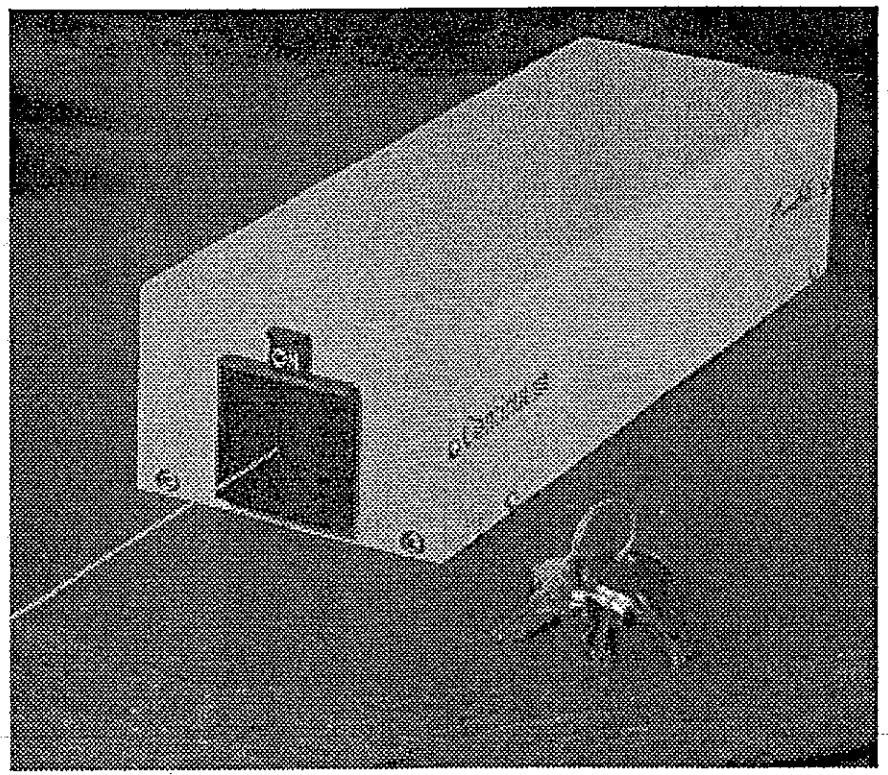
January 23, 1996
Part Number 996-0201
Revision B

MINILITE

Nd:YAG Laser



User Manual

Continuum

Minilite

Minilite-10

Wavelength	1064nm	532nm	355nm	266nm
Energy	25mJ	10mJ	4mJ	2mJ
Peak Power	5MW	2.5MW	1MW	0.5MW
Average Power	250mW	100mW	40mW	20mW
Pulsewidth	5-7ns	4-6ns	4-6ns	4-6ns
Jitter	<1nsec			
Beam Size	<3mm			
Divergence	<3mrad			
Repetition Rate	10Hz			

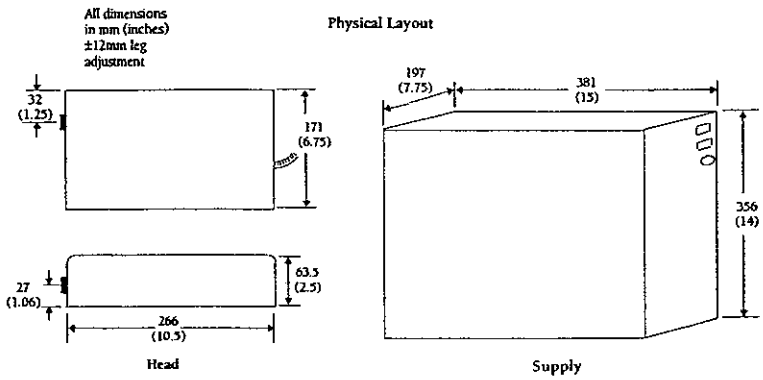
Minilite-20

Wavelength	1064nm	532nm	355nm	266nm
Energy	25mJ	10mJ	4mJ	2mJ
Peak Power	3.5MW	1.6MW	0.8MW	0.4MW
Average Power	500mW	200mW	80mW	40mW
Pulsewidth	6-8ns	5-7ns	4-6ns	4-6ns
Jitter	<1nsec			
Beam Size	<3mm			
Divergence	<3mrad			
Repetition Rate	20Hz			

Option	Description
Minilite	Pulsed Q-switched Nd:YAG laser, 1064nm operation
MD	Second harmonic crystal, 532nm output
MD, MT	Second and third harmonic crystals, 532nm or 355nm output
MD, MQ	Second and fourth harmonic crystals, 532nm or 266nm output
MD, MT, MQ	Second, third and fourth harmonic crystals, 532, 355 or 266nm output

10/20Hz Minilite Package Dimensions

Dimensions (L x W x H)	Head	10.5 x 6.75 x 2.5in (266 x 171 x 63.5mm)
	Supply	15 x 7.75 x 14in (381 x 197 x 356mm)
Weight	Head	3.6kg (8lbs)
	Supply	14.5kg (32lbs)
Utilities	110V (4A) or 220V (2A), 50/60 Hz	
Water	Closed loop cooling	
External trigger	TTL	



HOYA-Continuum, 23-2 Sakamachi Shinjuku-ku, Tokyo 160 Japan Tel: 33 353 5320, Fax: 33 353 6673, e-mail: ssalehcc@marinet.or.jp
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Section 1 Laser Safety

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.

BECAUSE THE 1064, 355 AND 266 NM OUTPUT BEAMS OF AN Nd:YAG LASER ARE INVISIBLE, THEY ARE 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.

AVOID EYE AND SKIN EXPOSURE TO DIRECT OR SCATTERED RADIATION.

General safety rules

- Located 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.

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.

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.
- 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.

Safety Features

Interlocks

The Minilite has interlock switches which stop it from firing when

- Laser head temperature is too high
- Laser power supply temperature is too high
- Laser power supply cover is open
- Laser head cover is open
- Cooling system flow too is low
- An external interlock (if installed) is open.

All interlock circuits must be closed before the Minilite will fire. If any of them or an external interlock are open, the red INTERLOCK LED will be on (some Minilites are equipped only with the last three interlocks).

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

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 Z136.1-1986) 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.

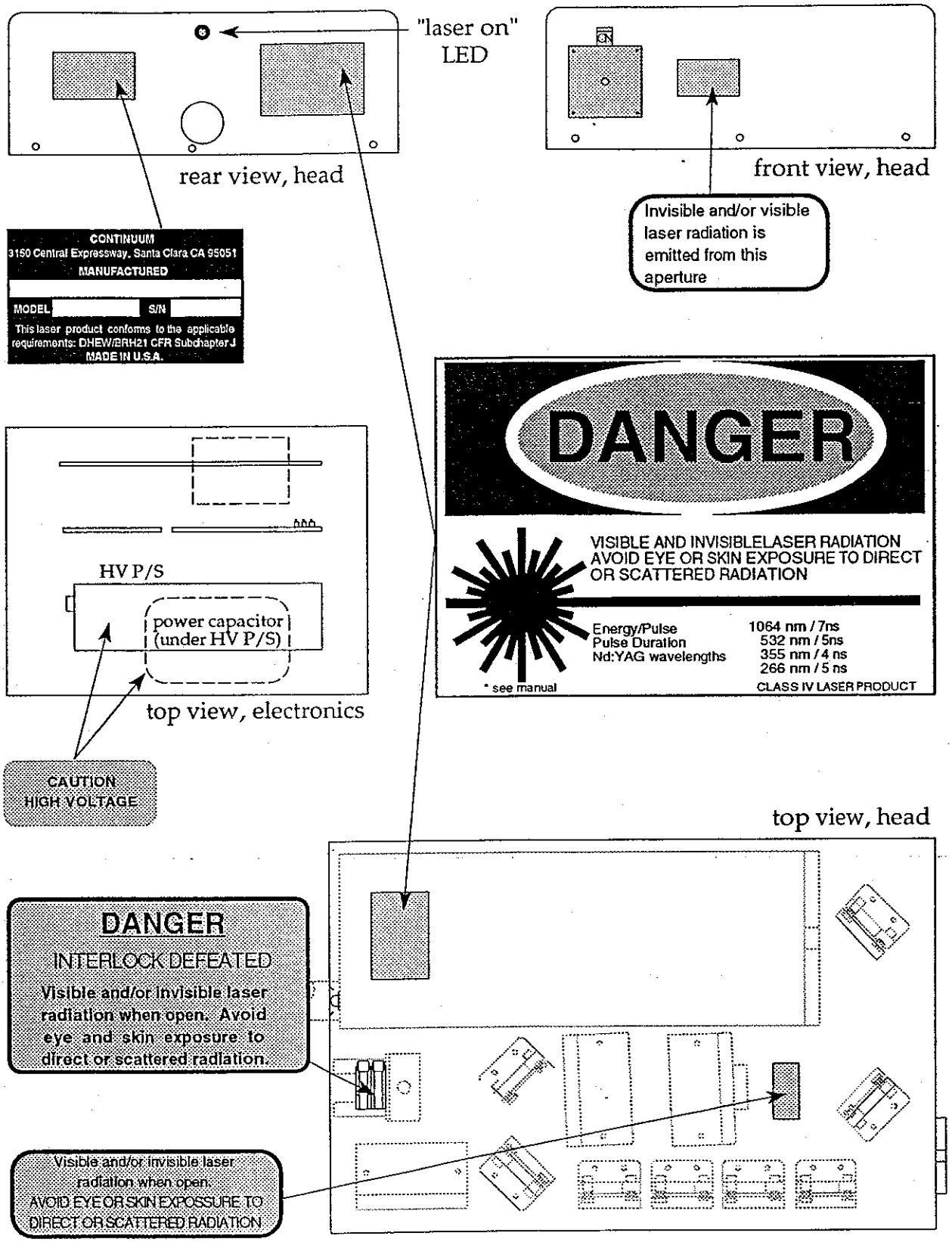
Continuum's user information complies with section 1040.10 of 21 CFR Chapter I, Subchapter J concerning Radiological Health published by U.S. Department of Health & Human Services Center for Devices & Radiological Health, 1988.

Laser Institute of America
12424 Research Parkway, Suite 130
Orlando, FL 32826
(800) 345-2737

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.
- *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.

Figure 1.1 Safety labels and their locations



The Center for Radiological Health, Office of Compliance, requires this drawing.

Section 2 Installation

DANGER

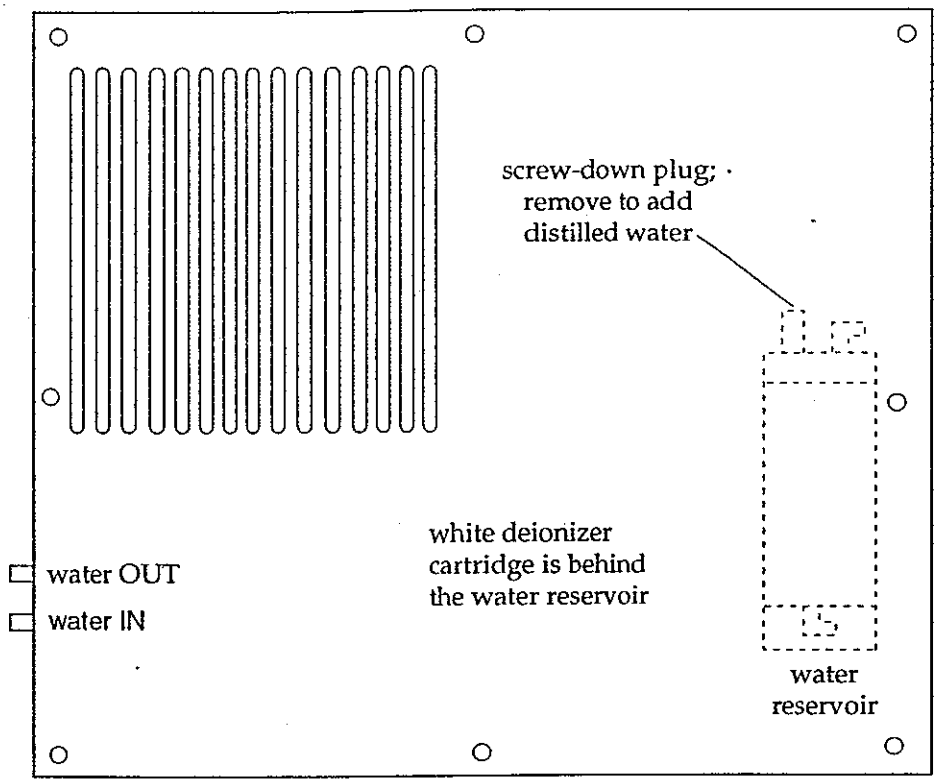
HIGH VOLTAGE AND CURRENT

The laser head and power supply contain LETHAL VOLTAGES AND CURRENTS. Do not attempt to operate the laser with the power supply cover or laser head cover removed. For service, contact: Continuum, 3150 Central Expressway, Santa Clara CA 95051 (408-727-3240)

Installation checklist

1) **Prepare the site for the laser;** refer to Section 1 safety rules.
2) Inspect the crates upon arrival for shipping damage and notify the shipper if any damage is visible.
3) **Unpack the system** and check that all parts are present as listed in the packing list. Notify Continuum customer service if any parts are missing. If any damage is found, notify 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,** again referring to safety issues (Section 1).
6) **Connect the umbilical cord** to the power supply and engage its tightening screws.
7) **Connect the two water lines** (in the umbilical cord) to the power supply nipple; twist the white hose connectors 1/8 turn to secure the lines.
8) **Fill the cooling water reservoir** (see Section 4, Maintenance).
9) **Remove any packing material** around or under the cooling fans in the power supply.
10) **Install an external interlock (optional):** Wire a switch to the EXTERNAL INTERLOCK BNC connector on the rear of the power supply. When this switch is open the Minilite will not fire. Use switches and wiring rated 50 volts ac at .1 A.
11) **Plug in the power supply.** The Minilite requires a single 15 amp ac outlet, 50 to 60 Hz. The power supply has been factory preset for either 100 - 125 Vac or 180 - 240 Vac single phase.

Figure 2.1 Cooling system



left side of Minilite electronics module

Section 3 Operation

Startup

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

CAUTION:

To prevent algae from growing in the cooling system, run the laser at least 15 minutes/week (perform the first 5 steps of this startup procedure). If you will not run the laser for more than 3 months, drain the cooling system and flush the laser head with methanol; see Draining the cooling system, *page 19, for details.*

1) Close the shutter on the front of the laser head.
2) Set the ENERGY HI/LOW switch on LOW.
3) Turn the key switch to the ON position.
4) Set the Trigger Selector switch to the START position.
5) Hold down the green ON button until the red INTERLOCK LED is off and the EMISSION LED is on. (After the red EMISSION LED lights, there is a 10 second delay before laser pulsing can occur.
6) Use the Trigger Selector switch to select the desired operation mode:

   EXT for single shot operation from the front panel via the remote single shot cable, or for multi-shot operation using the FIRE LASER BNC on the rear panel.

   10 Hz to fire the laser continuously at 10 Hz (10 Hz models only)

   20 Hz to fire continuously at 20 Hz (20 Hz models only)
7) Open the exit shutter; low power laser light will now exit the laser head. Verify the beam is correctly aligned after leaving the laser.
8) No further adjustment to the laser is necessary. Set the ENERGY HI/LOW switch on HI when ready to operate safely (see Section 1).

Shutdown

1) Push the OFF button.
2) Close the exit shutter.
3) Turn the key switch to the OFF position. The laser is now off.
4) Remove the key to prevent unauthorized use.
5) If shutting off the Minilite for more than 3 months, please drain the cooling system and flush it with methanol to prevent algae buildup; see *Draining the cooling system* on page 22 for details

Firing the Minilite

Firing at 10 Hz or 20 Hz

When the Trigger Selector is in the 10 Hz position (20 Hz position on the 20 Hz model) the Minilite will fire steadily at 10 Hz (or 20 Hz).

Single shot external operation

The Minilite may be fired remotely (single or multiple shots) when the Trigger Selector is in its EXT position:

For single shot operation, connect the remote single shot cable to the front panel PULSE BNC. Pushing the button fires the flashlamp and after a few milliseconds' delay the laser will fire.

Multiple shots

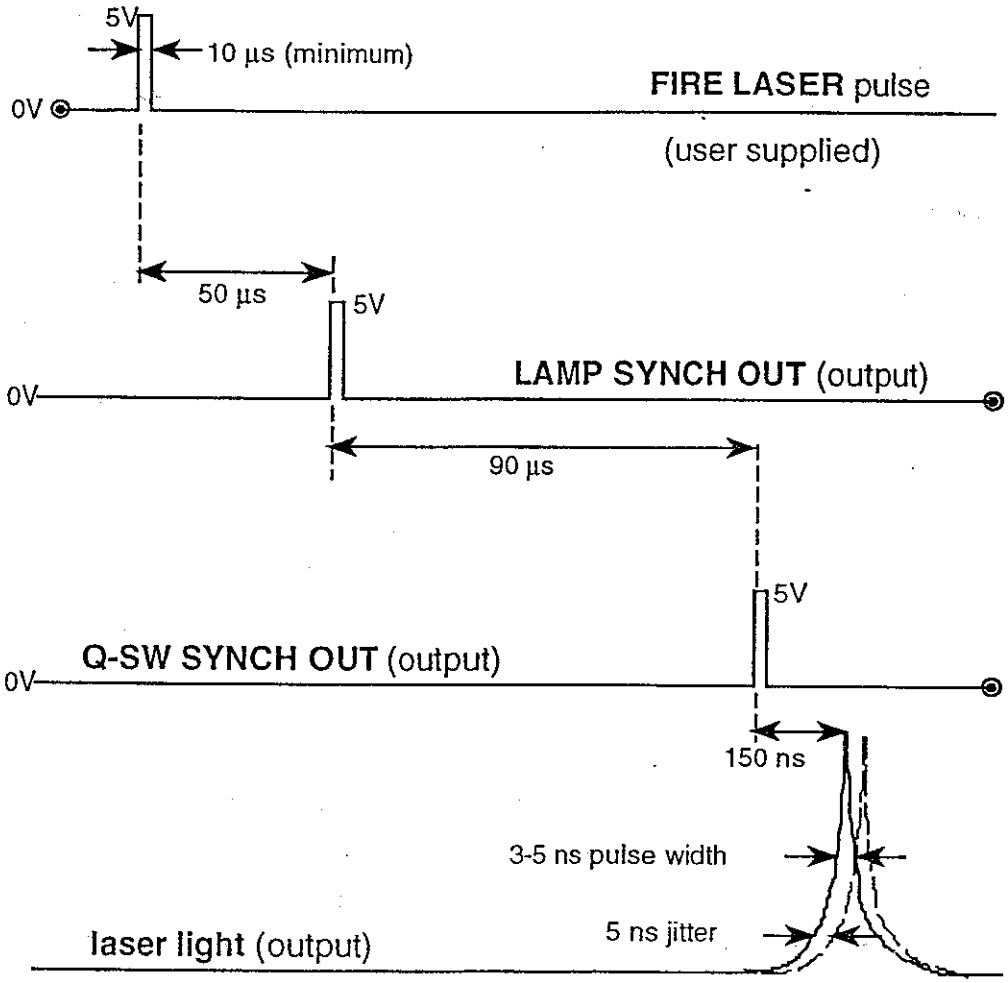
The Minilite power supply has 3 BNC connectors on the rear panel for external control (see Figure 3.2). A TTL pulse (0 to +5 Vdc at up to 10 Hz) sent to the "FIRE LASER" input BNC will fire the Minilite flashlamp and send a pulse to the "LAMP SYNCH OUT" BNC. When the laser fires, pulses will appear on the "Q-SW SYNCH OUT" BNC. Both these outputs are available to use for synchronizing the firing of the laser with other equipment. Figure 3.0 diagrams the relationship between the external firing signal and the Minilite responses.

FIRE LASER (input)	+5 volt, ≥20 µsec input pulse fires the flashlamp at up to 10 Hz (20 Hz on 20 Hz models).
LAMP SYNCH OUT	+5 volt, 20 µsec nominal pulse. Positive pulses (0 to +5V) appear when the flashlamps fire.
Q-SW SYNCH OUT	+5 volt, 20 µsec nominal pulse; Positive pulses (0 to +5V) appear when the Q-switch fires.

Low power operation

When the ENERGY HIGH/LOW switch is in the LOW position, the laser pump lamp is reduced in intensity, producing an output beam with <10% of normal power. Use this mode for external alignment of the Minilite's output beam.

Figure 3.0 Timing pulse sequences



Note: all timings are approximate.

This timing diagram shows the relationship between the pulse or pulse train sent to the rear panel FIRE LASER BNC, and the Q-SW SYNCH OUT and LAMP SYNCH OUT pulses supplied by the laser for synchronization of external events to the Minilite.

Generating harmonics

The Nd:YAG Minilite laser produces vertically polarized infrared light at 1064 nm. Optional non-linear crystals in the beam can double, triple, or quadruple the frequency of this Minilite fundamental, resulting in 532 nm, 355 nm or 266 nm light, respectively. These crystals, or harmonic generators, do not convert all of the fundamental beam to their harmonic, so the Minilite uses dichroics (a pair matched to each crystal's output harmonic) to separate the harmonic beam from the fundamental.

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

Tools needed

- Safety glasses
- Red fluorescent paper
- Burn paper
- Metric Allen wrenches
- Power meter with energy absorbing head.

Crystals and dichroics combinations and their output beam polarities

This table gives the combinations of crystals and dichroics needed to generate 532 nm, 355 nm and 266 nm light (refer to Figure 3.3 for the locations of positions 2 and 3 as well as part numbers).

CRYSTALS AND DICHROICS CREATE VARIOUS HARMONICS OUTPUTS AND POLARIZATIONS

output beam	crystal in position 2	crystal in position 3	dichroics needed	output beam polarization
1064 nm	none	none	MD	vertical
532 nm	MD	none	MD	horizontal
355 nm	MD	MT	MT	vertical
266 nm	MD	MQ	MQ	vertical

Installing harmonics crystals

WARNING!

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

1) Turn the Minilite OFF and remove the laser head's cover.
2) Remove the proper crystal and dichroics from their storage positions inside the laser head (see Figure 3.3 and table on previous page).
3) Remove any incorrect crystal(s) in position 2 and/or 3 by unbolting the two Allen mounting bolts on the top of the crystal's housing. Store an unused crystal in the storage position in the head (7).
4) Also remove any incorrect pair of dichroics; each dichroic mount is secured to the optical bench by a pair of Allen bolts. Use the storage positions inside the laser head (7) for the unused dichroics.
5) Bolt the selected crystal into its correct position (2 or 3). Tighten until its housing still moves slightly on the bench.
6) When installing or removing an MQ crystal, turn the quarter wave plate (4) 90°. To rotate, loosen the retaining bolt, place a thin rod into a hole in the plate's mounting ring and use the rod to rotate the plate.
7) Install the matching dichroics pair (5) (see table on the previous page).
8) Defeat the laser cover interlock (8) and open the output shutter.
9) Turn on the laser to fire at 10 Hz (20 Hz for the 20 Hz model) with the ENERGY switch set LOW.
10) Using a business card (or red paper for 532 nm and 1064 nm) to locate the beam after it leaves the dichroics, twist their mounts until the beam passes through the output aperture. Carefully tighten their mounting bolts.
11) Again using paper to locate the beam, use the dichroics' horizontal and vertical adjustments to center the beam in the exit aperture. These adjustments are the two set screws on the vertical face of each dichroic mount; the horizontal adjustment is the lower set screw, and the upper set screw adjusts the beam vertically. (The exact position of the crystal(s) does not materially affect the beam path.)
12) Angle tune the crystal(s) and adjust the quarter wave plate to maximize the beam energy (see *Maximizing beam energy*, next).
13) Turn off the laser, enable the cover interlock (8), and replace the cover.

Maximizing beam energy

Rotate the crystal(s) and adjust the quarter wave plate every time that a new crystal(s) is installed. This procedure, called angle tuning, maximizes the conversion efficiency of the crystal(s).

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, defeat (raise) the laser cover interlock and open the output shutter.
2) Turn the laser on so that it fires at 10 Hz (20 Hz for the 20 Hz model) with the ENERGY switch set on HI.
3) Place a power meter in the beam about 500 cm beyond the exit port and measure the beam energy.
4) Loosen each crystal's two mounting bolts, then carefully rotate each crystal horizontally to achieve maximum power.
5) Rotate the quarter wave plate (around the beam axis, but not more than 30°) to obtain maximum energy. To rotate, loosen the retaining set screw on the top of the mount (4), place a thin rod into a hole in the plate's mounting ring and rotate the rod.
6) Tighten the crystal mounting bolts slightly and repeat the crystal and wave plate rotations.
7) Securely tighten the crystal mounting bolts.
8) Check that the beam is still passing through the center of the exit aperture.
9) If not, repeat the final steps of *Installing harmonic crystals* (above).
10) Turn off the laser, lower the cover interlock, and replace the cover.

Aligning the output beam

The turning mirrors (1) and a pair of dichroics (5) steer the laser beam into the crystals and through the exit port. The turning mirrors (1) may require adjustment after a flashlamp is replaced; otherwise consider their position to be fixed.

To check the beam path and realign it,

WARNING!

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

1) Defeat the laser cover interlock and open the output shutter.
2) Set the laser to fire at 10 Hz (20 Hz for the 20 Hz model). Set the ENERGY switch to HI.

3) Take several burns 500 cm from the beam exit using burn paper. If the burns are unclipped, this procedure is not necessary.

4) Set the ENERGY switch to HI.

5) Use red paper to check that the beam strikes the center of the both turning mirrors (1). Only if the beam is close to a mirror's edge is it necessary to loosen their housing's mounting bolts and reposition them.

6) Again using red paper to see the beam, use the turning mirrors' horizontal and vertical adjustment screws to center the beam on the first dichroic (5). These adjustment screws are the same as those on the dichroics' housings: the horizontal adjustment is the lower set screw, and the upper set screw adjusts the beam vertically.

7) Angle tune the crystals (see *Maximizing beam energy,* above).

8) Turn off the laser, enable the cover interlock, and replace the cover.

Using interlocks

The Minilite laser is equipped with both internal and external interlocks.

Internal interlocks

The Minilite has internal interlock switches which sense:

- Laser head temperature is too high*
- Laser power supply temperature is too high*
- Laser power supply cover is open*
- Laser head cover is open
- Cooling system flow too is low

All interlock circuits must be closed before the Minilite will fire. If any of them or an external interlock are open, the red INTERLOCK LED will light and the laser will shut down; it must be reset (see below) before it will fire again. (*Some Minilites contain only with the last two interlocks).

External interlocks

The laser may be interlocked so that the laboratory or room can not be entered while the laser is running. When the rear panel **External Interlock** BNC is open, the laser will not fire. Use switches and wiring rated 50 volts AC at .1 A to construct an external interlock. When not in use, this BNC must be closed (shorted) using the cap provided.

Resetting an interlock

If the laser is interrupted during operation by an interlock opening,

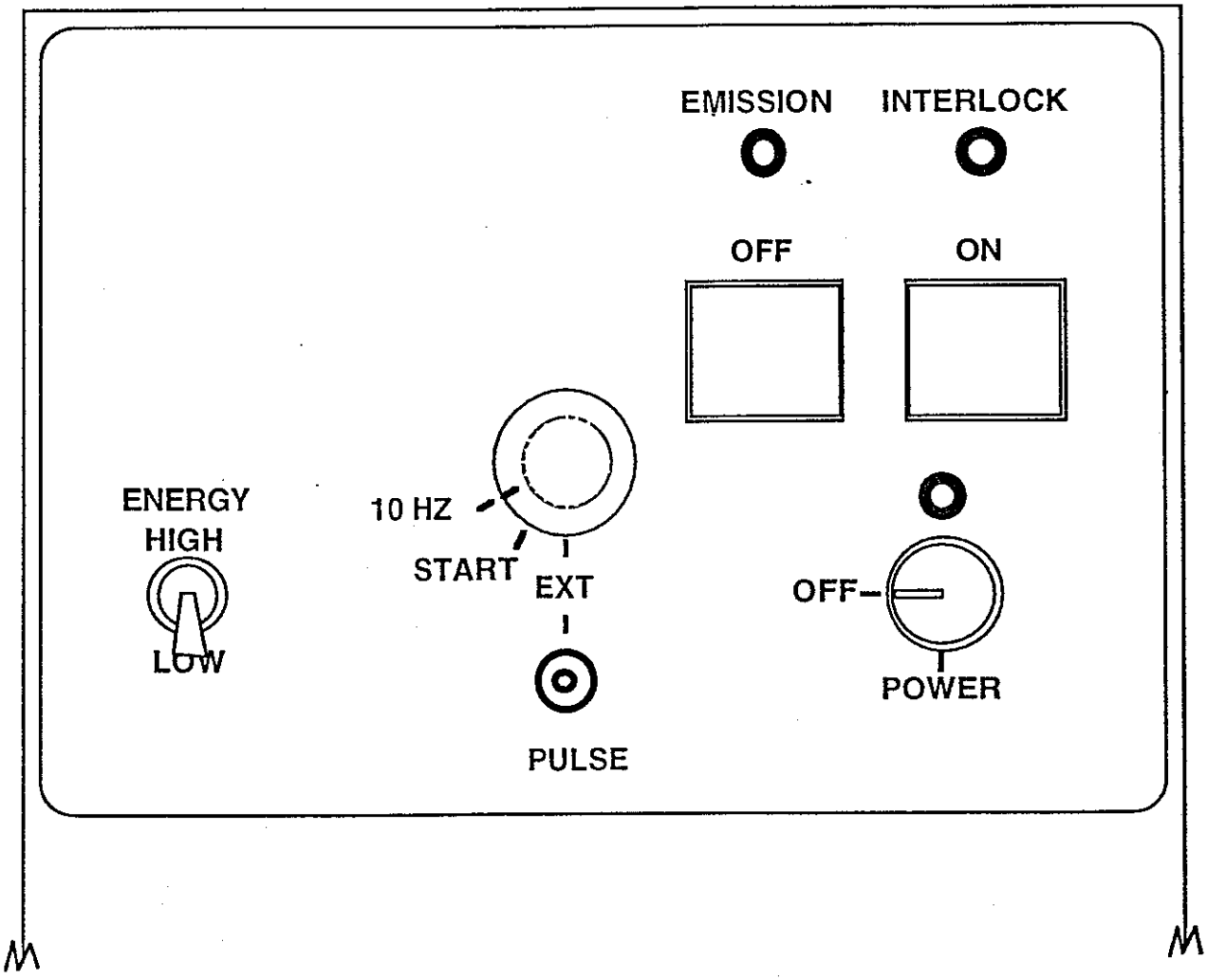
1) Correct the condition which opened the interlock.

2) Reset the laser by turning the key switch OFF, then restart.

Minilite front panel controls and indicators	
KEY SWITCH & POWER LED	The KEY SWITCH turns laser ac power on and off. In the ON position the amber (yellow) POWER LED above the key switch lights.
OFF BUTTON	The OFF BUTTON stops laser pulsing and shuts off the cooling system pump and fan.
ON BUTTON	The ON BUTTON starts the cooling system; after 10 seconds, the laser can fire.
EMISSION LED	The red EMISSION LED is ON when the start up sequence ends; after another 10 seconds, the laser is ready to fire.
TRIGGER Selector Switch & PULSE BNC	The **Selector Switch** chooses one of these operating modes: START Starts the laser startup sequence. 10 Hz Fires the laser at 10 Hz. 20 Hz Fires at 20 Hz (20 Hz model only) EXT Fires a single shot when the **PULSE BNC** is shorted; the SINGLE SHOT CABLE is a convenient way to use the PULSE BNC. Fires multiple shots at up to 10 Hz (20 Hz for the 20 Hz model) when the FIRE LASER BNC (rear panel) receives TTL pulses (see *Firing the Minilite*, above).
ENERGY HIGH/LOW	HIGH = full power, LOW = <10% power (low flashlamp power)
INTERLOCK LED	The red INTERLOCK LED lights when any interlock is activated: • Laser head cover is open • An external interlock has tripped • Laser head temperature is too high • Laser power supply cover is open • Laser power supply temperature is too high • Laser cooling system flow is too low

Minilite back panel controls and connectors	
FIRE LASER	BNC input for remote control (see *Firing the Minilite*, above).
Q-SW SYNCH	BNC output for remote control "
LAMP SYNCH	BNC output for remote control "
hose stubs	Cooling water connectors (lower is the inlet)
D connector	Umbilical cable to laser head
Remote interlock	BNC external interlock; must be shorted when not in use; when open, the Minilite will not fire
fuse	Power Supply fuse; see Maintenance for fuse type

Figure 3.1 Power supply front panel



These main control panel controls are described in the table on the preceding page.

Figure 3.2 Rear view of power supply

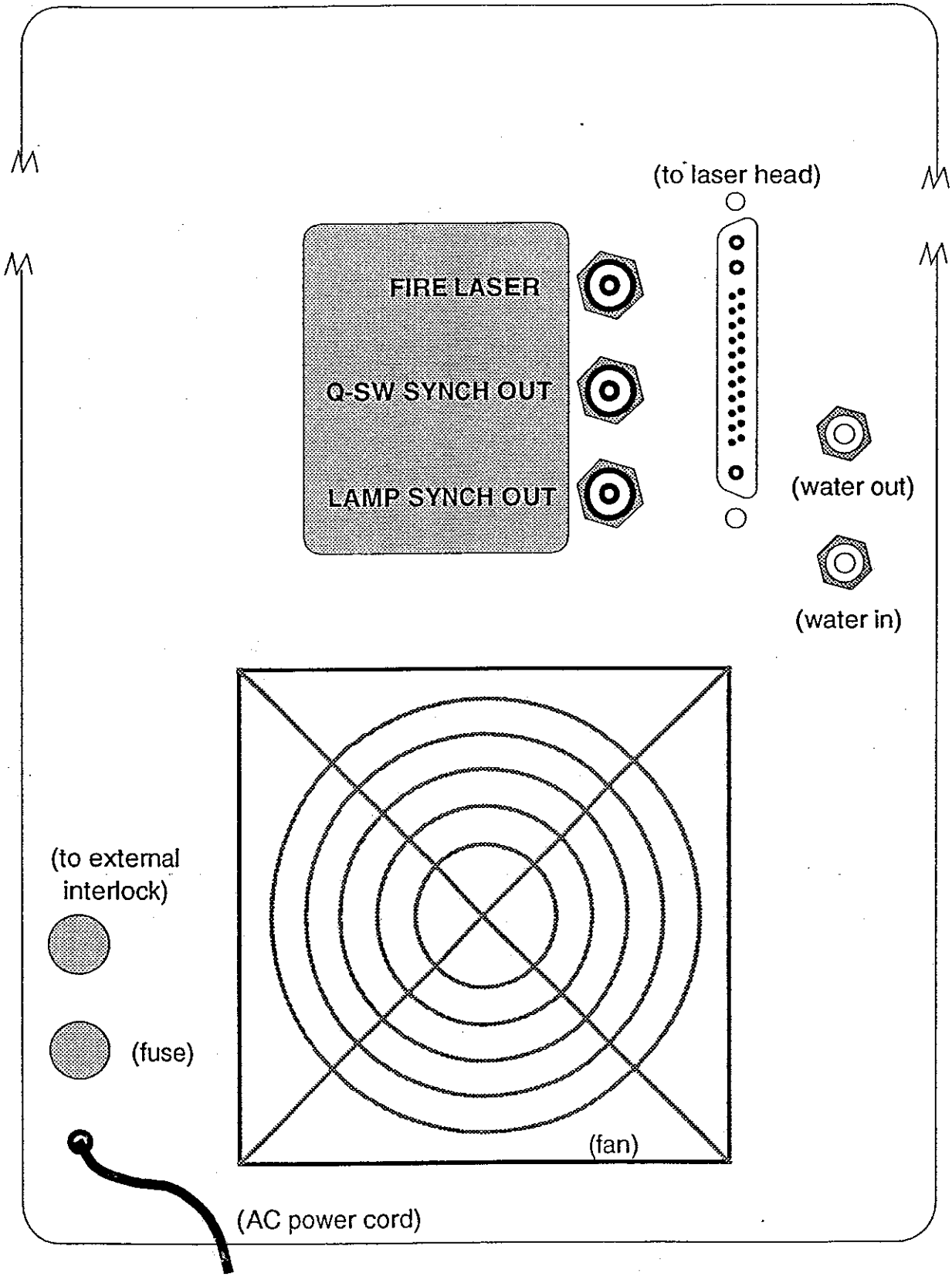
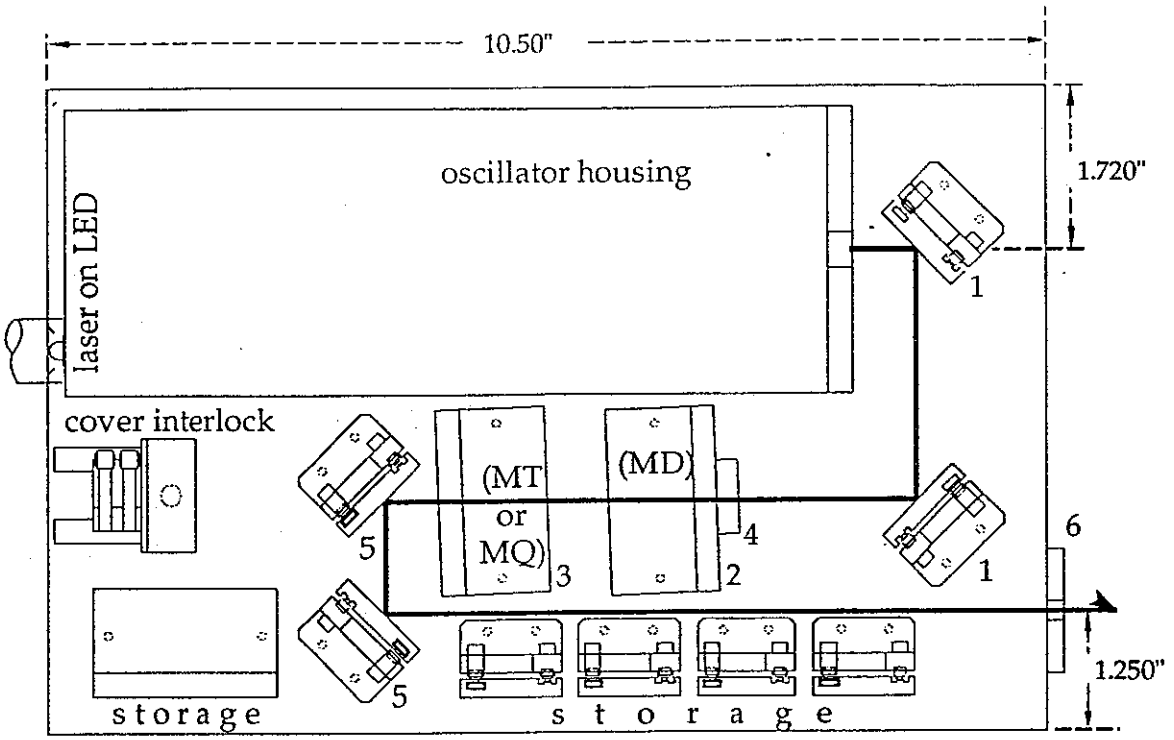


Figure 3.3 Minilite optical layout



In all configurations, turning optics (1) steer the 1064 nm beam to a pair of dichroics (5), which aim the beam through the exit aperture. When the doubling option is installed, the doubling crystal (MD) and the quarter wave plate are installed in positions 2 and 4. When the tripling option is in place, the tripling crystal (MQ) is in position 3, and tripling dichroics replace the normal dichroics in position 5. The doubling crystal (2) and quarter wave plate (4) remain. Similarly, the quadrupling option uses a quadrupling crystal (MT) in position 3 and a pair of quadrupling dichroics in position 5. There are also storage spaces for extra dichroics and crystals.

Please refer to *Installing harmonic crystals* and *Maximizing beam energy* in Chapter 3 when changing the Minilite's optical configuration.

Minilite crystals, dichroics and other optical elements			
key	P/N	option	description
1	105-0099	none	1064 nm turning mirror with mount
2	500-1800	MD	doubling crystal with mount (532 nm)
3	613-0300	MT	tripling crystal with mount (355 nm)
3	613-0350	MQ	quadrupling crystal with mount (266 nm)
4	---	---	quarter wave plate (on MD crystal mount)
5	105-0200	none	dichroic for 1064 nm and MD crystal
5	105-0201	MT	dichroic for MT crystal, with mount
5	105-0202	MQ	dichroic for MQ crystal, with mount
6	---	all	output shutter and beam stop

Section 4 Maintenance

Cooling system

Circulate water through the cooling system by turning on the laser for about 30 seconds every week when the laser in not in use.

Insure 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. Discharge the main capacitor (or wait 5 minutes) before checking the water level.

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

CAUTION:

If not using the Minilite for 3 months or more, drain the cooling systems and flush the laser head with methanol (see the next page).

Filling the cooling system

Fill the cooling system before operating the Minilite. (See Figure 2.1.) 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 filler cap (See Figure 2.1).
3) Fill the reservoir up to the cap with distilled (not deionized) water. If empty, this requires ~5 oz (150 ml). Use a syringe or tubing and funnel to minimize spillage.
4) Plug in the power supply, turn the key switch ON and the Trigger switch to START.
5) Depress the ON switch to run the cooling pump.
6) If the water level falls below 75% full, repeat steps 3 through 6.
7) If the head has been previously flushed with methanol, drain the water (see next procedure) and fill the cooling system again (repeat steps 3 through 5).
8) Repeat step 1, then replace the filler cap and power supply cover.

Draining the cooling system

Drain the cooling system before replacing its filter or before storing the laser. Also flush the head with methanol before storage. To drain and/or flush,

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 2.1).
3) Disconnect the water return (bottom) hose from the power supply and place its open end in a waste container.
4) Plug in the power supply, turn the key switch ON and the Trigger switch on START.
5) Depress the ON switch to run the cooling pump. Keep the switch depressed until no more water appears.
6) Using gentle air pressure on the disconnected (top) hose, blow the remaining water from the laser head into the reservoir.
7) Use the ON switch to drain this water also.
8) If storing the Minilite more than 3 months, remove both water hoses from the laser head. Then pour 20-30 ml of methanol into 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 in the head.
9) If refilling, refer to the previous procedure.
10) Reconnect all water hoses.

Replacing the deionizer cartridge

Replace the deionizer cartridge every two years. To replace the cartridge,

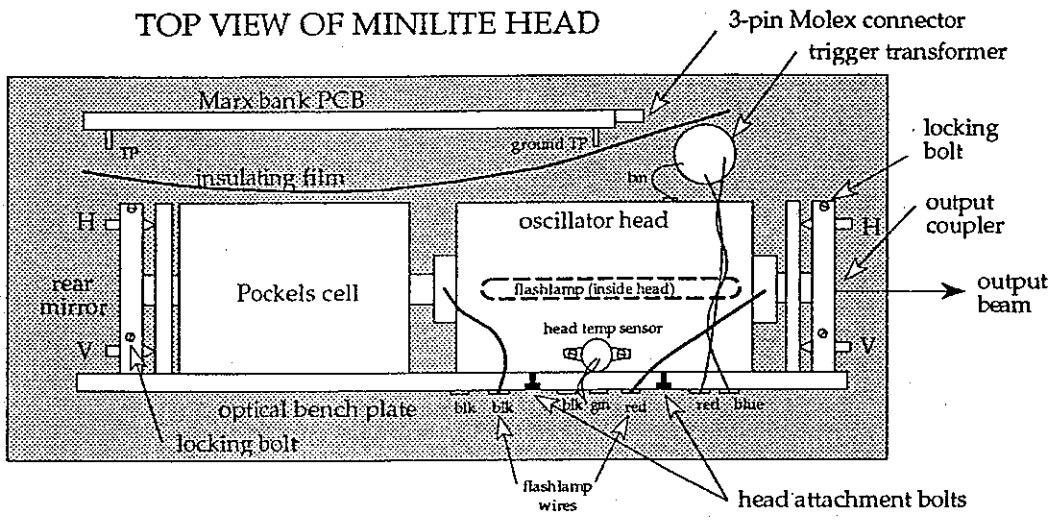
1) Drain the cooling system (see above), but don't replace the cover.
2) Turn the key switch off and unplug the power supply.
3) Disconnect both hoses from the deionizer cartridge (Figure 2.1).
4) Remove the old cartridge. Attach the hoses to the new cartridge and mount it on the power supply wall. Discard the used cartridge.
5) Refill the cooling system (see above). While running the cooling pump (step 5 of *Filling*), check for water leaks around the new filter.
6) If no leaks appear, shut down and unplug the Minilite and replace its power supply cover.

Replacing the power fuse

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

Manufacturer:	100-125 Vac	180-240 Vac
Bussmann	MDL-4	MDL-2
Littlefuse	313.004	313.002

Figure 4.1 Detail of laser cavity



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 (Section 3, *Aligning the output beam*) after replacing any optical element.

Tools and supplies required

- Finger cots or surgical or fine cotton gloves
- High intensity flashlight
- Reagent grade (or better) methanol
- Inspection mirror
- Eyedropper
- Lint-free lens tissues and cotton swabs.

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 lens, crystal and quarter wave plate for dust, fingerprints, discoloration, and burn marks in the surface coating.
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 not sufficient.

Cleaning optics

1) Wash your hands and put on gloves or finger cots.
2) Place one sheet of lens tissue over optic to be cleaned (use the hemostat if necessary). Using an eyedropper, place a few drops of good quality methanol on top of the tissue.
3) Drag the lens tissue across the optic once only. If a visible solvent residue remains on the optic, repeat using less solvent and a new tissue until no residue remains.
4) Wrap lens tissue on a cotton tipped applicator. Apply a few drops of solvent directly to the tissue; shake off any excess.
5) Swab optic gently with the applicator. Repeat these steps with a drier swab to remove remaining residue.

Section 5 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 *Crystal installation* and *Beam alignment* in Section 3.

If the laser fails to operate, check the following:

1) Is the laser head umbilical securely attached to the power supply?
2) Is the key switch on?
3) Is the power supply fuse OK?
4) Has the ON button been depressed long enough for the flow interlock switch to be activated?
5) If no external interlock is used, is the shorting plug of the external interlock BNC (back of power supply) in place?
6) If a door interlock is utilized, is the door interlock switch activated?
7) Is there adequate water in the cooling system?
8) Are the power supply and laser head covers installed?
9) Is the red INTERLOCK LED on? If so, recheck all interlocks:

Laser Head:	Cover removed Temperature too high*
Power Supply:	Temperature too high* Water flow low (kink in a hose?) Cover removed*
External interlock:	Door open*

* if interlock is present

Section 6 Theory

Pulsed 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.

Q-switching

A crystal, quarter wave plate and a vertical 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. Horizontally polarized light exiting the gain medium never returns; it is always blocked by the vertical polarizer. When the Q-switch is closed, it also blocks vertically polarized light: this light passes unchanged through the vertical polarizer and the crystal, then rotates 45° transiting the quarter wave plate. On its return path, it rotates another 45°. Now horizontally polarized, the vertical polarizer prevents it from reentering the rod.

After maximum storage occurs (about 100 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° (45° in each direction through the Q-switch). Vertically polarized light now rotates a total of 180°, 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.

Harmonics 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 **harmonics generation** produces additional frequencies which are multiples (double, triple, quadruple, etc.) of the fundamental. Since the Minilite fundamental is 1064 nm, its second, third, and fourth harmonics are 532, 355 and 266 nm, respectively.

For a crystal to be suitable for harmonics 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 KD*P and BBO crystals, widely know for their suitability, for harmonics generation. Simply replacing a crystal changes the Minilite's output frequency (cf. Chapter 3).

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 (horizontal) 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 laser 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 is stripped of the fundamental, and this beam enters a second doubling crystal, where it doubles again.

Output beam polarity

The Minilite's fundamental (1064 nm) output beam is always vertically polarized. Each harmonic crystal rotates the beam polarity 90°, giving the second harmonic beam horizontal polarity. Since both the third and forth harmonic require two crystals, these output beams also have vertical polarization.

Warranty

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.

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 which 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.

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.

Service centers

Continuum 3150 Central Expressway Santa Clara, CA 95051, USA	(408) 727-3240 (408) 727-3550 fax
Continuum GmbH Bochstrasse 12 D-82178 Puchheim, Germany	49 89 800 57 49 49 89 800 12 79 fax
Hoya Continuum Corporation Shinjuku Ito Building 23-2 Sakamachi Shinjuku-ku Tokyo 160 Japan	81 3 3353 5336 81 3 3353 6673 fax
Continuum E.U.R.L Z.A.C. des Aulnettes 10 Boulevard Louise Michel 9100 Evry, France	33 1 69 36 31 00 33 1 69 36 31 04 fax