Continuum

Operation and Maintenance Manual
Minilite Nd:YAG Laser

Minilite Test/Inspection Form

Work Order #: 94/2431

Name: Rutgers Univ.

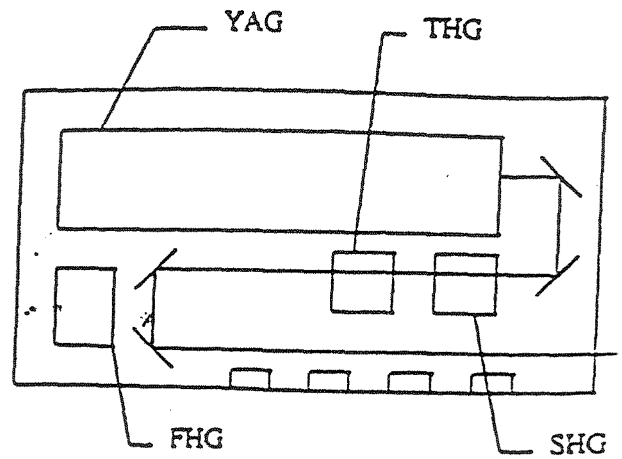
Date: 1-30-95

Tech: Jim B. Nichols

Options:

- ✓ SHG
- ✓ THG
- ___ FHG

Optical Layout:



Device serial numbers: Remove device serial number labels from the laser head and power supply and attach labels to back side of Test/Inspection form.

Crystals:

	SHG	THG	FHG
Supplier:		Skytech	
Length:		4x4x7	
Type:		31.3°	

Jitter: 1064 nM 1.0 (nS) Spec +/- .5 nS

Interlocks functioning properly: ✓

Energy:

1064 nM	29	(mJ)	Spec >25 mJ
532 nM	12.5	(mJ)	Spec >10 mJ
355 nM	4.5	(mJ)	Spec >4 mJ
266 nM	___	(mJ)	Spec >2 mJ

Pulsewidth:

1064 nM	6.95	(nS)	Spec 5–7 nS
532 nM	5.85	(nS)	Spec 4–6 nS
355 nM	5.60	(nS)	Spec 4–6 nS
266 nM	___	(nS)	Spec 4–6 nS

Long Term Stability:

- Wavelength: 355nM
- Initial energy: 4.5 mJ
- Final energy: 4.5 mJ
- Test time: 4.0 4 hours min

Electronic:

- Externals: N/A
- Single shot: Yes
- Lamp voltage: N/A
- Interlock shutdown: Yes

Shipping checklist:

- Water drained: ✓
- Single shot cable: ✓
- Interlock defeat bar: ✓
- 3/32" allen key: ✓
- Manual: ✓
- Labels: ✓
- 2 system keys: ✓
- Output shutter: ✓

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 EXTREMELY 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.

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 IR 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.

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.

Safety Features

Interlocks

The Minilite has interlock switches which stop the Minilite 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 light. *

* some Minilite models 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.

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 deionized or distilled water before starting.

1 Close the shutter on the front of the laser head.

2 Set the ENERGY HI/LO switch on LO.

3 Turn the key switch to the ON position.

4 Set the Trigger Selector switch to the START position.

5 Press and 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 mode of operation:

- 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/LO switch on HI when ready to operate safely (see safety section).

Shutdown

1 Push the OFF button.

2 Close the exit shutter.

3 Turn the key switch to the OFF position. The laser is now shut off.

4 Remove the key to prevent unauthorized use.

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).

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

Single shot

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 3.1). 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 SYNC OUT**" BNC. When the laser fires, pulses will appear on the "**Q-SWITCH SYNC 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 to fire the flashlamp at up to 10 Hz (20 Hz on 20 Hz models).
- **LAMP SYNC OUT** — +5 volt, 20 µsec nominal pulse. Positive pulses (0 to +5V) appear when the flashlamps fire.
- **Q-SWITCH SYNC OUT** — +5 volt, 20 µsec nominal pulse; Positive pulses (0 to +5V) appear when the Q-switch fires.

Low power operation

When the ENERGY HI/LO switch is in the LO 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.

LASER FIRING TIMING

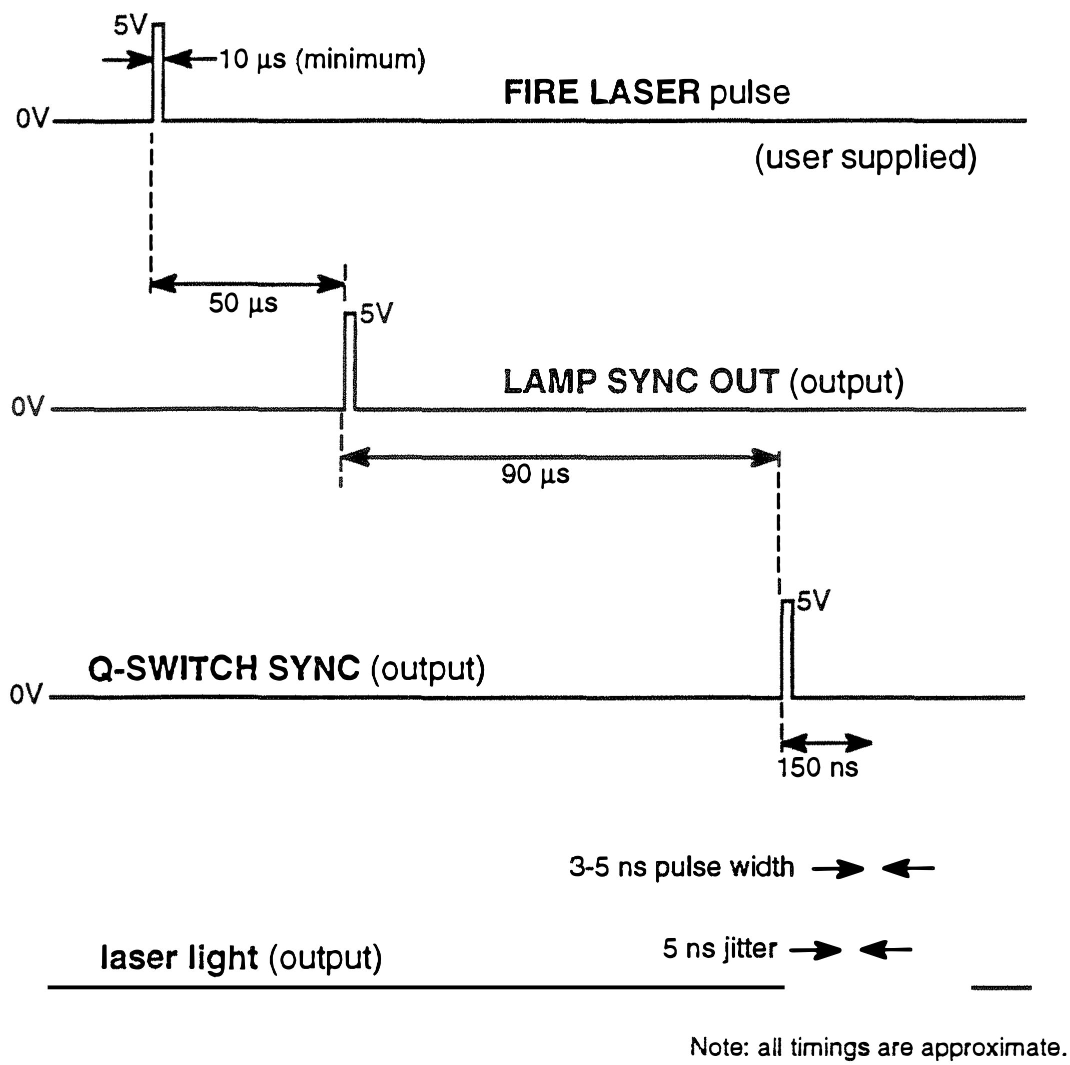


Figure 3.0 Timing when using an external firing signal.

Generating harmonics

The Nd:YAG Minilite laser produces vertically polarized IR 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

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).

CRYSTAL CONFIGURATIONS FOR VARIOUS OUTPUTS			
output	crystal in position 2	crystal in position 3	dichroics needed
1064 nm	none	none	MD
532 nm	MD	none	MD
355 nm	MD	MT	MT
266 nm	MD	MQ	MQ

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 Minilite models are equipped 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.

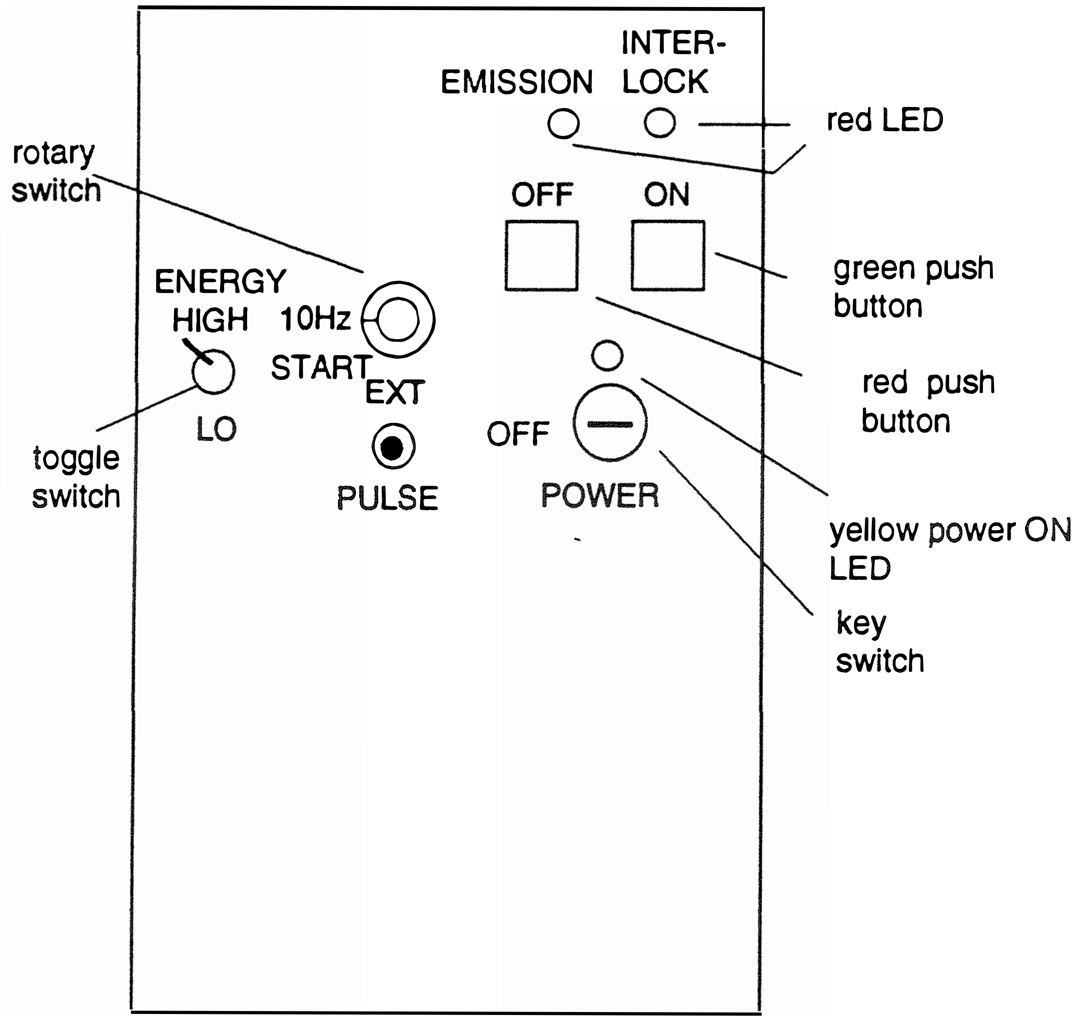
2 Reset the laser by turning the key switch OFF, then restart.

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: <u>START</u> Starts the laser startup sequence. <u>10 Hz</u> Fires the laser at 10 Hz. <u>20 Hz</u> Fires at 20 Hz (20 Hz model only) <u>EXT</u> 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 HI/LO	HI = full power, LO = <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 SYNC	BNC output for remote control "
LAMP SYNC	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



Front panel

Figure 3.1 Power supply front panel

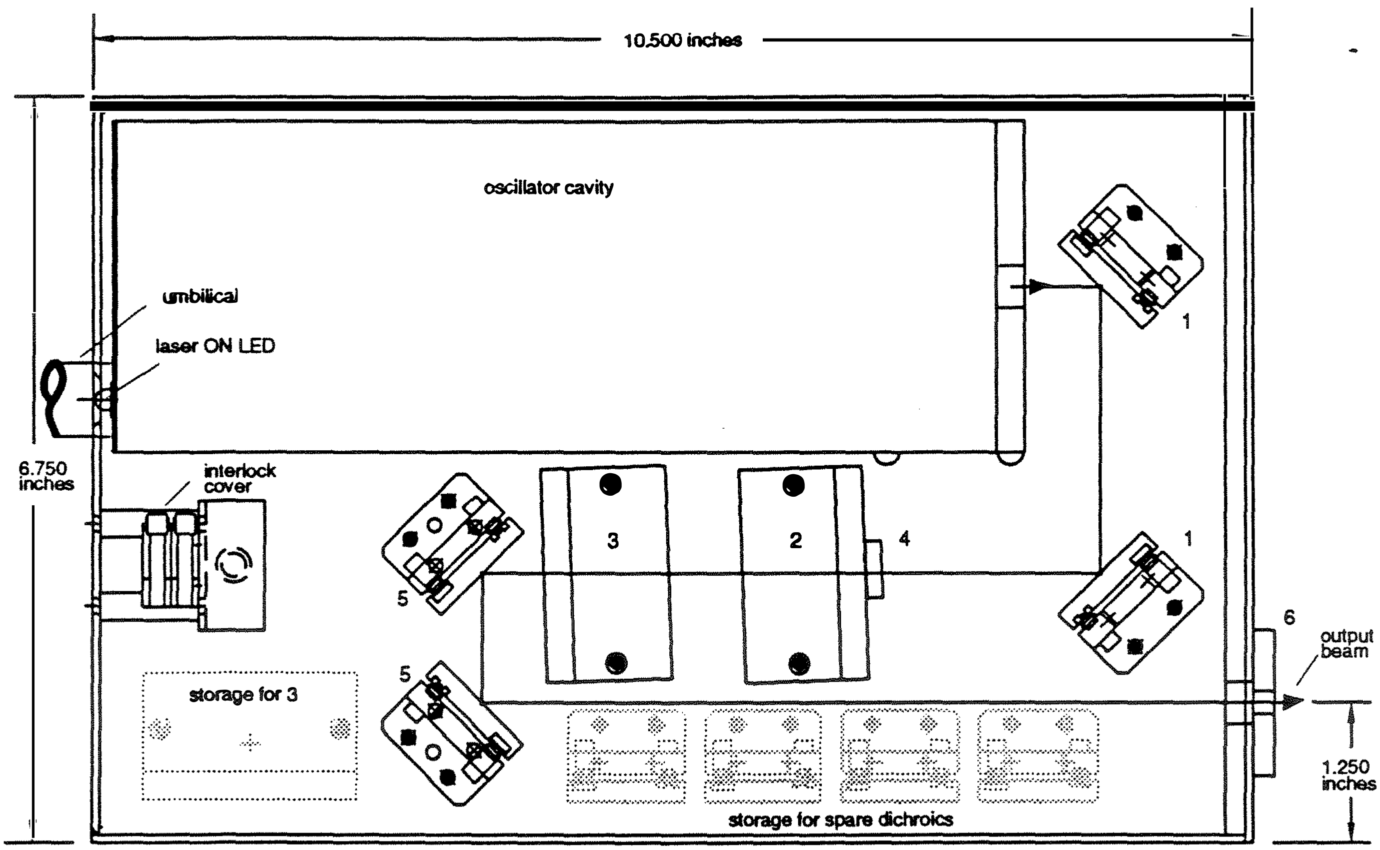


Figure 3.3 Minilite optical layout

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. Spare crystals and dichroics are stored in the laser head.

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		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		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	—		output shutter and beam stop

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 laser gain medium, a Nd:YAG rod.

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.

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 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 KD*P and BBO crystals, widely know for their suitability, for harmonic generation. Simply replacing a crystal changes the Minilite's output frequency (see 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.