% of the maximum. The attenuator is uncalibrated; use a power meter while adjusting it to achieve specific energies. This option permits wide changes in output power while maintaining beam shape and quality.

***Interlocks***

Your Minilite is equipped with four internal and one external interlock. Internal interlocks sense when:

- Laser head temperature is too high
- Laser head cover is open
- Cooling system flow is too low
- Cooling airflow is too low.

All interlocks must be OK before the Minilite will fire. If any of them or an external interlock are tripped, the yellow INTERLOCK LED will light and laser firing will stop; it must be reset (next) before it will fire again.

You may also wire your Minilite so that opening a door to the laser laboratory (or opening any other switch) shuts off the laser. To install an external interlock, see Chapter II.

***Resetting an interlock***

If the laser is interrupted during operation by an interlock opening, Correct the condition, which triggered the interlock: the front panel INTERLOCK LED should go out (see Figure 3.1).

1. Turn the key switch OFF, then ON. The KEY SWITCH RESET LED will go out and the LASER ON LED should come on.



2. Push START to resume normal, single shot or external operation.

### ***Using the cover interlock***

You must disable the cover interlock to operate the laser without its cover. After removing the laser head's cover:

1. Use the bolt provided to attach the interlock flag (Figure 1.1) on top of the cover interlock (Figure 3.3).
2. To enable the cover interlock, unbolt the interlock flag and store it and the bolt where you can find them again.

### ***External control***

Turning the rear panel FLASHLAMP and/or Q-SWITCH switches from INT to EXT will disable the internally generated signals, which respectively fire the flashlamp and/or open the Q-switch (Figure 3.2). At the same time, these switches let the Minilite accept TTL signals into the FLASHLAMP TRIG IN and Q-SWITCH TRIG IN BNC ports to trigger flashlamp firing and Q-switch opening. To operate remotely:

1. Set the two INT/EXT switches as desired (see Table 3.1).
2. Start up the laser normally and push the START key.



---

**Note:**

The START LED is now on (indicating flashlamps are on), the REP RATE reads 10 Hz and the single shot LED blinks.

---

3. Provide TTL signals (0 to +5 Vdc, 10-20  $\mu$ sec wide pulses) to the FLASHLAMP TRIG IN and/or Q-SWITCH TRIG IN ports.

<b>Flashlamp Int/Ext switch</b>	<b>Q-Switch Int/Ext switch</b>	<b>Operation Mode</b>
INT	INT	Normal (internal) operation mode: front panel and/or single shot controls laser firing
EXT	INT	TTL pulses sent to FLASHLAMP TRIG IN BNC fire the flashlamp; the Q-switch automatically opens after the same delay as in normal operation. However, this method introduces jitter in the laser pulse timing, and pulse energy will be the same as in normal mode.
INT	EXT	The flashlamps will fire at the rate set by the front panel, but the Q-switch will open only when a TTL pulse is sent to the Q-switch TRIG IN BNC. Timing accuracy is better than in the above mode, but the pulse energy may fluctuate more than in normal mode. You may wish to use the FLASHLAMP SYNC OUT pulse to time your Q-SWITCH TRIG IN pulse.
EXT	EXT	You must send a pulse to both fire the flashlamp, then another to open the Q-switch. This yields best accuracy in pulse timing (minimum jitter) and most constant pulse energy (constant Q-switch delay time). Varying the time between flashlamp firing and Q-switch opening affects pulse energy.

*Table 3.1  
Internal and External Operation Modes*

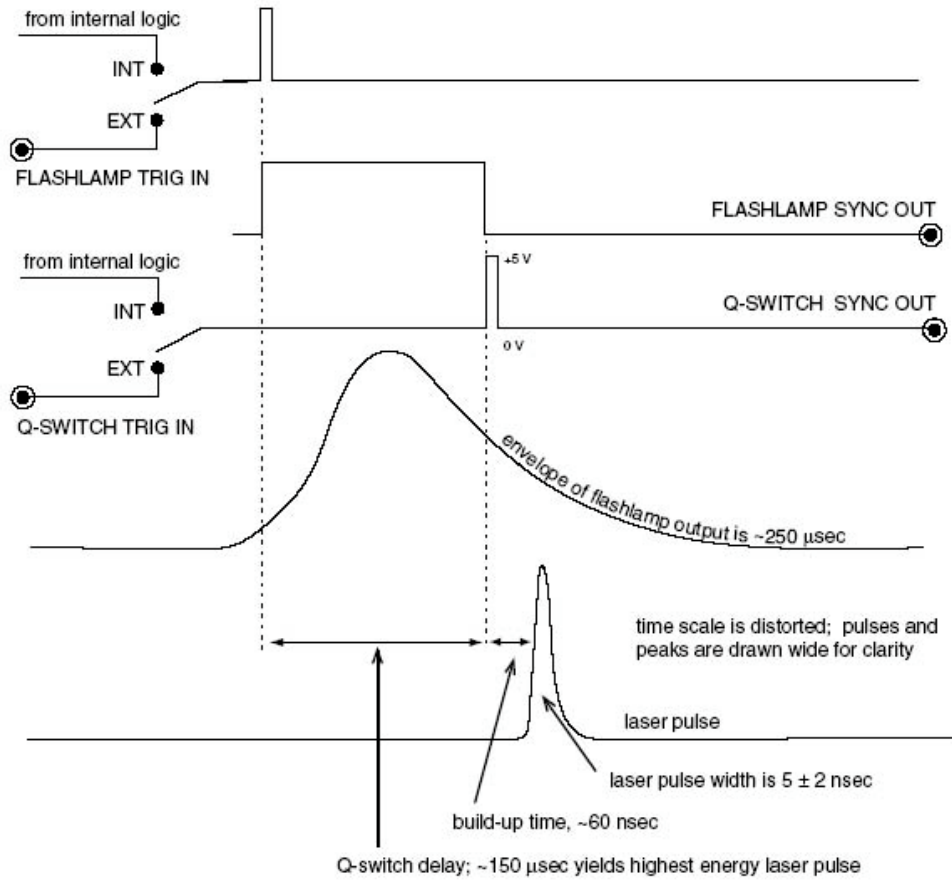


Figure 3.2  
Timing pulse sequences

**Synchronization**

You may synchronize events to Minilite laser pulses using signals provided on the rear panel of its Power Supply. The Q-SWITCH SYNC OUT signal is most closely synchronized to the laser pulse, which occurs ~60 nsec after the Q-switch opens. Figure 3.2 shows the approximate relationship between these two TTL signals and the laser pulse.

These synchronization signals appear in all internal, single shot and external operation modes.

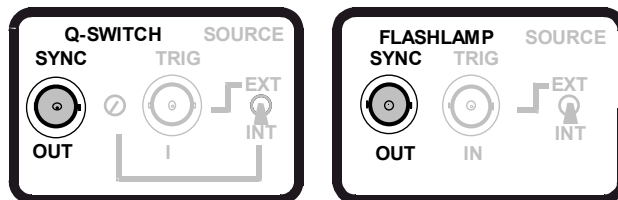
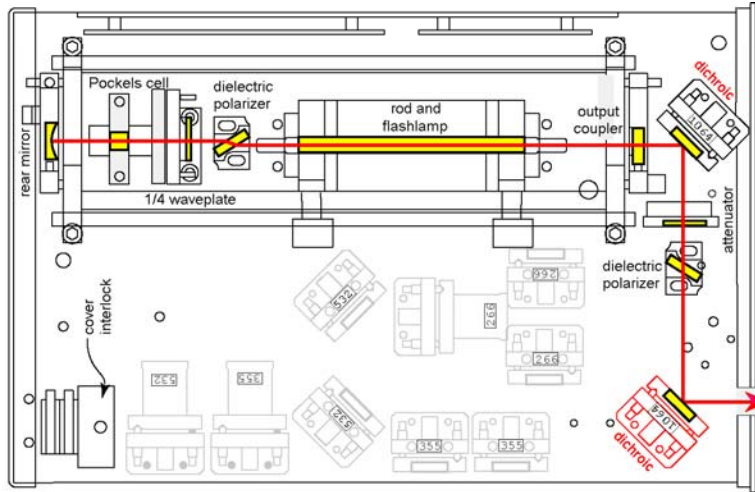


Figure 3.3 Optical layouts

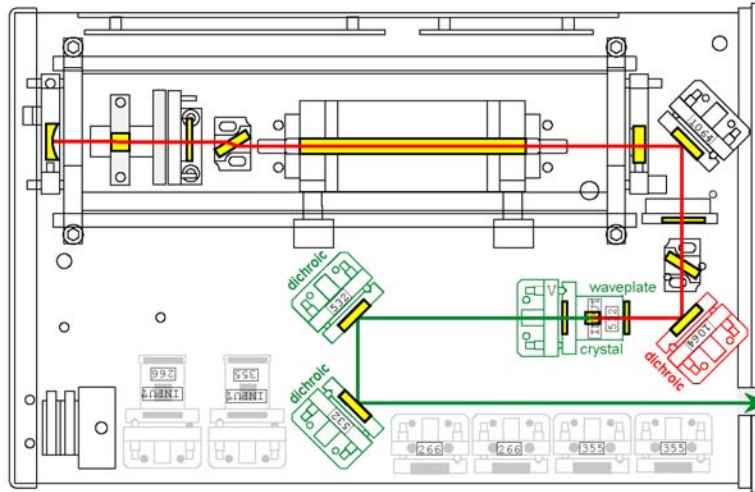
**Optical layout for 1064 nm output**

- install 1064 nm dichroic as shown.
- steer beam with dichroics' H, V screws.
- note: storage spots for spare dichroics and crystals are shown in grey.



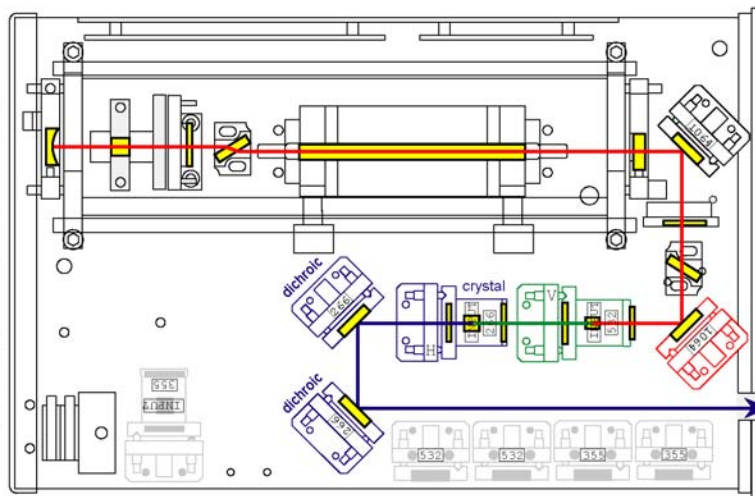
**Optical layout for 532 nm output**

- install 1064 dichroic, 532 dichroics, 532 nm crystal as shown.
- steer beam with dichroics' H, V screws.
- optimize power with 532 nm  $\lambda/2$  plate & 532 nm crystal's V adjustment screw.



**Optical layout for 266 (or 355) nm**

- install 1064, 532, nm dichroics.
- install 532 nm, 266 (or 355) nm crystals.
- steer beam with dichroics' H, V screws.
- optimize power with 532  $\lambda/2$  plate, V adj.
- optimize power with 266 (or 355 nm) crystal's H screw..
- repeat last two steps until satisfied.



## D. Generating 532, 355 and 266 nm output

The Nd:YAG Minilite laser produces horizontally polarized infrared light at 1064 nm. Optional non-linear crystals in the beam can double, triple, or quadruple the frequency of this fundamental, resulting in 532 nm, 355 nm or 266 nm light, respectively. These crystals do not convert all of the fundamental beam to their output frequency, so the Minilite uses pairs of dichroics (each pair matched to a crystal's output) to separate the output frequency from the residual input, and steer the output through the exit port. Figure 3.3 shows arrangements of dichroics and crystals for all outputs.

Switching between these wavelengths requires installing or removing the crystals and their associated pair of dichroics, then optimizing the energy of the resulting output beam. These operations are detailed in the next 2 procedures, Installing optics and dichroics and Maximizing beam energy.

### *Tools required*

- Safety glasses
- Red fluorescent paper and a white business card
- Metric Allen wrenches
- Power meter with energy absorbing head

### *Optics required and beam polarizations*

This table gives the combinations of crystals and dichroics required to generate 532 nm, 355 nm and 266 nm light.

\*1064 dichroic in different position for 1064 nm output

<b>output beam</b>	<b>set of 1st dichroics</b>	<b>first crystal</b>	<b>second crystal</b>	<b>set of 2nd dichroics</b>	<b>output polarization</b>
1064 nm	1064*	none	none	1064	horizontal
532 nm	532	532	none	532	vertical
355 nm	355	532	355	355	horizontal
266 nm	266	532	266	266	horizontal

## E. Installing optics and dichroics

For 1064 nm output, install the 1064 nm dichroic and use its H and V adjustments to steer the beam out of the exit port (Figure 3.3). This procedure describes 532 nm, 355 nm, and 266 nm optics installation.



---

### WARNING!

This procedure requires operating the laser with its cover removed. Wear safety goggles and observe all safety rules.

---

1. Turn the key switch OFF and remove the laser head's cover.
2. Remove the proper crystal and pair of dichroics from their storage positions inside the laser head (see Table 3.2 and Figure 3.3).
3. Remove any unneeded crystal(s) and dichroics. Bolt all unused optics into storage positions (Figure 3.3).
4. Install the selected crystal(s) and dichroics; refer to Figure 3.3 to orient the optics. Be sure to reposition the 1064 nm dichroic if switching from 1064 nm output.
5. Defeat the laser cover interlock and open the output shutter.
6. Start the laser at 10 Hz in **low energy mode**.
7. Using red fluorescent paper, make sure the 1064 nm beam passes through the 532 nm crystal without being clipped. Use the H and V adjustments of the first 1064 nm dichroic (Figure 3.4) to center the beam in the 532 nm crystal.
8. If there is a 355 nm or 266 nm crystal present, use the H and V screws of the second 1064 nm dichroic (Figure 3.4) to center the beam in this crystal. Use a business card to ensure the exit beam isn't clipped.
9. Use the H and V adjustments of the second pair of dichroics to steer the final beam through the center of the exit port.

10. Angle tune the crystal(s) and adjust the 532 nm half wave plate (Figure 3.4) to maximize beam energy (see next procedure).
11. Turn off the laser, remove the interlock flag, and replace the cover.
12. Switch to high power mode and resume operation.

Figure 3.4a  
Dichroic mounts

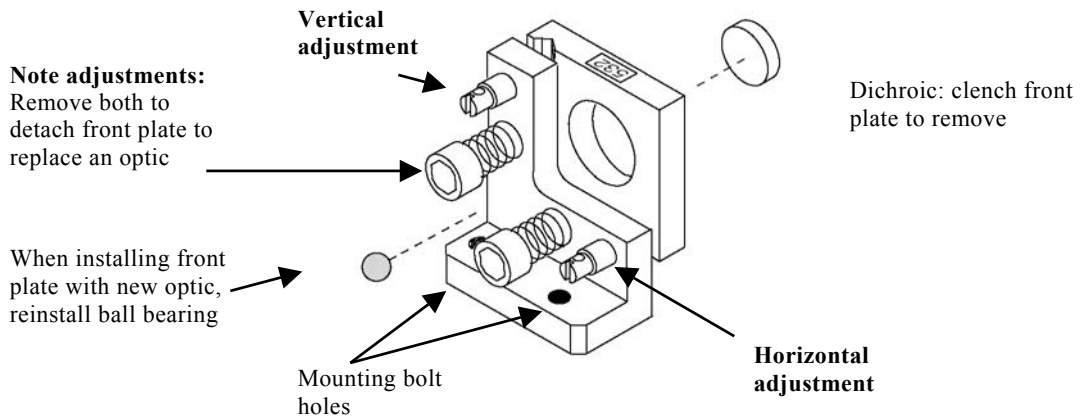
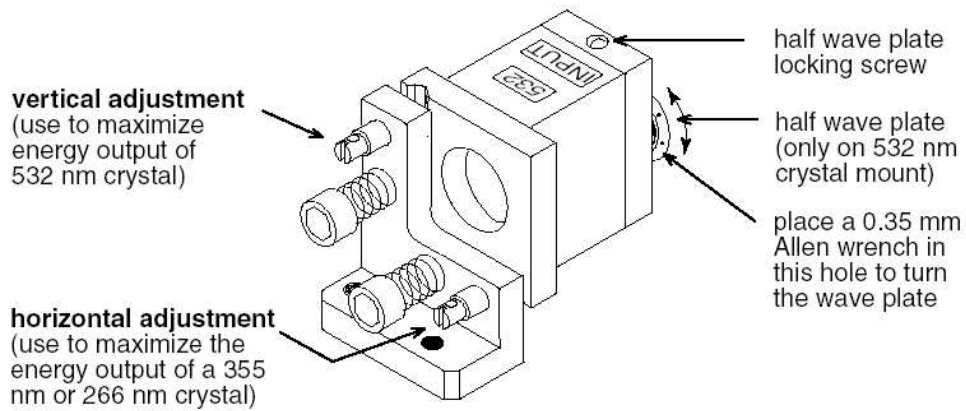


Figure 3.4b  
Crystal mounts



### *Maximizing harmonic energy*

For maximum harmonic conversion, you must adjust the crystal angle(s) and the 532 nm wave plate (Figure 3.4). All crystals are Type II, meaning that their conversion efficiency is highly dependent on their angle to the input light beam's polarization plane.

Perform this procedure after installing any new crystal, or if output energy is low. This procedure isn't needed for 1064 nm output.



---

#### **WARNING!**

This procedure requires operating the laser with its cover removed. Wear safety goggles and observe all safety rules.

---

1. With the laser off, remove the laser head outer cover, install the cover interlock defeat flag and open the output shutter. Place the head of a power meter in the exit port.
2. Start the laser at 10 Hz in normal (high) energy mode, and measure the beam energy with a power meter.
3. Turn the 532 nm crystal's V adjustment to maximize beam energy.
4. Unlock its half wave plate and rotate it slightly to maximize energy.
5. Repeat the last two steps once or twice, until no additional energy increase occurs.
6. If generating 532 nm or 266 nm light, re-tighten the half wave plate's locking screw. This completes the 532 nm energy maximization.
7. If generating 266 nm or 355 nm light, move the second crystal's H adjustment screw to produce maximum beam energy. This finishes the 266 nm maximization.
8. If generating 355 nm light, rotate the half wave plate slightly to maximize energy.
9. Repeat the last two steps once or twice, until no additional energy increase occurs.



- 10.** Turn off the laser, remove its interlock flag and replace the cover.

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## Chapter IV Maintenance

### A. Cooling system

Circulate water through the cooling system by turning on the laser (turn on the ac power) for ~30 seconds every week when the laser is not in use.

Ensure that the reservoir's water level is always at least 75% full. If the water level is low, top off the reservoir with distilled (not deionized) water. To check, unplug the power supply and remove its cover. Figure 4.1 shows the location of the water reservoir.

The Minilite is shipped without water. Be sure to fill the cooling system upon installation; a water flow interlock prevents operation without water.



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#### CAUTION!

If not using the Minilite for 3 months or more, drain the cooling water and then flush the laser head with methanol.

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#### *Draining and flushing the cooling water, Tower Supply*

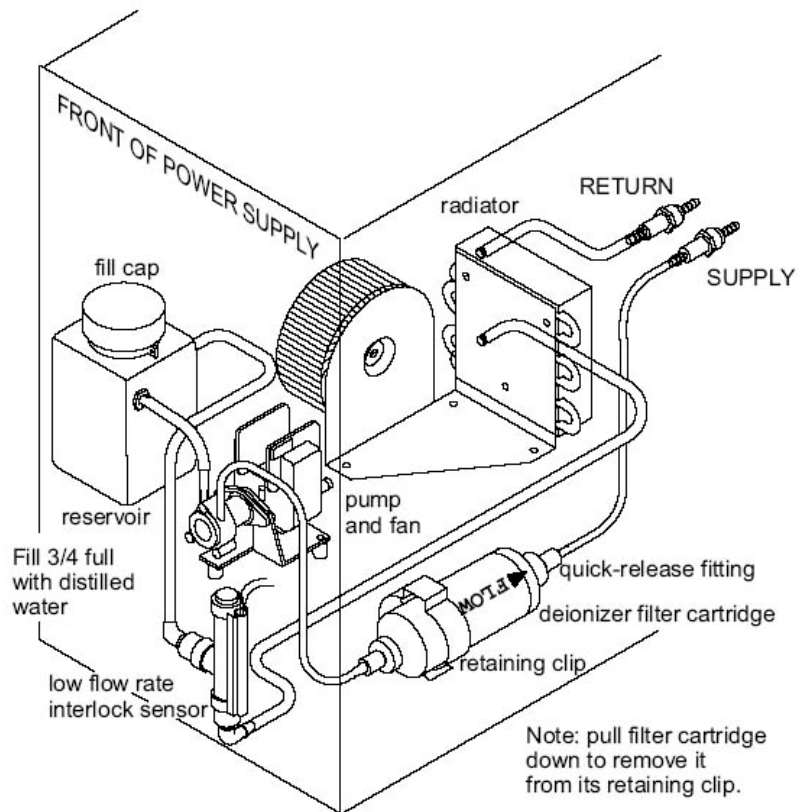
This procedure is for the standard tower power supply. See the following section for the procedure for the rack mount supply.

Drain the cooling system before replacing its deionizer or before storing the laser. Also flush the head with methanol before storage (DO NOT flush DI cartridge with methanol.)

1. Shut down the Minilite, unplug it and close its exit beam shutter.
2. Remove the power supply cover and unscrew the reservoir filler cap (See Figure 4.1).
3. Disconnect the water hose from the power supply RETURN coupling; attach a piece of scrap hose and put its other end in a waste bucket.

4. Plug in the power supply and turn on the ac power to run the cooling pump until no more water appears; turn off the power.
5. Using gentle air pressure (<10 PSI) on the disconnected RETURN hose coupling, blow any remaining water from the laser head into the reservoir.
6. Turn the ac power on again briefly to pump this water away.
7. If storing the Minilite more than 3 months, remove both water hoses from the power supply. Then pour 20-30 ml of methanol into the OUT hose leading to the laser head (tubing and a syringe or a funnel will make adding methanol easier). Follow with gentle air pressure (-5 psi) to blow the solvent out of the head. This methanol flush prevents algae buildup.
8. If refilling, refer to the previous procedure, and also replace the deionizer cartridge (next procedure).
9. Reconnect all water hoses and replace the power supply cover.

Figure 4.1  
Cooling system



### ***Draining and flushing the cooling water, Rack Mount Supply***

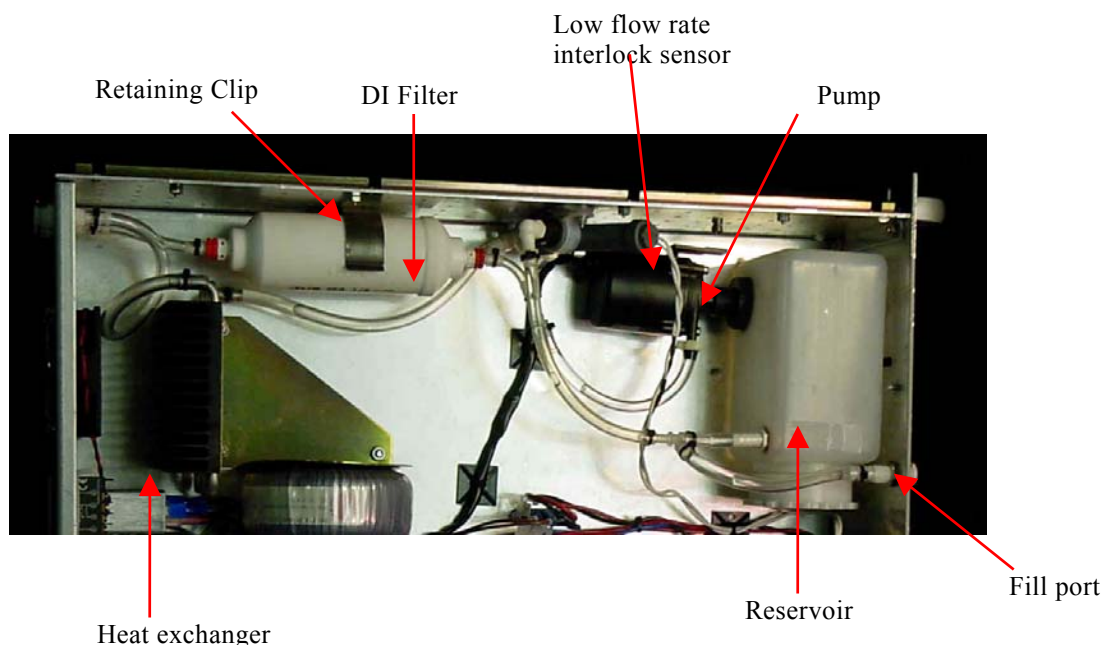
This procedure is for the rack mount power supply. See the preceding section for the procedure for the standard Tower supply.

Drain the cooling system before replacing its deionizer or before storing the laser. Also flush the head with methanol before storage.

10. Shut down the Minilite, unplug it and close its exit beam shutter.
11. Connect a piece of scrap tubing to the fill port on the front panel of the supply (See Figure 4.2).
12. Disconnect the water hose from the power supply RETURN coupling; attach a piece of scrap hose and put its other end in a waste bucket.

13. Plug in the power supply and turn on the ac power to run the cooling pump until no more water appears; turn off the power.
14. Using gentle air pressure on the disconnected RETURN hose coupling, blow any remaining water from the laser head into the reservoir.
15. Turn the ac power on again briefly to pump this water away.
16. If storing the Minilite more than 3 months, remove both water hoses from the power supply. Then pour 20-30 ml of methanol into the OUT hose leading to the laser head (tubing and a syringe or a funnel will make adding methanol easier). Follow with gentle air pressure (-5 psi) to blow the solvent out of the head. This methanol flush prevents algae buildup.
17. If refilling, refer to the previous procedure, and also replace the deionizer cartridge (next procedure).
18. Reconnect all water hoses and replace the power supply cover.

*Figure 4.2*  
*Rack Mount Supply cooling system*



**Replacing the deionizer cartridge**

Replace the deionizer cartridge (p/n 309-0309) and the cooling water every six months. To replace the cartridge;

1. Drain the cooling system (above), but don't replace the cover.
2. Turn the ac power switch off, and then unplug the power supply.
3. Pull down the old cartridge to remove it from its retaining clip. Note float direction arrow.
4. Disconnect both hoses from the cartridge; quick-release couplings secure both of them (push and rotate  $\frac{1}{4}$  turn to release)
  - Remove quick connectors from old DI filter.
  - Install quick connectors on new DI filter. It is advised to replace Teflon tape on QC threads to avoid leaks.
5. Attach the hoses to the new filter and push it into its retaining clip.



---

**Note:**

The cartridge's flow direction arrow should point to the rear.

---

6. Refill the cooling system (next). While running the pump (step 5 of the next procedure), check for water leaks around the new cartridge.

***Filling the cooling system***

Fill the cooling system before beginning operation (see Figure 4.1). To fill:

1. Shut down the Minilite, unplug it and close its exit beam shutter.
2. Remove the power supply cover and unscrew the reservoir's cap.
3. Replace the deionizer cartridge (above).
4. Fill the reservoir up to the cap with distilled (not deionized) water. If empty, this requires ~10 oz (300 ml). Use a syringe or tubing and funnel to minimize spillage.
5. Plug in the power supply and turn the ac power on for one minute to run the water pump. Correct any leaks.
6. If the water level falls below 75% full, unplug the power supply and repeat the last two steps.
7. If the head has been previously flushed with methanol, drain the water again (previous page) and replace it a second time.
8. Unplug the power supply, and then replace the reservoir's cap and the outer cover of the power supply.

***Electrical system***

A power line fuse is installed on the back panel near the power cord. This table gives recommended fuses:

<b>Manufacturer</b>	<b>100-125 VAC (3.0 A)</b>	<b>180-240 VAC (1.6 A)</b>
Bussmann	MDL-4	MDL-2
Littlefuse	313.004	313.002



## **B. Optical maintenance**

Periodically inspect the crystals and coated surfaces of all optical components for dust, discoloration, and damage, and clean or replace them if necessary. Realign the beam (see Chapter III) after replacing any optical element.

### *Tools and supplies*

- Finger cots or surgical or fine cotton gloves
- High intensity flashlight and inspection mirror
- Metric Allen wrenches (supplied)
- Reagent grade (or better) methanol
- Eyedropper
- Lint-free lens tissues and cotton swabs
- Flashlamp

### *Inspecting and dusting optics*

Dust on optical surfaces absorbs laser light and the hot spot will burn the surface. Follow these steps to dust the optics and determine whether an optical surface needs cleaning or a component requires replacement.

1. Turn the key switch OFF and remove the laser and laser head cover.
2. Systematically examine the surfaces of each dichroic, crystal window and half wave plate for dust, fingerprints, discoloration, and burn marks in the surface coating. Also look at the crystals.
3. Use a bright flashlight to light the surfaces and eliminate reflections, and an inspection mirror where needed.
4. Use clean compressed air to clear dust and loose debris on surfaces.
5. Note which components need cleaning and which need replacing. Do not use solvent unless compressed air is inefficient.

### ***Cleaning and replacing optics***

1. Wash your hands and put on gloves or finger cots.
2. Wrap lens tissue on a cotton tipped applicator. Apply a few drops of solvent directly to the tissue; shake off any excess.
3. Swab optic gently with the applicator. Repeat these steps with a drier swab to remove remaining residue.
4. If damage is still visible, order a replacement optic (Table 4.1). Continuum will ship it already mounted. To replace a mounted dichroic, remove the mount from the bench, and unscrew both spring-loaded bolts on the back of the mount. The plate with the optic will come free, as will a 4 mm ball bearing. When replacing the new plate, be sure to re-install the ball bearing (See Figure 3.4).

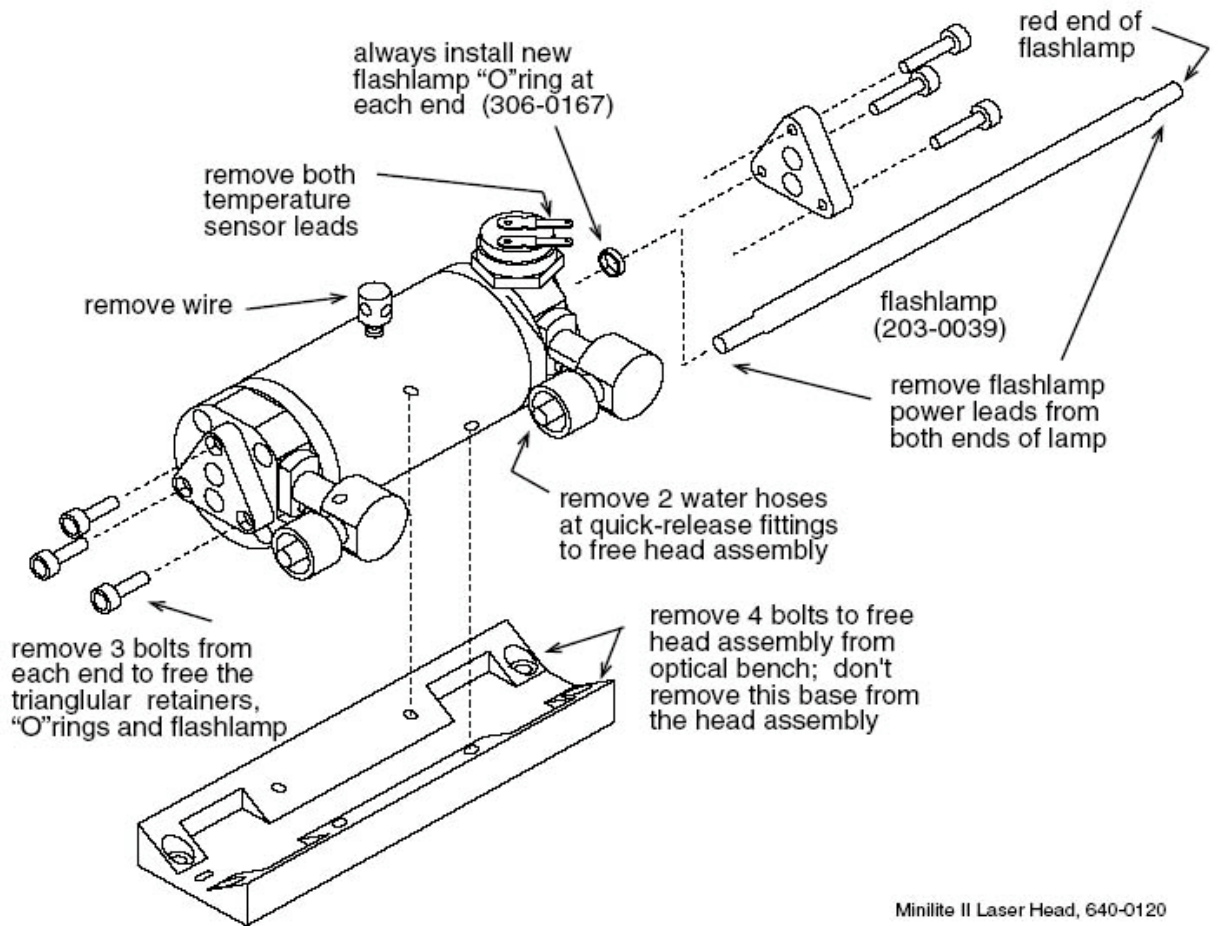
### ***Replacing the flashlamp***

Replace the flashlamp (p/n 203-0041, “O”rings are p/n 306-0167) after about 30 million shots, or if output beam energy has fallen below an unacceptable level or firing has become erratic.

1. Drain the cooling system water (see the first page of this Chapter).
2. Unplug the laser’s ac power cord, and then remove the laser head cover.
3. Remove the cooling system hoses from the head (Figure 4.3).
4. Remove 5 wires from the laser head assembly (Figure 4.3):
  - 4a. Pull the red and black flashlamp leads up to remove them; one is at each end of the head, encased in a square white insulator.
  - 4b. Slip the thick red wire at the top center of the head out of its connection post.

- 4c.** Remove the two thin wires from the head temperature sensor, located on top of the head.
- 5.** Remove the four recessed bolts that secure the Marx Bank PCB from the optical bench, and then remove the four more bolts, which hold the head assembly to the optical bench. Remove the two wires to the Pockels cell, the PCB, and finally, remove the head assembly.
- 6.** Remove the three bolts from each triangular end piece and slide the end pieces off the head assembly.
- 7.** Slide the flashlamp forward to remove it from the head. Note which end of the head has a red mark; it should be the end connected to the red flashlamp lead. Also be sure to remove both flashlamp “O”rings, on at each end of the head assembly.
- 8.** Wearing finger cots or clean white cotton surgical gloves, clean the new flashlamp with methanol on a tissue.
- 9.** Install the flashlamp with its red mark oriented properly (Figure 4.3).
- 10.** Slip a new “O”ring on each end of the lamp, and re-attach the triangular end pieces.
- 11.** Bolt the head assembly onto the optical bench then bolt the Marx Bank onto the bench.
- 12.** Re-connect the five wires: thin pair to the temperature sensor, the two flashlamp leads at the ends, and a thick red wire at top center.
- 13.** Re-connect the water hoses and refill the water reservoir.
- 14.** Plug in the power supply, turn the key switch on and turn on the key switch to start the cooling system pump.
- 15.** Look for leaks around the laser head. If no leaks occur, turn the key switch off and replace both covers.
- 16.** Restart the laser and examine the beam about 500 cm from the exit port. If the beam seems to be clipped, realign beam in LOW ENERGY mode (see Installing optics and dichroics in Chapter III)

Figure 4.3  
Flashlamp details



Minilite II Laser Head, 640-0120

**Table 4.1**  
**Selected Minilite part numbers**

NAME	P/N	OUTPUT
1064 nm dichroic	640-1020*	All
532 nm crystal	640-1110*	All but 1064
355 nm crystal	640-1210*	355 only
266 nm crystal	640-1310*	266 only
532 nm dichroic (2)	640-1120*	532 only
355 nm dichroic (2)	640-1120*	355 only
266 nm dichroic (2)	640-1320*	266 only
Attenuator option, with waveplate	640-1800*	All
Deionizer filter	309-0309	All
Flashlamp	203-0041	All
Flashlamp "o" rings (2)	306-0167	All

\* an assembly which includes the optic and its mount

## Chapter V Troubleshooting



### WARNING!

Do not operate the laser with the covers of the laser head or power supply removed. Laser radiation and/or high voltages are present inside of the laser head and power supply. If after following the guide below, the laser still does not function, contact Continuum for assistance.

If beam energy is low or beam shape is clipped refer to Installing optics and dichroics and Maximizing beam energy in Chapter III.

### If the laser fails to operate, check the following:

1. Is the laser head's high voltage cable and Q-switch trigger cable both properly attached to the power supply?
2. Are both the AC POWER switch and the key switch on?
3. Is the power supply fuse OK?
4. Are both INT/EXT switches on the top rear of the power supply back panel OFF?
5. Is the KEY SWITCH RESET LED on? Cycle the key switch off, then on again.
6. If no external interlock is used, is the shorting Molex plug installed in the INTLK socket (on the back of power supply) in place?
7. If an external interlock is utilized, is its switch closed?
8. Is there adequate water in the cooling system? Are there kinks in the water hoses?
9. Is the laser head cover properly installed, engaging the cover interlock?
10. Is the yellow INTERLOCK LED on? If so, recheck all interlocks:

Laser Head:	Cover removed or not tight Rod Temperature too high
Power Supply:	Water flow low

External interlock: Door open or other switch open

## Chapter VI Theory

### A. Pulsed Nd:YAG lasers

The Minilite uses traditional flashlamp pumping. Distilled water cools the lamp and gain medium, reducing thermal lensing. When electrically pulsed, the lamp emits light which excites the Nd:YAG gain medium.

Similar to a capacitor storing electrical energy, the Nd:YAG rod absorbs the flashlamp's optical energy. Neodymium atoms that have been excited to a higher electronic state (the lasing level) store this energy. These atoms remain excited for a fraction of a millisecond before spontaneous emission starts.

In the absence of Q-switching, spontaneous emission (lasing, or light amplification through stimulated emission) begins as soon as the cavity gain overcomes its losses. The duration of this spontaneous laser pulse is almost as long as the driving lamp pulse. This non Q-switched pulse has high energy, but its peak power is low, because of its relatively long width. The Minilite Q-switch improves performance by both increasing the amount of energy stored in the rod and by preventing or delaying spontaneous emission.

While closed, a Q-switch in the laser cavity introduces an additional loss and blocks spontaneous emission, allowing the number of excited atoms in the rod to build further. When instantaneously opened, it releases the cavity's stored energy in a shorter pulse with both higher average and peak power.

### B. Q-switching

A crystal, quarter wave plate and a horizontal polarizer, placed in the laser cavity between its end mirrors, comprise a Q-switch. The lamp pumps the gain medium while the Q-switch is closed (there is no voltage applied to its crystal, and the crystal does not rotate light.) While closed, light exiting the rod cannot return to stimulate spontaneous emission, and the rod stores more energy. Vertically polarized light exiting the gain medium never returns; it is always blocked by the horizontal polarizer. When the Q-switch is closed, it also blocks horizontally polarized light: this light passes unchanged through the horizontal polarizer and the crystal, then rotates  $45^\circ$  transiting the quarter wave plate. On its return path, it rotates another  $45^\circ$ . Now vertically polarized, the horizontal polarizer prevents it from reentering the rod.

After maximum storage occurs (about 200 microseconds after the lamp begins pumping), the Q-switch opens: a Marx bank suddenly applies a high voltage to the crystal. When so energized, the crystal now rotates the light another  $90^\circ$  ( $45^\circ$  in each direction through the Q-switch). Horizontally polarized light now rotates a total of  $180^\circ$ , so it retains its polarization traveling through the Q-switch, and can reenter the laser rod. This light is now free to oscillate between the cavity end mirrors. During these oscillations, the light increases in energy by extracting the energy stored in the gain medium. The resultant laser pulse is 5-6 nanoseconds long, with high peak and total power.

### C. Harmonic generation

The Minilite can produce laser light at other frequencies besides the natural, or fundamental frequency of its Nd:YAG gain medium. In some crystals, a non-linear process known as harmonic generation produces additional frequencies which are multiples (double, triple, quadruple, etc.) of the fundamental. Since the Minilite's fundamental is 1064 nm, its second, third, and fourth harmonics are 532, 355 and 266 nm, respectively.

For a crystal to be suitable for harmonic generation, it must transmit both the fundamental and the harmonic it produces, withstand high peak intensity laser beams without damage, and convert the fundamental to the harmonic efficiently. The Minilite employs KTP and BBO crystals, widely known for their suitability, for harmonic generation. Simply replace a crystal to change the Minilite's output frequency (Chapter III).

Non-linear materials transmit light at differing speeds, depending on the light's angle to the crystal's non-linear axis and on the light's polarization relative to that axis. This second property is called birefringence.

During doubling, two 1064 nm photons enter the crystal collinear and with the same (circular) polarization. This would allow the two photons to combine into a single photon, provided that the resulting photon conserves both energy and momentum. A combined (doubled) photon with doubled frequency satisfies energy conservation. Angular momentum conservation gives the output photon a different (vertical) polarization. Momentum conservation requires the combined photon to have the same velocity as the incoming photon pair. In the non-linear crystal, there is a particular angle (the phase matched angle), at which the crystal's birefringence equalizes the velocities of the input photons and the differently polarized combined photon. Satisfying these three conservation conditions permits doubling, provided that the two input photons enter the crystal close together. The high peak power of the



Minilite generates a sufficiently large photon density inside the crystal for efficient doubling to occur.

Tripling (third harmonic generation) is a similar process, except that one photon of the fundamental combines with one photon of doubled light. The output of a doubling crystal contains these necessary two photons. This twin beam enters another crystal, where the two different photons combine (mix). The resulting photon's energy (355 nm) is the frequency sum of the two mixed photons ( $1/355 = 1/1064 + 1/532$ ).

Quadrupling is simply a two-stage doubling process: the 532 nm output of the doubling crystal enters a second doubling crystal, where it doubles again.

#### **D. Output beam polarity**

The Minilite's fundamental (1064 nm) output beam is always horizontally polarized. Each harmonic crystal rotates the beam polarity 90°, giving the second harmonic beam vertical polarity. Since both the third and fourth harmonic require a second crystal, these output beams have horizontal polarization. The Minilite PIV's 532 nm beam is circularly polarized.

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## Chapter VII Warranty

### A. Express warranty

Unless otherwise specified, all mechanical, electrical and electro-optical components are warranted to be free from defects in materials and workmanship for 1 year after delivery to the FOB point. Optics, crystals and flashlamps have a 90-day warranty.

This warranty is in lieu of all other warranties, express or implied, and no warranties of Merchantability or fitness or any other remedies are available.

### B. Limitations

This warranty's remedy is limited to repair or replacement of the defective materials, and depends on these conditions:

- This warranty does not apply to materials that have been damaged by abuse, misuse, mishandling, accidental alteration, improper operation, negligence or other conditions not under Continuum's control.
- This warranty does not apply if the original identification markings have been removed, defaced or altered, or if modifications or substitutions have been made without Continuum's prior consent.
- This warranty does not apply if the Customer's account is delinquent.

### C. Returns, adjustments and servicing

To request any warranty or other repair or service to any Continuum product:

- Obtain a return authorization number from our Service Dept.

- Package properly in the original shipping container. Drain any water from the cooling system. Pre-pay freight and full-value insurance, and assume all risks of loss, damage, or delay in shipment.
- Continuum will examine the received laser to determine the cause of failure and warranty status, and is not obligated to perform a warranty repair if shipping damage obscures whether the warranty defect existed.
- The warranty period on a repaired or replaced product is the remainder of the product's original warranty period. If the product is not under warranty, Continuum will advise the customer of repair charges and require a written purchase order for repairs before work begins.

## D. Continuum service centers

**[www.continuumlasers.com](http://www.continuumlasers.com)**

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## Notes

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## Chapter VIII Minilite PIV

### A. Particle Image Velocimetry

Particle Image Velocimetry (PIV) is a powerful method for monitoring complex velocity distributions in complex media. Typical applications include shear and laminar flows, exhaust plumes, and vehicular and aircraft airflows.

The PIV process compares two images, separated in time, from a scatterer injected into the airflow distribution. A Q-switched, pulsed Nd:YAG laser beam, shaped by cylindrical optics, produces a sheet of light which illuminates a cross-section of the flow medium.

Photographic film or a CCD camera is used to capture two consecutive images of the scatter passing through this cross section. This “double exposure” captures a wealth of information on the scattering particles’ velocities. The recorded data is deconvoluted using several correlation integrals, achieving a complete two dimension velocity vector field for large flow areas.

### B. Minilite PIV overview

#### *PIV systems*

Continuum’s Minilite PIV systems are designed for stability, beam quality, and variable pulse separation. The Minilite PIV contains two Minilite laser heads mounted on a stable, compact laser bench. Optics on the same bench combine a pulse from each laser to pass through a single KTP frequency doubling crystal, creating two 532 nm pulses with nearly identical energy, beam uniformity and polarization. Dichroic mirrors then remove the undoubled residual beams. Separation times between the pulses may vary over a wide range, from 40 ns up to 100 ms. Minilite PIV lasers maintain long-term energy and excellent beam pointing stability.

#### *Beam quality*

PIV requires that the dual pulses have the same spatial overlap, energy and symmetry. Each PIV system leaves the factory with each laser pulse matched in energy and beam quality. Extensive long-term stability testing ensures that performance remains optimized.

### Stability

A solid mechanical design is the key to the Minilite PIV's stability and overall reliability. A decoupled Invar mount holds each resonator securely, isolated from thermal and mechanical stress.

### Ease of use

All PIV systems feature two digitally controlled power supplies, which gives push-button access to all system parameters. Timing outputs synchronize PIV pulses to other events. Independent power supplies for each laser provide easy control of the PIV system, and the TTL interface allow flexible external control.

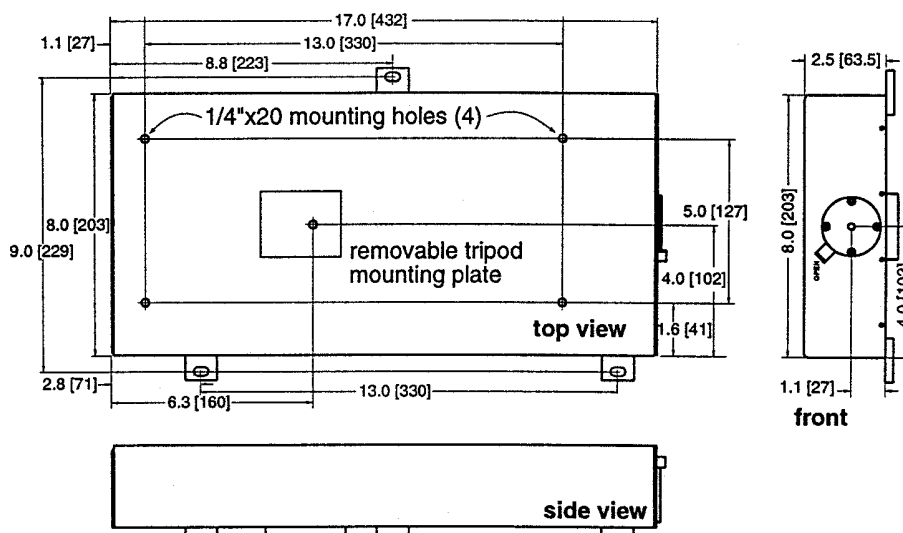
### Safety

Safety interlocks continually check for proper cooling water flow and temperature.

### Lifetime

Minilite PIV systems run at low output power levels. Reduced power operation means longer lifetime for key components: rods, lamps and power supplies last longer because of reduced stress.

Figure 8.1  
Minilite PIV dimensions

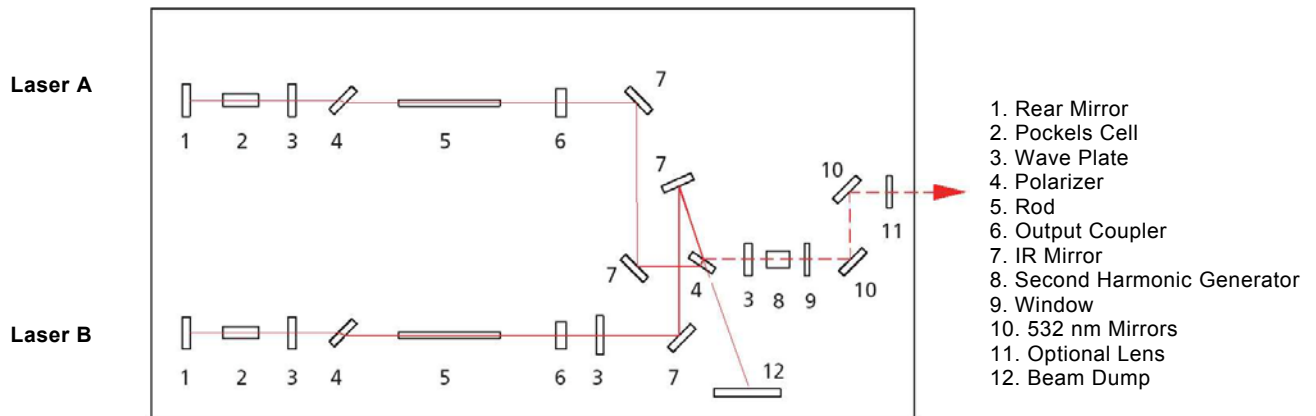


## C. PIV optical description

Figure 8.2 shows the Minilite PIV optical layout. Two 1064 nm fundamental Nd:YAG laser beams are first superimposed on a common optical axis, passing through a single doubling crystal. 532 nm dichroics then separate the two green output pulses from residual 1064 nm light.

The beam from laser A defines this common optical axis. Horizontally polarized, it passes directly through the beam merger, a dielectric polarizer (4), which combines this beam with the second laser's output.

Figure 8.2  
Minilite PIV optical layout



Half waveplate (3) gives the fundamental output of laser B vertical polarization so that the dielectric polarizer (4) superimposes the beam into the horizontally polarized beam path. Mirrors (7) optimize this overlap. The quarter waveplate (3) then gives both beams circular polarization. Because they now have the same polarization, the doubling crystal (8) converts them equally to the second harmonic. A pair of dichroics (10) now removes the unconverted 1064 nm and steers the 532 nm vertically polarized output beam.

## D. PIV operation

### *Startup*

1. Place a power meter in the output beam and open the exit shutter.



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#### **WARNING!**

Be sure to wear goggles and observe all safety procedures. Read the detailed safety instructions in the front of this manual and follow them.

---

2. Set both lasers' FLASHLAMP and Q-SWITCH switches (Chapter II) to INT.
3. Turn on both lasers and allow them to warm up for at least five minutes at 10 Hz or the desired final repetition rate. Follow the Startup instructions in Chapter III.
4. Check each beam's energy separately. If both beams' energy are similar but low, perform the Maximizing harmonic power procedure in Chapter III.
5. Place a target 3-5 m from the PIV and check beam overlap by firing the lasers individually. Perform Beam overlap (next page) if needed.
6. Turn both lasers to EXT mode (either FLASHLAMP or Q-SWITCH or both), depending on whether you are providing external TTL signal to fire the flashlamps, open the Q-switches, or both (see this chapter).
7. Begin sending the external pulse sequences to both lasers.
8. Check both beam energies again and perform the Beam power balance procedure if desired (next page).
9. Check the time between the laser pulses and adjust if desired.
10. Begin PIV operation.

### ***Shutdown***

1. Turn off both lasers and close the output shutter; refer to Chapter III.
2. Turn off the timing pulse generator.

## **E. Dual beam overlap and power balancing**

### ***Adjustable optics***

Laser B beam steering mirrors (2) and (3), and output steering dichroics (7) and (8) all use the same mounts. Each mount has vertical and horizontal adjustments (see Figure 3.4).



---

**Note:**

It is unnecessary and undesirable to move the waveplates (1, 5), the dielectric polarizer (4) or the beam A steering dichroics (9,10) for any reason.

---

### ***Beam overlap***

Beam alignment involves steering optics (2), (3), (7) and (8) only.

1. Warm up both lasers ~5 minutes and switch both to LOW power.
2. Fire laser A at 10-15 Hz and set laser B to single shot operation.
3. Center a 1 mm pinhole on the beams ~20 mm in front of the PIV and set a target at least 3 m from the laser.
4. Steer the green laser A beam to the PIV target with dichroic (7) while keeping the beam centered on the pinhole with (8).

5. Set laser A to single-shot mode, fire laser B at 10-15 Hz, and steer the laser B beam to the target with dichroic (3) while keeping the beam centered on the pinhole with dichroic (2).
6. Turn both lasers off and remove the target and pinhole.

### ***Beam power balance***

PIV requires that both laser pulses have the same energy. Beam energy is a function of the time interval between flashlamp firing and Q-switch opening (“Q-switch delay”).

## **F. PIV pulse timing**

The External Control section (Chapter III) describes fully how to control flashlamp firing and Q-switch opening of a Minilite with TTL signals. For PIV operation, you must control two Minilites simultaneously. There are several strategies to follow, using either external TTL signals and/or internal laser system signals. Remember that the PIV’s internal signals have jitter of 1-2  $\mu$ sec, while your TTL signals can easily be accurate to  $\pm 1$  nsec.



---

### **Note:**

Remember that for external TTL signals to control a flashlamp or Q-switch, its corresponding INT/EXT switch must be on EXT. TTL signals are 0 to +5 Vdc, 10-20  $\mu$ sec wide pulses.

---

### ***Total flexibility***

For maximum flexibility, you may supply four separate TTL signals, firing both flashlamps and opening both Q-switches independently. This method allows complete control of both Q-switch delays for more ways of balancing pulse energies. In addition, this method allows separating the PIV pulses by an arbitrarily long time. To use this method, all four INT/EXT switches must be in the EXT position.

### ***Simultaneous flashlamps***

If you wish, you may use a “Y” shaped BNC cable to send one TTL signal to fire both flashlamps. This requires three TTL signals for timing; one for both flashlamps and two more for the Q-switches. Now, balancing beam energies and choosing beam delays are interdependent, with adjustments become more difficult with larger pulse separations ( $>20 \mu\text{sec}$ ). For short separation times, this method is as flexible as separate control of both flashlamps. Again, all four switches must be set to EXT.

### ***Internal flashlamp control***

With a flashlamp switch in the INT position and its corresponding Q-switch setting on EXT, the flashlamp will fire at the selected repetition rate. You may allow one flashlamp to fire at its normal repetition rate, using its FLASHLAMP SYNC OUT signal to fire the other flashlamp and synchronize the Q-switch control signals you generate.

### ***Internal control***

To eliminate the need for any external TTL signals, you may keep one flashlamp in INT and use its FLASHLAMP SYNC OUT signal to fire the other flashlamp (in its EXT mode) at the same time. By using both lasers' Q-switch delay adjustment pot (see Figure 2.1 and “Q-switch delay lowers power” in Chapter III), you may choose different Q-switch opening times. This method will have high jitter (1-2  $\mu\text{sec}$ ), and will also affect pulse energies. It may be a convenient method when pulse separations are  $<20 \mu\text{sec}$  and a few  $\mu\text{sec}$  of jitter are acceptable.

### ***Maintaining PIV optics***

Periodically inspect the crystal and surfaces of all PIV optical components for dust, discoloration, and damage. Cleaning or replacing them, if necessary, will promote good system performance and longer lifetime. See Optical maintenance in Chapter IV for details.

---

#### **Note:**



When cleaning the dielectric polarizer or a waveplate, only clean the center of the optic. If solvent reaches the edge of the optic, it may

dissolve mounting glue, contaminating the optic. Do not apply pressure during cleaning, for these optics are thin and delicate.

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### ***Replacing the SHG crystal***

The SHG (doubling) crystal is sealed in its mount, and damage to a crystal face can be seen through the windows. If damage is visible (see Inspecting and dusting optics, Chapter IV), Continuum recommends returning the entire assembly for repair. To replace the crystal assembly:

1. Turn both lasers off and bolt the new crystal mount (Figure 3.4) into position. With either laser firing in LOW mode, center the beam on the input window (5). Use an IR viewing card to see this beam.
2. Center the beam in the exit window by rotating the mount; use a business card to see the green beam.
3. Recheck the input window alignment and tighten the mount.
4. Phase match the crystal (see Maximize harmonic energy, Chapter III).



<b>Table 8.1 PIV Optical Parts</b>			
<b>Item #</b>	<b>P/N</b>	<b>Description</b>	<b>Use</b>
1	108-0004	½ plate	Vertically polarizes beam B
2	105-0199	1064 nm dichroic, 45°	Steer beam B onto beam combiner (4)
3	199-0235	1064 nm dichroic, 90°	
4	199-0131	Dielectric polarizer	Combines beam A&B
5	199-0004	½ plate	Circularly polarizes both beams
6	202-0174	SHG Crystal	Converts 1064 nm to 532 nm
7, 8	105-0200	532 nm dichroic	Steer 532 nm output beams
9, 10	105-0199	1064 nm dichroic, 45°	Steer beam B to beam combiner
11	640-1110	SHG assembly	Includes window (13), crystal (6), waveplate (5) & adjustment mount
12	314-0277	Beam dump	Safety feature
13	110-0084	SHG exit window	Controls crystal humidity