Operator's Manual
New Wave Research, Inc.
Tempest and Gemini PIV
Nd: YAG Lasers

New Wave Research, Inc.
47613 Warm Springs Blvd.
Fremont, CA 94539
October 2000

Preface

This manual contains information for proper installation and operation of the Tempest, Gemini PIV and accessories. The Tempest and Gemini PIV comply with the Center for Device and Radiological Health (CDRH) Standard 21 CFR 1040.

The Tempest and Gemini PIV laser systems are Class 4 lasers and emit laser radiation that can be harmful to your eyes and skin. It is essential that the safety section of this manual be read before installing this laser and that the user follows the instructions given for safe laser operation.

Do not attempt to repair the laser while it is under warranty. Report all problems to New Wave Research, Inc. for warranty repair.

New Wave Research, Inc. can be reached at:

47613 Warm Springs Blvd.
Fremont CA 94539
Tel: 510-249-1550
Tel: 800-566-1743
FAX: 510-249-1551
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Web: http://www.new-wave.com

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NEW WAVE
RESEARCH

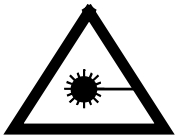
Introduction

The New Wave Research Tempest Nd:YAG laser is a high performance laser that requires care in handling. As with any high power laser system, it is important that every person who works with the laser is trained in the safe operation. It is also important that each person who works in the area is aware of necessary procedures to safely turn the laser off.

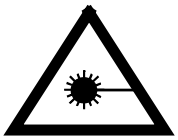
The Gemini-PIV laser system is a specific configuration of the Tempest designed for particle image velocimetry (PIV). The Gemini-PIV consists of two IR laser heads combined in a single package with a second harmonic generator and two discrete power supplies. All information for the Tempest applies to the Gemini-PIV, so the Gemini PIV will be inferred by reference.

Optical Safety

The Tempest Nd:YAG laser generates high energy infrared radiation that can pose serious risks to eye safety. Infrared radiation is invisible to the eye, so the hazard is not immediately obvious, but the radiation can be focused onto the retina. For this reason it is very important to always wear safety glasses and to be aware of any possible reflections.



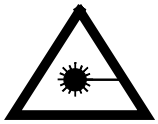
WARNING: The New Wave Research Tempest Nd:YAG laser is a Class 4 high power laser whose beam is, by definition, a safety and fire hazard. Take all necessary precautions to prevent accidental exposure to both direct and reflected beams. DIFFUSE AS WELL AS SPECULAR BEAM REFLECTIONS CAN CAUSE SEVERE EYE AND SKIN DAMAGE.



BECAUSE THE 1064, 355, AND 266 NM OUTPUT BEAMS OF A ND:YAG LASER ARE INVISIBLE THEY ARE EXTREMELY DANGEROUS. Infrared radiation passes easily through the cornea, which focuses it on the retina of the eye, where it can cause instantaneous permanent damage including blindness. AVOID EYE AND SKIN EXPOSURE TO DIRECT OR SCATTERED RADIATION.

CAUTION: USE OF CONTROLS, ADJUSTMENTS OR PERFORMANCE OF PROCEDURES OTHER THAN THOSE SPECIFICIED HEREIN MAY RESULT IN HAZARDOUS RADIATION EXPOSURE.

Follow the instructions contained in this manual for proper installation and safe operation of your laser. Wear protective eye wear; selection depends on the energy and wavelength of the laser beam as well as operating conditions. Consult ANSI, ACGIH or OSHA standards for guidance.



At all times during installation, operation, maintenance or service of your laser, avoid exposure to laser or collateral radiation exceeding the accessible emission limits listed in "Performance Standards for Laser Products," 21 CFR 1040 10(d).

Laser Safety

Laser light poses safety hazards that are not associated with conventional light sources. Special precautions must be observed when working with the Tempest pulsed Nd:YAG laser. The safe use of lasers requires that all laser users, and people working in the same area as the laser, are aware of the dangers involved.

Laser beams are intense enough to burn skin, clothing or paint. They can ignite volatile substances such as alcohol, or other solvents. The beam may also cause damage if reflected from some other surface. For this reason it is important that the following precautions are observed.

- Keep the protective cover on the laser head at all times.
- Avoid looking at the output beam, even diffuse reflections are hazardous.
- Treat back reflections from any optic surface as you would the main laser beam. Even though the energy of such reflections is only a fraction of that contained in the main beam, it is sufficient to cause serious bodily harm, especially to the eye.
- Use protective eyewear at all times. Selection depends on the wavelength and the intensity of the radiation, the conditions of use, and the visual function required.
- Operate the laser at the lowest beam intensity possible, given the requirements of the application.
- Expand the beam wherever possible to reduce beam intensity.
- Avoid blocking the output beam or its reflection with any part of the body.
- Use an IR detector or energy detector to verify that the laser beam is off before working in front of the laser.
- Establish a controlled access area for laser operation. Limit access to those trained in the principles of laser safety.

- Maintain a high ambient light level in the laser operation area to constrict the pupil of the eye, reducing the possibility of injury.
- Post warning signs prominently near the laser operation area.
- Provide enclosures for beam paths whenever possible.
- Set up an energy absorbing target to capture the laser beam, preventing unnecessary reflections and scattering.
- Do not open laser head or power supply. Dangerous voltages and laser energies are present.

If laser service is required, return it to New Wave Research, 47613 Warm Springs Blvd. Fremont CA 94539 Tel: 510-249-1550 FAX: 510-249-1551

Electrical Safety

The laser head and power supply contain electrical circuits operating at lethal voltage and current levels. Do not attempt to operate the laser with the power supply cover or laser head cover removed. For service, please contact New Wave Research at 47613 Warm Springs Blvd. Fremont, CA, 94539. The phone number for New Wave Research is (510) 249-1550; Fax (510) 249-1551.

Certain procedures such as changing the flash lamp, water filter, or cleaning optical components require removal of the protective systems. It is important that all safety precautions outlined in this manual are observed by anyone using the laser. The most important rule when performing maintenance procedures on this laser is to unplug the power cord from the electrical outlet.

There are no user serviceable parts on the electrical side of the power supply. Service procedures on system electronics must be carried out by New Wave Research.

Safety Features

The following features are built into the Tempest Nd:YAG lasers to conform to government regulations and provide safe laser operation.

Laser Covers

The Tempest laser head is enclosed in a protective housing that prevents access to radiation in excess of Class I limits, except for the output beam, which is Class IV. The cover also protects against stray radiation from the Tempest. Do not remove the cover, except to perform maintenance procedures by a trained person.

Interlocks

The Tempest Nd:YAG laser system has a series of interlocks to prevent accidental exposure to dangerous levels of electricity or radiation. In

addition, there are interlocks designed to interrupt laser operation if the laser may be damaged. The interrupts are

- Laser head cover opened
- Control panel detached
- Laser head umbilical detached
- Cooling water temperature too high
- Cooling water flow too low
- Remote interlock interrupted (if installed)

Exit Shutter

The Tempest has an exit beam shutter located on the laser head housing. The laser beam may be blocked by closing the shutter. Do not use the exit beam shutter as a method of blocking the beam for more than a few seconds. Turn off the laser if the output beam is not needed for longer time periods.

CE Declaration

Declaration of Conformity

Application of Council Directives:

- 73/23/EEC, 89/336/EEC

Standards to which Conformity is Declared:

- EN 61010; EN 60825
- EN 55011; EN 50082

Manufacture's Name and Address:

47613 Warm Springs Blvd.
Fremont CA 94539 USA

Type of Equipment: Nd:YAG Laser Systems
Model Numbers: Tempest, Gemini
Date CE Mark Affixed: 1998
Supplementary Information:

I the undersigned, hereby declare that the equipment specified above conforms to the above Directives and Standards.

Place: Fremont, CA Date: December 20, 1998
Edward North
President

Government Regulations

New Wave Research suggests that laser users purchase a copy of the American National Standard for the Safe Use of Lasers (ANSI Z136.1-1993). This publication provides recommendations for the safe use of lasers and laser systems that operate at wavelengths between 180 nm and 1 mm. The publication is available from:

Laser Institute of America
12424 Research Parkway, Suite 125
Orlando, FL 32826
(407) 380-1553

Laser Classification

The governmental standards and regulations specify that the laser must be classified according to the output power or energy and the laser wavelength. The Tempest is classified as Class IV based on 21 CFR, subchapter J, part II, section 1040-10 (d). According to the European Community standards, the Tempest is classified as Class IV based on EN 60825-1, clause 9. This manual and other documentation for the Tempest will refer to the classification as Class 4.

Location of Safety Labels

Refer to Figures 1-1 through 1-7 for the location of all labels for the Tempest laser system. The labels are for safety, certification and identification, and a copy of each label is shown in the following figures.

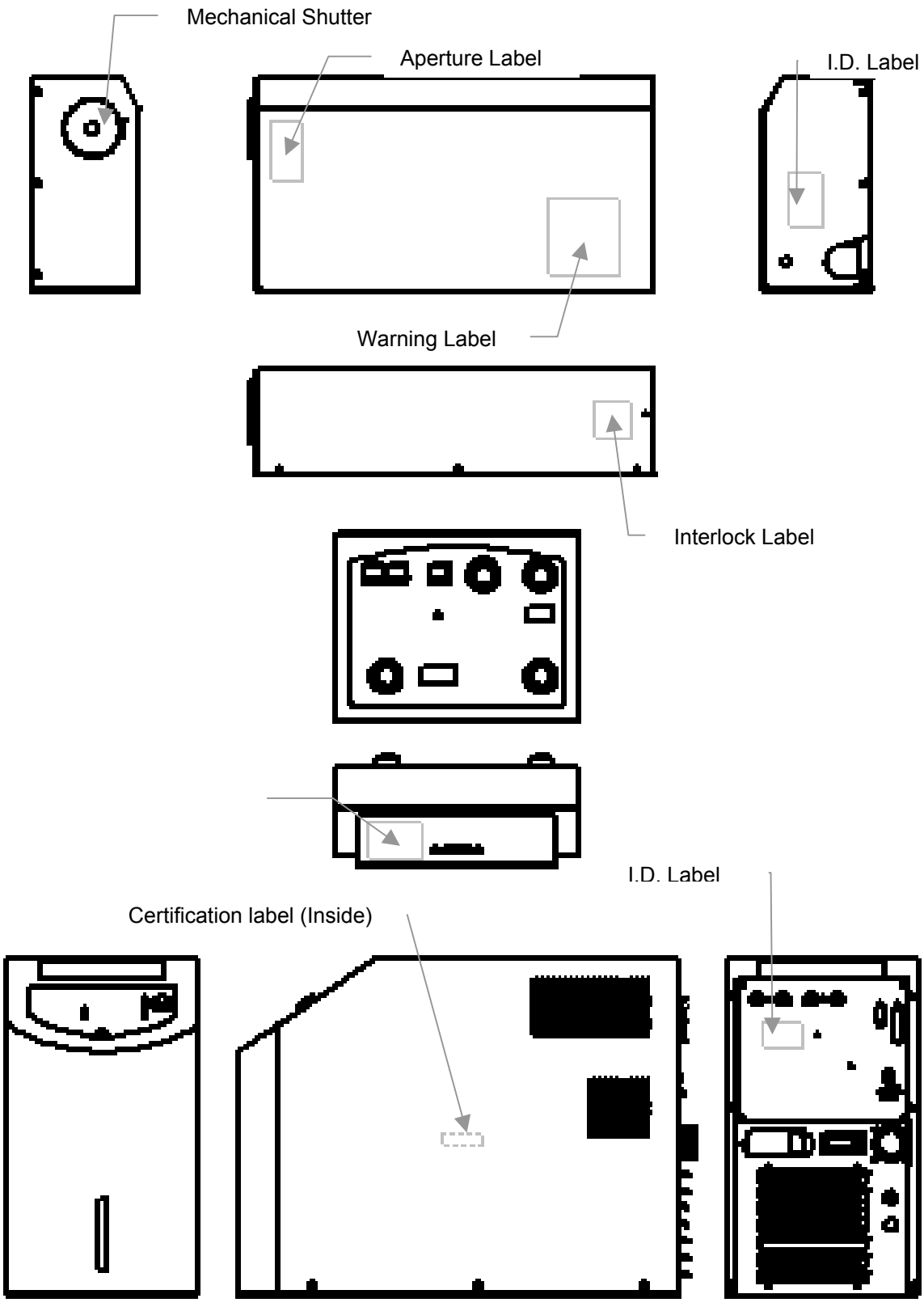


Figure 1-1: Location of Labels

COMPLIES WITH 21 CFR
1040.10 AND 1040.11

Figure 1-2: Certification Label

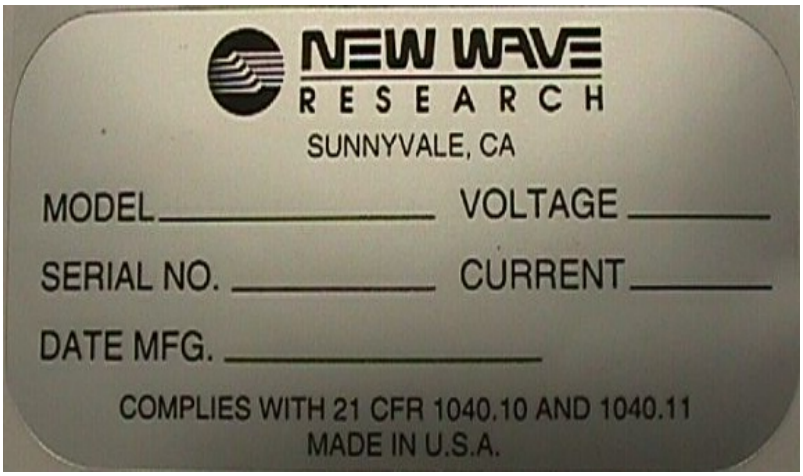


Figure 1-3: Power Supply Identification Label

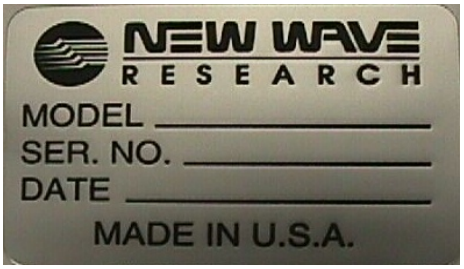


Figure 1-4: Laser Head Identification Label

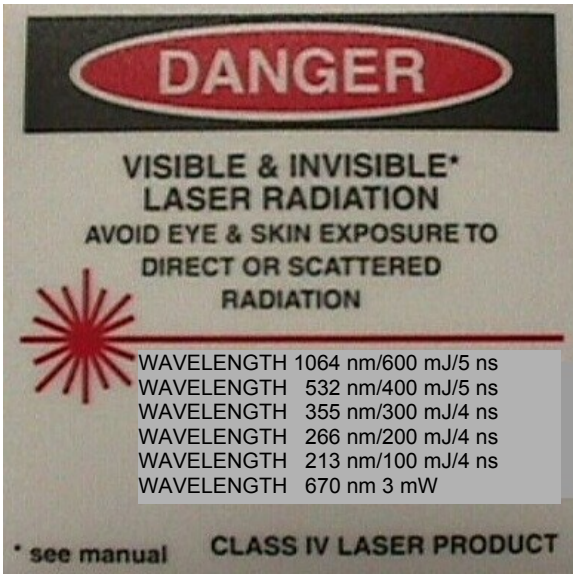


Figure 1-5: Warning Label, U.S.

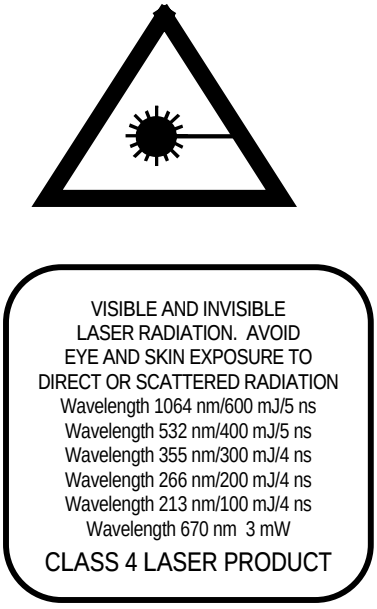


Figure 1-6: Warning Label, International

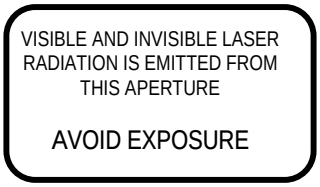


Figure 1-7: Aperture Label

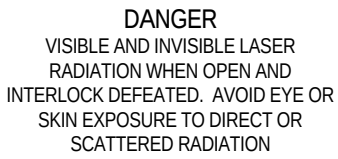


Figure 1-8: Defeatable Interlock Label

Chapter Two, Description and Specifications

Introduction

This chapter provides an introduction to the Tempest Nd: YAG laser system. The optical layout of the head is explained in the following section, including the different Tempest head configurations. This section also includes the location of harmonic generators. A summary of system specifications is given on the last page of this chapter.

Optical Layout

This section gives an introduction to the optical layout in the Tempest Nd: YAG laser. The standard Tempest configuration is a wide body, with room for installing the optional attenuator and harmonics. The Tempest is shown with optional items in Figure 2-1.

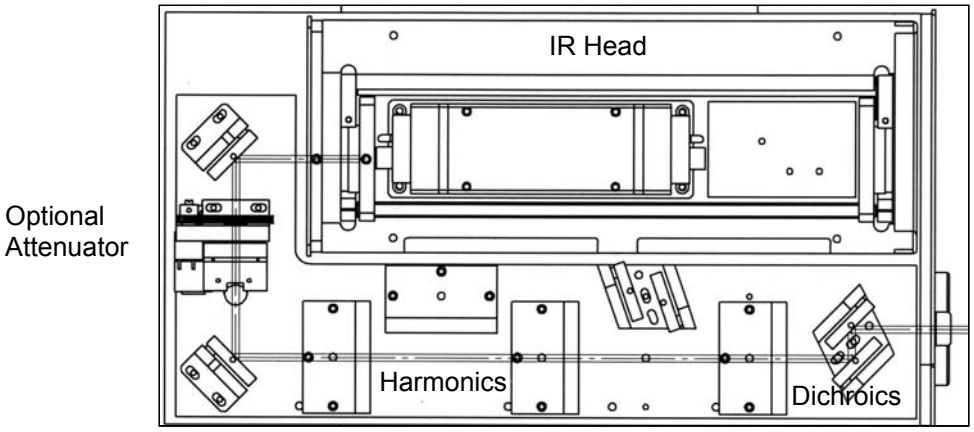


Figure 2-1. Layout of Tempest Head with Options

The Tempest employs a flash lamp-pumped Nd: YAG rod in a thermally compensated resonator to generate radiation at 1064 nm. The resonator is very compact, mechanically isolated from the laser housing, which makes the system relatively insensitive to vibrations and temperature change. The IR head is housed in a separate sealed area that requires no adjustments in normal operation. The only time the IR head needs to be opened is on the rare occasion that the flash lamp needs to be changed during a maintenance procedure.

Optical Attenuator

The optional optical attenuator serves to control the laser energy without affecting the beam quality. The optical attenuator is designed to work on the 1064 nm beam, so it is placed directly after the IR head, before any harmonic generation crystals.

The optical attenuator consists of a half wave plate, followed by a polarizer. The half wave plate is secured to a motorized rotating mount. The servo motor controlled angle is set by input from the control panel.

The polarizer is permanently aligned to transmit vertically polarized light. This maintains the polarization of the IR light as emitted from the IR head in the standard configuration.

Second Harmonic Generation

The 1064 nm laser pulse exits the IR head and then different harmonic wavelengths may be generated if these options have been installed. The second harmonic at 532 nm is generated by passing the IR beam through an angle tuned KTP crystal. The Tempest uses Type II phase matching in KTP to generate the second harmonic, so the polarization of the IR beam must be adjusted to maximize SHG intensity. Dichroic mirrors separate the second harmonic from the fundamental light and direct the beam to the output port. The second harmonic light is vertically polarized.

Third Harmonic Generation

The third harmonic at 355 nm may be generated in the Tempest if the option has been purchased and installed. The third harmonic at 355 nm is generated by combining one photon at 532 nm with one photon at 1064 nm. Third harmonic generation is accomplished by Type I phase matching in BBO. The second harmonic must be detuned slightly to achieve the maximum third harmonic conversion efficiency. The third harmonic light is separated from the fundamental and second harmonic using a pair of dichroic mirrors. The third harmonic light is vertically polarized.

Fourth Harmonic Generation

The fourth harmonic of Nd: YAG at 266 nm can be generated by doubling the 532 nm second harmonic light. This is done by placing the correct BBO crystal in the optical path and combining two photons at 532 nm to give one photon at 266 nm. The light at 266 nm is separated using a pair of dichroic mirrors to select only the fourth harmonic light. The fourth harmonic light is vertically polarized.

External Computer Control

The Tempest Nd: YAG laser system can be controlled externally by a computer using the TTL direct port. TTL commands can be sent to the laser power supply through the female DB 25 connector.

Safety Interlocks

One internal interlock, one external interlock, and one mechanical shutter provide protection to the user(s). Opening the laser head trips the internal interlock. The external interlock connector is located at the rear of the power supply, and can be shorted with the supplied connector. The user can install safety interlock to the door or some other device to provide increased safety when using the laser.

Power Supply

The power supply controls the Tempest Nd: YAG laser, supplying the required power and signals to safely operate the laser. The Tempest power supply is built on three levels, with functional groups separated on the three different levels.

Electronics

The power entry module brings AC power to the laser, with the input line going directly to the line filter and transformer. The upper portion of the power supply contains the electronics to run the laser.

Water Cooling System

The closed loop water cooling system is located completely on the lower level of the power supply. A water pump recirculates the deionized water from the water-to-air heat exchanger to the laser head. The water circulates through the pump chamber to keep the temperature of the YAG rod at an acceptable level. Part of the water flow is directed through a deionization cartridge to maintain the water purity. The cooling control board controls the fan attached to the heat exchanger and monitors the temperature sensor to ensure that the laser operates reliably.

Tempest Specifications

The following table shows the Tempest specifications for the different models that are available. The specifications are subject to change without notice.

Table 2-1: Tempest Performance Specifications

Energy[1]	1064 nm	532 nm	355 nm	266 nm
Tempest-10	200 mJ	100 mJ	50 mJ	30 mJ
Tempest-20	200 mJ	100 mJ	50 mJ	30 mJ
Tempest-30	180 mJ	90 mJ	40 mJ	20 mJ
Energy stability[2]	± 2 %	± 3.5 %	± 6 %	± 7 %
Pulse width[3]	3-5 ns	3-5 ns	3-5 ns	3-5 ns
Beam divergence[4]	< 1 mrad	< 1 mrad	< 1 mrad	< 1 mrad
Beam pointing[5]	< 200 μrad	< 200 μrad	< 200 μrad	< 200 μrad
Jitter	± 0.5 ns	± 0.5 ns	± 0.5 ns	± 0.5 ns
Beam Diameter	~5mm	~5mm	~5mm	~5mm

1. Optical losses due to optional attenuator will reduce maximum energy by 10%
2. Pulse-to-pulse for 98% of shots after 30 minute warm up
3. Full width half maximum
4. Full angle for 86% of the energy, $1/e^2$ point
5. Full angle for 86% of the energy, $1/e^2$ point

Gemini PIV Specifications

The following table shows the Gemini PIV specifications for the different models that are available. The specifications are subject to change without notice.

Table 2-2: Gemini PIV Performance Specifications

Energy[1]	532 nm
Gemini PIV 15	120 mJ
Gemini PIV 30	90 mJ
Beam Diameter	~5 mm
Energy stability[2]	± 3.5 %
Pulse width[3]	3-5 ns
Beam divergence[4]	< 1 mrad
Beam pointing[5]	< 200 μrad
Jitter	± 0.5 ns

1. Optical losses due to optional attenuator will reduce maximum energy by 10%
2. Pulse-to-pulse for 98% of shots after 30 minute warm up
3. Full width half maximum
4. Full angle for 86% of the energy, $1/e^2$ point
5. Full angle for 86% of the energy, $1/e^2$ point

Chapter Three,
Installation

Voltage Requirements

The power supply has been preset at the factory for 95 – 125 VAC or 200 – 250 VAC single phase operation, depending upon the voltage supply available at your location. However, the laser can be switched on site from 95-125 VAC to 200-250 VAC. In addition, the fuses must be changed to match the voltage setting.

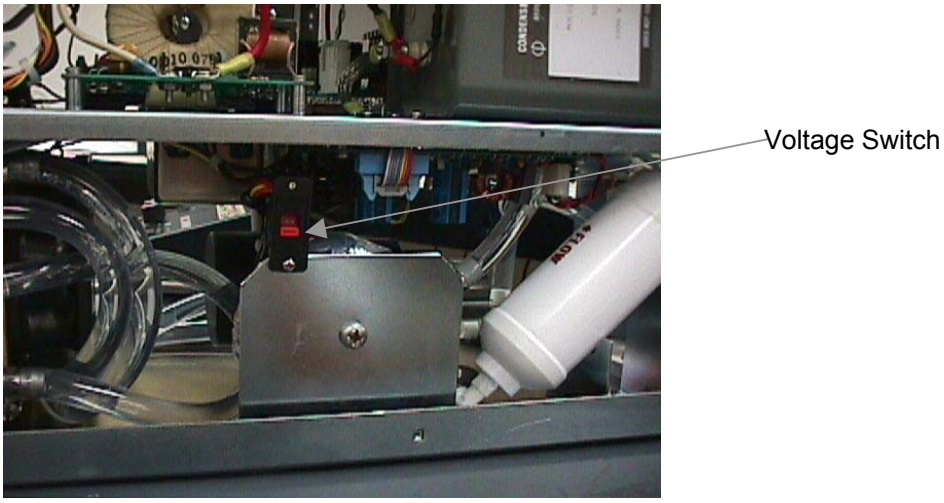


Figure 3-1: Voltage Switch

WARNING: Make sure that the switch is flipped to the correct voltage. In addition, both fuses must be changed to match the current voltage setting.

Power Line Fuse

The AC power entry module located on the back of the power supply holds two power line fuses. For 95 – 125 VAC operation two 10 amp/250V, 5 x 20 mm, time lag, high breaking capacity fuses are installed. For 200 – 250 VAC operation two 6.3 amp/250V SPT 5 x 20 mm time lag, high breaking capacity fuses are installed. Acceptable fuses are:

Manufacturer	90–125 VAC	200–250 VAC
Schurter	001.2514	001.2512

The high voltage switching power supply, located on the top shelf of the power supply, has two PC board mounted type 3AG fuses. One fuse, labeled F1, is a 10A 32 V SloBlo, while F2 is a 1/32 A 250 V SloBlo fuse. Acceptable fuses are:

Manufacturer	Fuse	90–250 VAC
Littelfuse	F1	**313**.010
Littelfuse	F2	**313**.031

There is also a fuse on the cooling control board. The cooling control board mounts underneath the middle shelf. The fuse is type 3AG SloBlo, rated for 3 Amps, 250 V. An acceptable fuse for the cooling control board is:

Manufacturer	Fuse	90–250 VAC
Littelfuse	F1	**313**.003

Laser Umbilical

Connect the main and secondary laser umbilicals to the power supply back panel connector. The main umbilical has a threaded AMP connector that must be completely attached to ensure safe operation. Press the connector into the receptacle as you simultaneously thread the fitting.

The secondary laser umbilical carries control signals and connects to the power supply through a D-Sub miniature 15 pin connector. The secondary umbilical must be fully attached by tightening both screws. Connect the cooling system hoses to the cooling system fittings on the back panel of the power supply. Observe the color coding in attaching the cooling system hoses. The blue lines attach to the WATER OUT, while the red lines attach to the WATER RETURN connection.

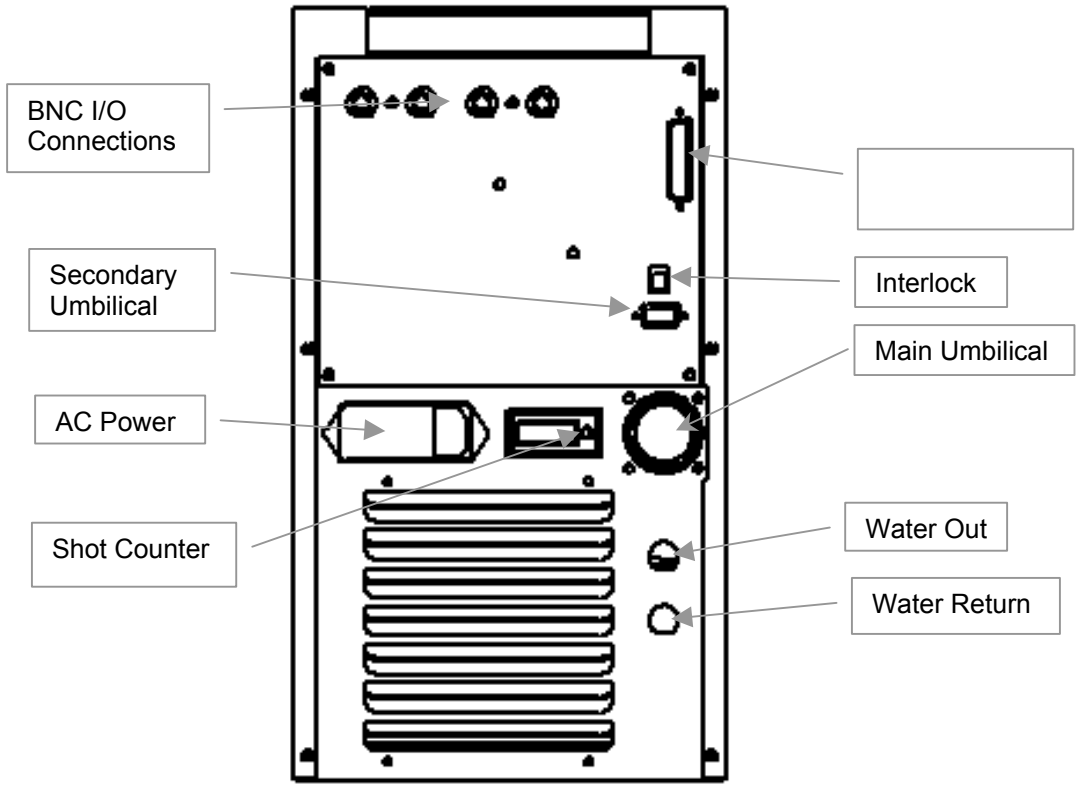


Figure 3-2: Power Supply Back Panel

Control Panel

The control panel is connected to the power supply through a 10 foot detachable DB15 extension cable. The connectors on both the control panel and the power supply are female DB-15. Connect the control panel cable to the control panel and to the back of the power supply. Secure the cable at both connectors by tightening the screws.

Interlock Connector

An interlock connector is supplied with the system and must be installed before the system can be operated. The purpose of the interlock connector is to provide a method of interlocking the operation of the laser with a safety switch which may be installed on a laboratory door or other location. See Figure 1-1 for the location of the interlock connector.

The laser operation is stopped when the interlock circuit has been tripped by the internal or external interlock. The user must fix the situation that tripped the interlock and restart the laser to begin operating again. The flashlamp energy knob must be set to the minimum and the START button must be pressed.

Cooling System

Prior to operating the laser, the cooling system must be filled with deionized/distilled water. Remove the water fill cap on the front of the power supply. Fill the reservoir with approximately 800 ml of deionized/distilled water.

NOTE: Only fill the system with deionized or distilled water. Use of any other water will damage the system and void the warranty.

Close the shutter on the laser head. Rotate the Flashlamp Voltage knob to the minimum energy START position. Press the START/STDBY button on the control panel to activate the pump. Add additional deionized (distilled) water, approximately 400 ml, until the reservoir is at least 75% full. The water level may be seen through the water level window on the front of the power supply. Press the OFF button. Replace the water fill cap. Note: The pump may require priming to initiate water flow. This may be done by squeezing the WATER OUT line on the back of the power supply to force some water into the pump. If that does not work, then disconnect the water hose at the WATER OUT connector and force water into the system from this connector on the back of the power supply

Chapter Four,
Operation

Starting the Laser

After the installation procedure is completed and the laser safety section is thoroughly understood, the laser may be started. All covers must be installed and the reservoir filled with deionized (distilled) water. See Figure 4-1 for location of controls on the control panel.

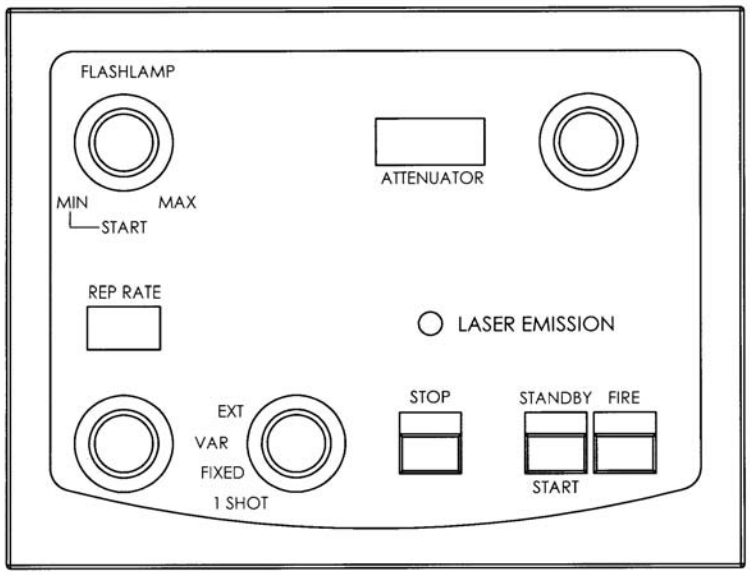


Figure 4-1: Control Panel Layout

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

2) Plug the laser power cord into the appropriate single phase power source. Place the power switch on the AC entry module to the ON position.

3) Turn the power supply key switch clockwise to the ON position.

4) Rotate the Flashlamp Voltage knob counterclockwise to the minimum, START position.

5) Press the START/STDBY button on the control panel until the power supply INTERLOCK LED is off and the control panel LASER EMISSION LED is on.

6) Note that after the LASER EMISSION LED is illuminated, there is an eight second delay before laser firing can occur.

7) Use the trigger selector switch to select the desired operation mode. The operating modes are described in the Triggering and Timing section below.

8) Open shutter when ready to operate safely (see safety section).

9) Press the Fire button on the control panel to initiate laser firing. Pressing the Fire button in 1 Shot mode will fire one shot. Pressing the Fire button in Var. or Fixed mode will fire the laser at the set repetition rate.

10) Rotate the Flashlamp Voltage knob clockwise until the desired relative energy is achieved.

Turning the Laser Off

The laser can be turned off at any time and will shut off automatically if an interlock is interrupted. There is a standard way to turn the laser off and this is performed using the following method.

1) Rotate the energy knob to the minimum (optional).

2) Press the OFF button.

3) Close the laser shutter (optional).

4) Turn the power supply key switch to the OFF position.

5) Turn the AC power line switch OFF.

Controls and Indicators

The Tempest Nd: YAG laser can be operated by using the standard control panel. The control panel connects to the laser power supply via a 10 ft (3 m) cable that allows the control panel to be placed in a convenient location. All controls and indicators are located on the control panel, except for the key switch, LED power ON indicator and INTERLOCK LED indicators, which are located on the power supply.

Power Supply

The AC input module is at the rear of the power supply. The power supply should be plugged into the standard single phase AC line. The AC Power switch is located on the rear of the power supply. When the power supply is plugged in and the power switch is in the ON position the AC POWER ON LED on the power supply front panel will illuminate. The KEY switch is located on the power supply front panel. When the key switch is in the ON position the INTERLOCK LED will illuminate. The laser cannot operate with the key in the OFF position, so removing the key will serve to prevent unapproved laser usage. The key switch cannot be removed while in the ON position.

The LASER ON LED on the power supply is redundant with the laser emission LED on the remote control. This LED is illuminated when the laser is powered and can be fired.

The interlock LEDs are located on the front panel of the power supply. The INTERLOCK LED will be illuminated when an internal or an external interlock has been activated. The internal interlock is located in the laser head. The laser head cover cannot be removed without activating this interlock. The external interlock is located on the back of the power supply, and can be put in series with a laboratory door or some other circuit for safety purposes.

Control Panel

There are several controls and indicators on the control panel to make it easy to operate the laser. Three knobs on the control panel are used to set the flashlamp voltage, the repetition rate and to select the firing mode. Three buttons on the control panel are used to stop the laser, fire the laser and to put the laser into standby mode. LEDs on the STANDBY and FIRE buttons indicate the actual state of the laser. A LASER EMISSION LED serves as warning when the laser is enabled to fire. An optional attenuator provides wide range energy adjustment without affecting beam quality.

Interlocks

The Tempest Nd: YAG laser system is equipped with both internal and external interlock switches. The interlocks are designed to ensure that the laser is operated only when this can be done in a safe manner. The internal interlocks ensure that the laser itself is safe and will not be damaged. The external interlock can be used to ensure that the surrounding facilities and people in the area are protected.

Internal Interlocks

The Tempest Nd: YAG laser system has the following internal interlocks:

1) Laser head cover opened
2) Control panel detached
3) Laser head umbilical detached
4) Cooling water temperature too high
5) Cooling water flow too low

External Interlock

The laser may be interlocked so that laboratory and room doors cannot be entered while the laser is running continuously. The connector on the back of the power supply may be wired so as to interrupt power to the supply, thus disabling the laser. If the external interlock circuit is opened the red INTERLOCK LED will be illuminated. To restart the laser, turn the key switch to the OFF position to reset the external interlock switch.

The laser may then be started using the procedure given above in the section "Starting the Laser."

Triggering and Timing

The process to fire the Tempest laser requires two steps. The first step is triggering the flashlamp, and the second is triggering the Q-switch. Both the flashlamp and the Q-switch can be triggered either internally or externally, resulting in four operating modes. The trigger mode is determined by the position of the toggle switches on the back of the power supply. The laser can also be controlled using the external TTL control, with input through the DB25 connector on the back of the power supply. The inputs, outputs and implications of the triggering mode are discussed in this section.

Inputs and Outputs

Four external BNC connectors are located on the back of the power supply. Two of the connectors are inputs for triggering the laser. The other two are outputs used for synchronizing the laser to other equipment. The location of the BNC I/O connectors is shown in Figure 3-1, with detail in Figure 4-2.

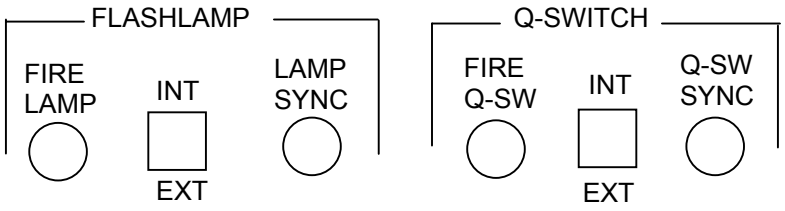


Figure 4-2: Power Supply BNC input/output Connections

- Fire Flashlamp – A positive 5 volt, 10 millisecond, 5 mA pulse. This input will fire the flashlamp. The Q-switch will be fired after the default Q-switch delay if the Q-switch toggle switch is set to the "INT" position.

- Fire Q-switch – A positive, 5 volt, 10 millisecond, 5 mA pulse. This input will fire the Q-switch at a user defined time if the Q-switch toggle switch is set to the "EXT" position.

- "Lamp Sync Out" – A 5 volt, 20 microsecond pulse. A positive transition from 0 volts to +5 volts occurs when the flash lamp is fired. With the default Q-switch delay, the laser pulse exits the laser head approximately 180 microseconds after the lamp synch out signal.

- "Q-Switch Sync Out" – A 5 volt, 10 microsecond pulse. A positive transition from 0 volts to +5 volts occurs when the Q-switch is energized. The laser pulse will exit the laser head approximately 130 nanoseconds after this signal.

- "Q-switch Source":
  "INT" – The Q-switch will fire after the default Q-switch delay. The Q-switch delay is started after a flashlamp fire signal a) has been input into the "Flashlamp Fire" BNC or b) the front panel trigger control is set to "1 Shot", "Fixed" or "Variable," and the Fire button has been pressed.
  "EXT" – The Q-switch will fire at a user defined time when a pulse is input to the "Q-switch Trigger" BNC. NOTE: Pulse energy and pulse stability will vary depending upon the timing between the "Fire Laser" signal and the "Fire Q-SW" signal. Refer to Figure 4-3, the timing diagram for the optimum setting for the highest pulse energy and the best pulse to pulse stability.

- "Flashlamp Source":
  "INT" – The flashlamp will be fired by the control electronics at the repetition rate set through the control panel.
  "EXT" – The flashlamp will be fired at a user defined time. The flashlamp will fire after receiving the trigger from the "Flashlamp Trigger" BNC.

Internal Triggering

Internal triggering is the simplest way to run the Tempest Nd: YAG laser. The control electronics provide the necessary triggers to fire the laser. The flashlamp and Q-switch toggle switches should both be up, in the INT position. The repetition rate and energy can be changed by the controls on the control panel.

The trigger selector switch determines the operating mode, 1 shot, continuous or variable. In 1 shot mode, the laser is fired once each time the Fire button on the control panel is pressed. In fixed mode, the laser fires at the maximum repetition rate of the laser. In Variable mode, the laser fires at the repetition rate set by the control knob, shown in the LED display. In Fixed and Variable modes the laser begins firing when the Fire button on the control panel is pressed.

Two output signals are available to synchronize the Tempest and the user's setup. The relationship between the synchronization pulses and the laser pulse are shown below in Figure 4-3.

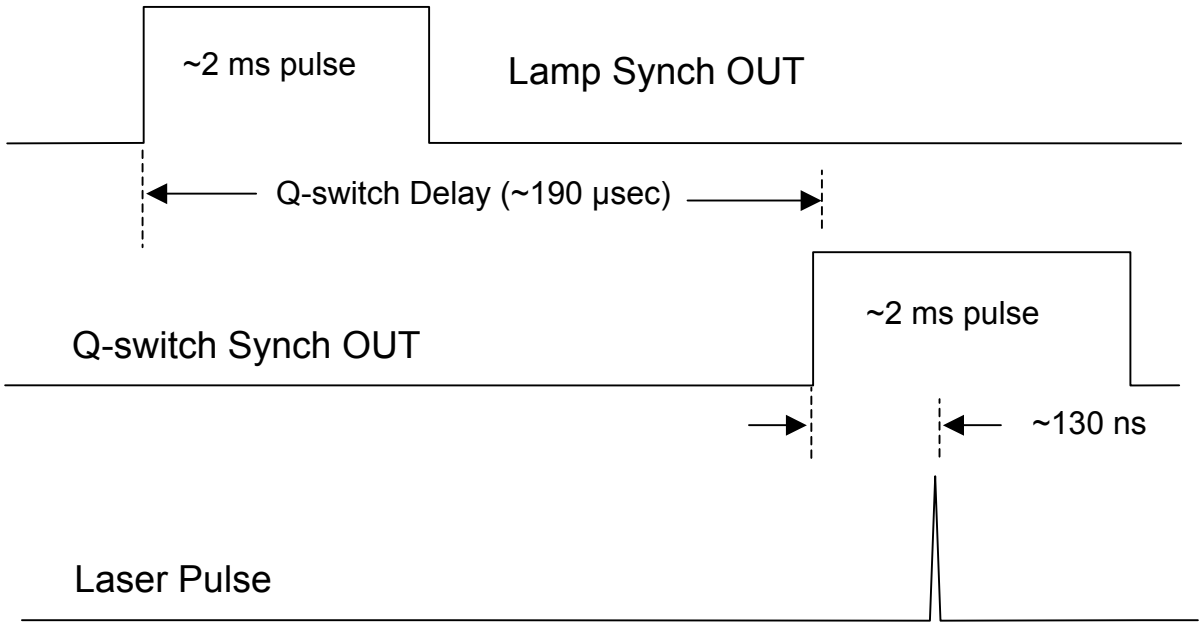


Figure 4-3: Timing Diagram for Internal Triggering

External Triggering

External triggering gives the user control over the timing of the laser pulse. The user must supply TTL pulses to the flashlamp and Q-switch trigger with the appropriate delay. The Flashlamp and Q-switch toggle switches should both be down, in the EXT position. The delay between the flashlamp and the Q-switch TTL fire pulses is important in getting the best laser performance.

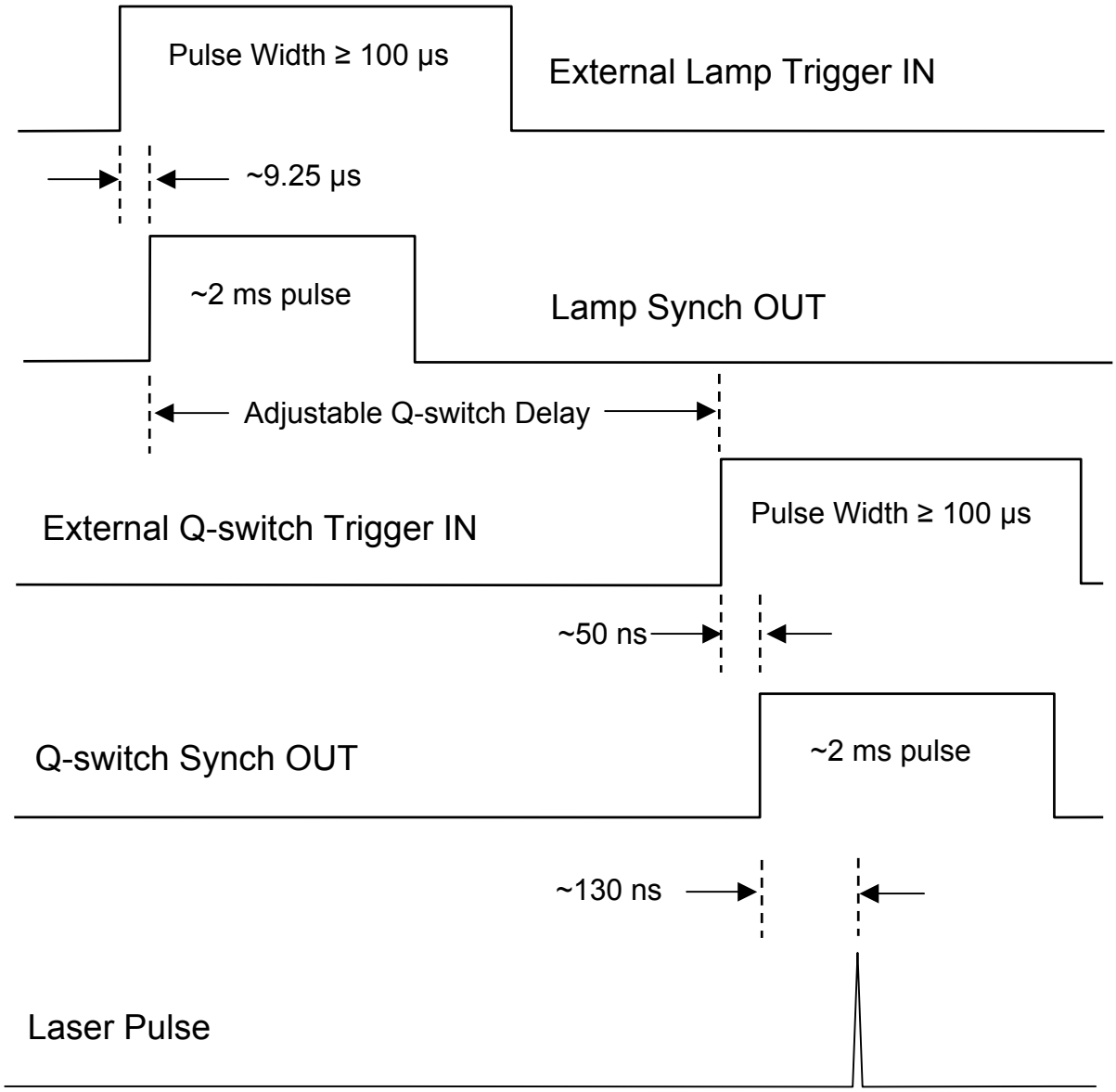


Figure 4-4: Timing Diagram for External Triggering

External Q-switch Triggering

External Q-switch triggering allows the user to fire the Q-switch externally while the internal electronics control the flashlamp firing. The user must supply a TTL pulse to the Q-switch trigger with the appropriate delay following the internal flashlamp pulse. The Flashlamp toggle switch should be up (INT) and the Q-switch toggle switch should be down (EXT). The delay between the flashlamp and the Q-switch TTL fire pulses is important in getting optimum laser performance.

The trigger selector switch on the control panel determines the operating mode, 1 shot, continuous or variable. In 1 shot mode, the flashlamp is fired once each time the Fire button on the control panel is pressed. In Fixed mode, the flashlamp fires at the maximum repetition rate of the laser. In Variable mode, the flashlamp fires at the repetition rate set by the control knob, shown in the LED display. In Fixed and Variable modes the flashlamp begins firing when the Fire button on the control panel is pressed.

The Q-switch must be fired using a user supplied TTL pulse at the Q-switch fire BNC. The flashlamp synch out pulse may be used to trigger an external delay generator that creates the Q-switch fire TTL pulse.

External Flashlamp Triggering

External flashlamp triggering allows the user to fire the flashlamp externally while the internal electronics control the Q-switch firing. The user must supply a TTL pulse to the flashlamp trigger to start the laser firing sequence. The internal electronics will fire the Q-switch after the default delay. The Flashlamp toggle switch should be down (EXT) and the Q-switch toggle switch should be up (INT). The delay between the flashlamp and the Q-switch TTL fire pulses is important in getting optimum laser performance.

External TTL Direct Triggering

External TTL direct triggering allows the user to externally control many laser parameters. User supplied control signals are sent through the TTL Direct DB 25 connector on the back of the power supply. The impedance of the signal inputs is approximately 1 MΩ. The remote box must be removed because it is plugged into the TTL port (see pg 19). The flashlamp and Q-switch toggle switches should both be up, in the INT position. The control electronics provide the necessary triggers to fire the laser in the selected mode.

The pin assignments for the DB 25 connector are shown in Table 4-1. Further explanation of the control signal inputs and feedback signals are given in Tables 4-2 and 4-3, respectively.

Table 4-1: DB 25 Pin Assignments

Input/Output	Pin	Function	Signal	Mode
Input	1	Start/Stop Laser. See table 4-2.	+ 5 VDC	Level
Output	2	Laser Ready	+ 5 VDC	Level
Input	3	Inhibit Q-switch	+ 5 VDC	Level
Input	4	External Single Shot Trigger	+ 5 VDC	Pulse
Input	5	Enable External Fixed	+ 5 VDC	Level
Input	6	Enable External Variable Rep Rate	+ 5 VDC	Level
Input	7	External Variable Rep Rate Set	0 – 5 VDC	Analog
Input	8	External Attenuator Set	0 – 5 VDC	Analog
Input	9	External PFN Voltage Set	0 – 5 VDC	Analog
Output	10	Lamp Sync Out	+ 5 VDC	Pulse
Output	11	Interlock ok	+ 5 VDC	Level
Input	12	Stop	+ 5 VDC	Pulse
Input	13	Enable TTL Direct Port	+ 5 VDC	Level
	14	Ground		
	15	Ground		
	16	Ground		
	17	Ground		
	18	Ground		
	19	Ground		
	20	Ground		
	21	Ground		
	22	Ground		
	23	4x rate (system use only)		
	24	500 Hz (system use only)		
	25	+12 switched (do not use)	+12Vds	level

Table 4-2: TTL Direct Control Signals

Pin	Function	Function
1	Start/Stop Laser	0 VDC level turns laser off. +5 V level turns laser on—must be held high for laser to operate. The laser will not fire for eight seconds after this signal is set high. If a signal (500 µs pulse) is placed on pin 12, the laser may not be restarted until pin 1 is reset to 0 VDC and then back to 5 VDC.
3	Inhibit Q-switch	0 VDC level allows Q-switch to operate normally + 5 VDC level inhibits Q-switch—lamp will fire normally, but no laser pulse is emitted. Used for warm up.
4	External Single Shot Trigger	+ 5 VDC, 500 µs pulse fires a single laser shot.
5	Enable External Fixed	+ 5 VDC level fires the laser at a fixed, maximum repetition rate of the laser.
6	Enable External Variable Rep Rate	+ 5 VDC level fires the laser at a variable repetition rate, determined by the external variable repetition rate set by pin 7.
7	External Variable Rep Rate Set	0 – 5 VDC analog level, with 5 VDC corresponding to the maximum laser repetition rate.
8	External Attenuator Set	0 – 5 VDC analog level, with 0 VDC corresponding to minimum energy and 5 VDC corresponding to maximum energy.

9	External PFN Voltage Set	0 – 5 VDC analog level, with 5 VDC corresponding to the maximum laser energy.
12	Stop	A 5 V, 500 µs pulse stops the laser from firing and places the laser in the STOP mode.
13	Enable TTL direct port	0 VDC level ends Ext TTL, and shuts the laser off. +5 V level enables Ext TTL control—must be held high for laser to operate.

Table 4-3: TTL Direct Feedback Signals

2	Laser Ready	0 VDC level, laser is not ready to fire. +5 VDC level that goes high when the laser is ready to fire, eight seconds after pin 1, Start/Stop laser is brought high.
10	Lamp Sync Out	A 2 milliseconds pulse is generated each time the flashlamp fires. The Q-switch will fire after the default delay of ~ 190 microseconds.
11	Interlock OK	+5 VDC level indicates the interlock is OK (closed). O VDC level indicates the interlock is open. The laser will not fire in this condition.

Harmonic Generators

Tempest Nd:YAG laser systems can be purchased with optional second, third and fourth harmonic generators. The desired wavelength is generally selected using dichroic mirrors to reflect the selected wavelength and transmit the undesired wavelengths to a beam dump.

The procedures described below require the laser to be operated with the laser head cover open and the interlock defeated. Stray IR and visible laser radiation may be generated. For safety reasons room access should be limited and everyone in the room should wear safety glasses.

Second Harmonic Installation

The second harmonic generator is used to produce visible radiation at 532 nm. The 1064 nm fundamental beam is polarized vertically. The second harmonic generation process is Type II in KTP, so the fundamental polarization vector must be oriented at 45° with respect to the x-axis. This is accomplished with a half wave plate that is mounted on the input to the SHG housing. The SHG crystal is oriented so that the second harmonic output is vertically polarized. Use the following procedure to install the second harmonic generator.

1) Remove the Tempest laser head cover and install the interlock defeat.

2) Install the second harmonic generator using the alignment pins and screw holes closest to the laser head. Insure that the harmonic generator housing is installed such that it is flush against the second alignment pin.

3) Install the 532 nm dichroic separation mirrors using the alignment pins and screw holes closest to the beam exit.

4) Turn the laser on at low energy to ensure that the beam is passing through the center of the SHG crystal. Increase the lamp voltage to increase the SHG energy.

5) Release the half wave plate set screw on the top of the second harmonic generator housing, Figure 4-5. Rotate the half wave plate to maximize the green energy (532 nm) output.

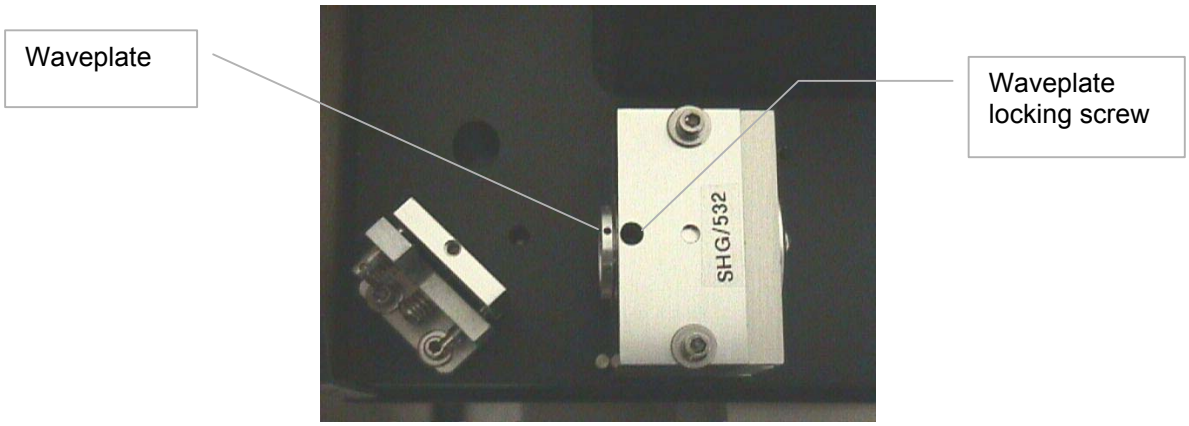


Figure 4-5: Second harmonic Waveplate Optimization

6) Rotate the second harmonic generator crystal to optimize the phase matching angle and maximize the 532 nm energy. The crystal angle may be adjusted using a trim pot adjustment tool or small screwdriver, Figure 4-6.

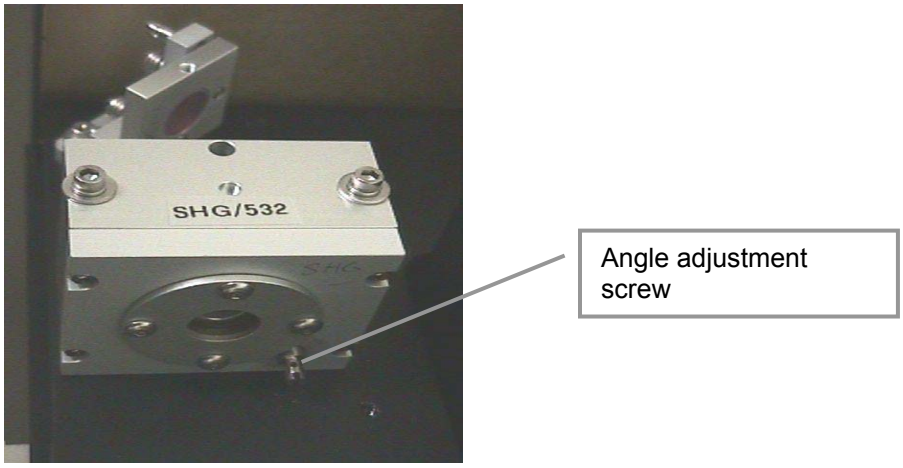


Figure 4-6: Second harmonic Angle Adjustment

7) Remove the interlock defeat and reinstall the Tempest laser head cover.

Third Harmonic Installation

The third harmonic generator (THG) crystal may be used to provide UV radiation at 355 nm. The third harmonic generation process is Type I in BBO, created with horizontally polarized fundamental and second harmonic light. A half wave plate for the second harmonic is mounted on the input to the THG housing. The third harmonic output is vertically polarized. The THG housing may be installed by the end user. THG generation requires that the SHG crystal has been installed and is aligned.

1) Remove the Tempest laser head.

2) Insure that the second harmonic generator is installed according to the preceding instructions.

3) Install the third harmonic generator using the second set of alignment pins and screw holes. Insure that the harmonic generator housing is installed such that it is against the second alignment pin.

4) Install the 355 nm dichroic separation mirrors using the alignment pins and screw holes closest to the beam exit.

5) Adjust the wave plate on the second harmonic generator housing to maximize the 355 nm energy.

6) Adjust the external screw on the THG housing to optimize the crystal angle, maximizing 355 nm energy.

7) Reinstall the harmonic generator housing cover.

NOTE: DO NOT DISASSEMBLE THE HARMONIC GENERATOR. THE CRYSTAL INSIDE IS HYGROSCOPIC. DUST, DIRT AND HUMIDITY WILL DESTROY THE CRYSTAL.

Fourth Harmonic Installation

The fourth harmonic generator is used to produce ultraviolet radiation at 266 nm by doubling the second harmonic output in BBO. A half wave plate for the second harmonic is mounted on the input to the fourth harmonic housing. The fourth harmonic output is vertically polarized. Fourth harmonic generation (4HG) requires that the SHG crystal has been installed and is aligned. Use the following procedure to install the fourth harmonic generator.

1) Remove the Tempest laser head cover.

2) Insure that the second harmonic generator is installed according to the instructions given above.

3) Install the fourth harmonic generator using the second set of alignment pins and screw holes. Insure that the harmonic generator housing is installed such that it is against the second alignment pin.

4) Install the 266 nm dichroic separation mirrors using the alignment pins and screw holes closest to the beam exit.

5) Adjust the wave plate on the second harmonic generator housing to maximize the 266 nm energy.

6) Adjust the external screw on the 4HG housing to optimize the crystal angle, maximizing 266 nm energy.

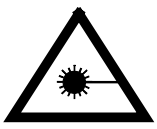
7) Reinstall the harmonic generator housing cover.

NOTE: DO NOT DISASSEMBLE THE FOURTH HARMONIC GENERATOR. THE CRYSTALS INSIDE ARE HYGROSCOPIC. DUST, DIRT AND HUMIDITY WILL DESTROY THE CRYSTALS.

Gemini PIV Alignment

The Gemini PIV laser is a dual head, independently triggerable system. The fundamental laser output beams are polarization combined, then frequency doubled in KTP. The temporally separated visible pulses must generally overlap each other to produce the best signal in the PIV experiment.

The alignment is optimized by adjusting the beam from laser 2 to overlap the beam from laser 1 as shown in Figure 4-7. The beam from laser 1 is fixed and cannot be adjusted, so beam overlap is optimized by steering the beam from laser 2. This is an iterative process, switching between overlap measurements at the laser head and at a distance several meters from the head. The following procedure provides a tested method to align the beams from the two laser heads.



The procedures described below require the laser to be operated with the harmonic head cover open and the interlock defeated. Stray IR and visible laser radiation may be generated. For safety reasons room access should be limited and everyone in the room should wear safety glasses.

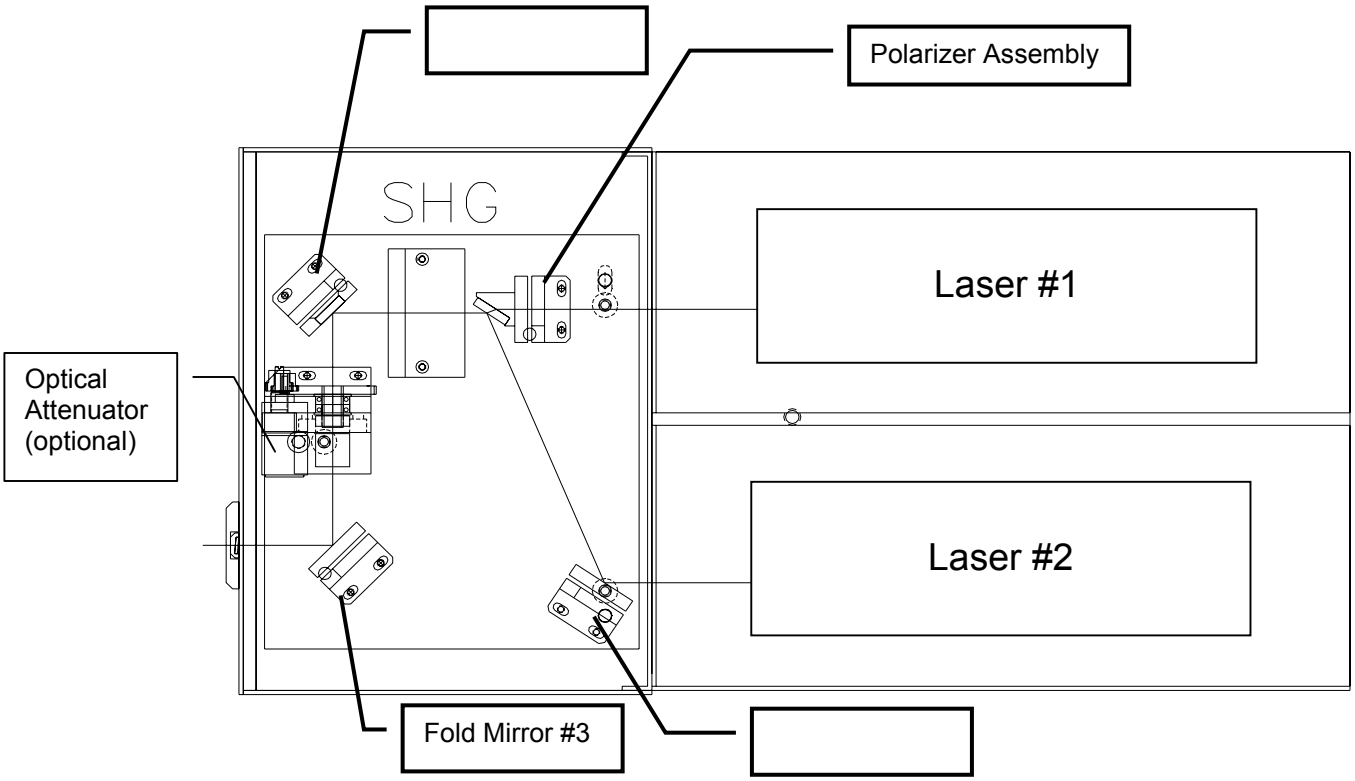


Figure 4-7: Gemini PIV Beam Overlap Adjustment

1) Remove the smaller optics head cover to provide access to the beam combining optics and second harmonic generator. Install the interlock defeat mechanism.

2) Put both lasers into standby mode with the flashlamp voltage just above threshold for generating second harmonic light.

3) Observe the overlap of the two beams at the point where PIV measurements will be made. Adjust the polarizer assembly mount to optimize the overlap of the two beams. Note that the top adjustment screw on the mirrors controls vertical beam motion, while the bottom adjustment screw controls horizontal motion.

4) Observe the overlap of the two beams from the measurement area to the laser. You have finished the alignment if the beams overlap over the entire distance. If not, continue with step 5.

5) Fire laser #1 and observe the position of the visible beam on the folding mirror immediately after the second harmonic generator.

6) Fire laser #2 and note the position of the beam on the mirror, relative to the beam from laser #1. Adjust the fold mirror #1 to overlap the two visible beams immediately after the second harmonic generator.

7) Observe the overlap of the two beams at a point 1-2 meters away from the laser head.

8) Adjust the polarizer assembly mount to optimize the overlap of the two beams.

9) Repeat steps 5 – 8 to get the optimal overlap between the beams from laser #1 and laser #2. The overlap can be observed along the beam line from the laser head exit for several meters.

10) Turn off both lasers and reinstall the secondary head cover. Check the alignment with both lasers operating at the desired energy.

Gemini UV Operation

An optional configuration of Gemini includes an extetnded base plate that allows installation of a third or fourth harmonic generator to produce UV wavelengths. In this configuration the Gemini can operate at 532 nm or 266 nm using both laser heads or at 355 nm using only one laser head. The green (532 nm) wavelength is generated as in the standard Gemini. The UV wavelength (355 nm or 266 nm) is generated by placing the third (355 nm) or fourth (266 nm) harmonic generator in the beam path just before the dichroic mirror set near the exit aperture. See Figure 4-8.

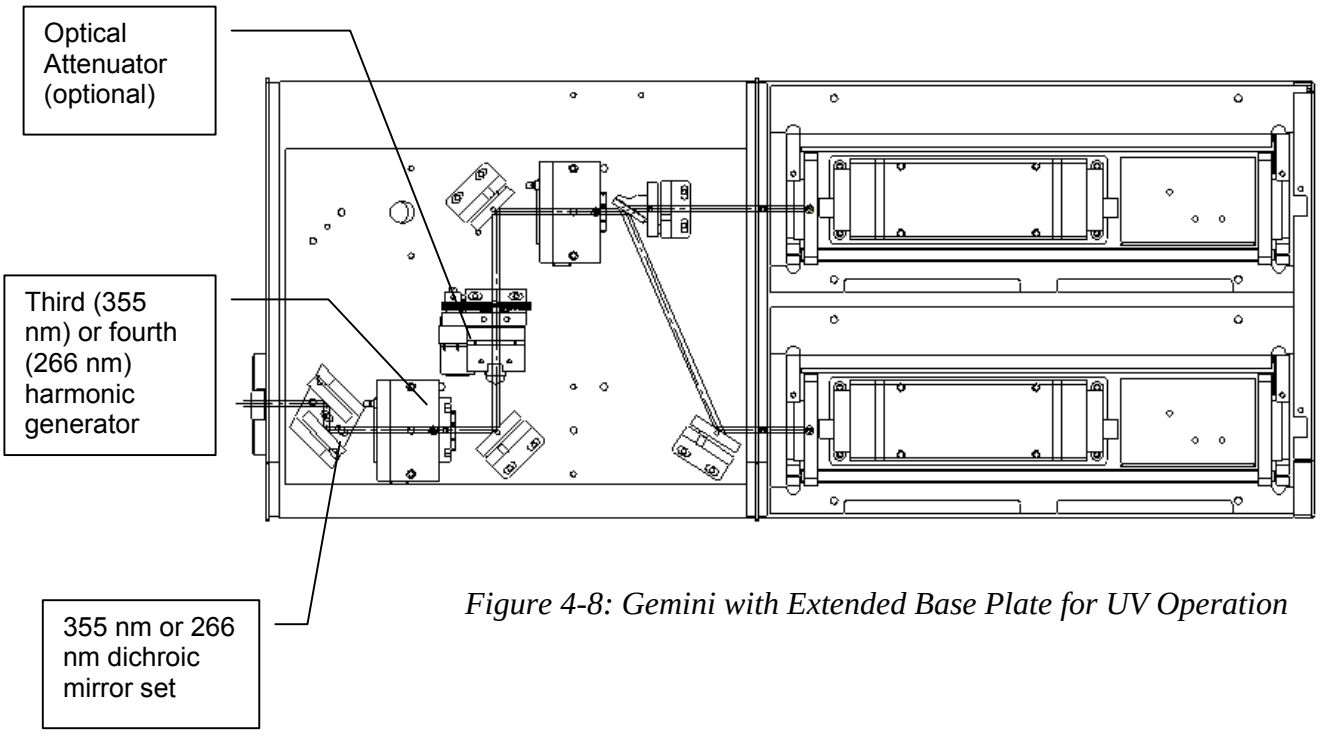


Figure 4-8: Gemini with Extended Base Plate for UV Operation

Third Harmonic Installation

The third harmonic generator (THG) crystal may be used to provide UV radiation at 355 nm. The third harmonic generation process is Type I in BBO, created with horizontally polarized fundamental and second harmonic light. A half wave plate for the second harmonic is mounted on the input to the THG housing. The third harmonic output is vertically polarized. The THG housing may be installed by the end user. THG generation requires that the SHG crystal has been installed and is aligned. Third harmonic energy (355 nm) energy may be optimized for only one laser head. Installation is described below.

1) Remove the laser head harmonic housing (front) cover.

2) Install the third harmonic generator using the last set of alignment pins and screw holes just before the dichroic mirror set next to the exit aperture. Insure that the harmonic generator housing is installed such that it is against the second alignment pin.

3) Remove the 532 nm dichroic mirror set closest to the exit aperture and install the 355 nm dichroic mirror set using the same alignment pins and screw holes.

4) Adjust the wave plate on the second harmonic generator housing to maximize the 355 nm energy, figure 4-5. This adjustment maximizes 355 nm energy for only one laser head.

5) Adjust the external screw on the THG housing to optimize the crystal angle, maximizing 355 nm energy. The crystal angle may be adjusted using a trim pot adjustment tool. Only one laser head will be optimized for 355 nm energy.

6) Reinstall the laser head harmonic generator housing (front) cover.

Fourth Harmonic Installation

The fourth harmonic generator is used to produce ultraviolet radiation at 266 nm by doubling the second harmonic output in BBO. A half wave plate for the second harmonic is mounted on the input to the fourth harmonic housing. The fourth harmonic output is vertically polarized. Fourth harmonic generation (4HG) requires that the SHG crystal has been installed and is aligned. Fourth harmonic generation may be optimized for both laser heads. Use the following procedure to install the fourth harmonic generator.

1) Remove the laser head harmonic housing (front) cover.

2) Install the fourth harmonic generator using the last set of alignment pins and screw holes closest to the dichroic mirror set next to the exit aperture. Insure that the harmonic generator housing is installed such that it is against the second alignment pin.

3) Remove the 532 nm dichroic mirror set closest to the exit aperture and install the 266 nm dichroic mirror set using the same alignment pins and screw holes.

4) Adjust the wave plate on the second harmonic generator housing to maximize the 266 nm energy, Figure 4-5. The adjustment that maximizes 266 nm energy for one laser head will also maximize it for the second laser head.

5) Adjust the external screw on the 4HG housing to optimize the crystal angle, maximizing 266 nm energy. The crystal angle may be adjusted using a trim pot adjustment tool. This adjustment maximizes 266 nm energy for both laser heads.

6) Reinstall the laser head harmonic generator housing (front) cover.

NOTE: DO NOT DISASSEMBLE THE THIRD OR FOURTH HARMONIC GENERATORS. THE CRYSTALS INSIDE ARE HYGROSCOPIC. DUST, DIRT AND HUMIDITY WILL DESTROY THE CRYSTALS.

Return to 532 nm operation

Use the following procedure to remove UV harmonic generators and return the Gemini to 532 nm operation.

1) Remove the laser head harmonic housing cover.

2) Remove the third or fourth harmonic generator.

1) Remove the 355 nm or 266 nm dichroic mirror set. Install the 532 nm dichroic mirror set.

2) Release the half wave plate set screw on the top of the second harmonic generator housing, Figure 4-5. Rotate the half wave plate to maximize the green energy (532 nm) output.

3) Rotate the second harmonic generator crystal to optimize the phase matching angle and maximize the 532 nm energy. The crystal angle may be adjusted using a trim pot adjustment tool or small screwdriver, Figure 4-6.

4) Reinstall the laser head harmonic generator housing cover.

Chapter Five,
Maintenance

NEW WAVE
RESEARCH

Introduction

The Tempest Nd:YAG laser is a high power laser system and it is important to keep the laser clean and well maintained. This section describes several procedures that should be performed on a regular basis to ensure that the laser system works properly for many years.

It is recommended to inspect the optics in the laser once per month for burn marks, dust or scratches.

The most common reason for decreased performance in a high power laser system is dirty optics.

Cooling System

If a noticeable drop in laser energy has occurred, it may be necessary to flush the cooling system to remove any contaminants. Carbon dioxide from the air and metal ions will naturally collect in the cooling water over time. Running the pump allows the deionizing filter to purify the water

Circulate the cooling water by running the laser power supply and pump at least 30 minutes each week. This is essential to prevent the build-up of contaminants in the system, which will be deposited on the flash lamp and laser rod resulting in decreased output energy. If you cannot run the laser at least 30 minutes each week, you must completely drain the cooling system and blow clean, dry compressed air or nitrogen through the lines.

WARNING!!! Never add tap water to the cooling system. Only deionized or distilled water may be used.

Deionization Cartridge Replacement

The deionization cartridge must be replaced approximately once every two years. The following procedure can be used to replace the deionization cartridge.

1) Turn the flashlamp voltage knob fully counterclockwise to the minimum position.

2) Disconnect the lower WATER RETURN hose from the back of the power supply and hold it over a drain container.

3) Depress the START/STDBY button on the control panel to start the pump. The pump will force the cooling water from the hose into the drain container. Repeatedly press the START/STDBY button down

until all water has been pumped out of the system. Press the OFF button on the remote to stop the pump.

4) Turn the power supply off with the switch at the AC power entry module on the back of the power supply, and disconnect the AC power cord from the power supply.

5) Remove the power supply cover.

6) Disconnect the hose from the top of the deionization cartridge, Figure 5-1.

7) Disconnect the hose from the bottom of the deionization cartridge, Figure 5-1.

Figure 5-1. Cooling System in the Power Supply

8) Unscrew the clamp holding the deionization cartridge in place and remove the deionization cartridge.

9) Connect the hose to the bottom of the new deionization cartridge. Reconnect the water hose to the top of the cartridge. Secure the water hoses on the cartridge connectors using tie wraps. Install the new deionization cartridge. Screw the clamp back in to secure the cartridge in place.

10) Refill the cooling system with deionized or distilled water and run the system briefly to check for leaks before replacing the power supply cover. See Chapter 3, Installation, in the cooling system

section for detailed instructions. Disconnect power before replacing cover.

Cooling System Flush

If a noticeable drop in laser energy has occurred, it may be necessary to flush the cooling system to remove any contaminants. Carbon dioxide from the air and metal ions will naturally collect in the cooling water over time. The cooling system can be cleaned using a dilute acetic acid solution. Follow the procedure below to flush the cooling system:

1) Turn the flashlamp voltage knob on the control fully counterclockwise to the minimum.

2) Disconnect the lower WATER RETURN hose from the back of the power supply and hold it over a drain container.

3) Depress the START/STDBY button on the control panel to start the pump. The pump will force the cooling water from the hose into the drain container.

4) Remove the water out connection on the back of the power supply. Use clean compressed air or nitrogen to blow the remaining water from the laser head umbilical tubing. Also, blow clean compressed air or nitrogen into either hose fitting on the back of the power supply. Additional water will be forced into the reservoir. Remove this water with a syringe.

5) Turn the power supply off with switch at the AC power entry module on the back of the power supply, and disconnect the AC power cord from the power supply.

6) Clamp the water supply hose leading to the deionization cartridge at the T connection, Figure 5-2.

7) Reconnect the laser head umbilical hoses and power cable to the power supply.

Ensure that the deionization cartridge is bypassed before any acetic acid is added to the cooling system. Acetic acid will destroy the deionization cartridge.

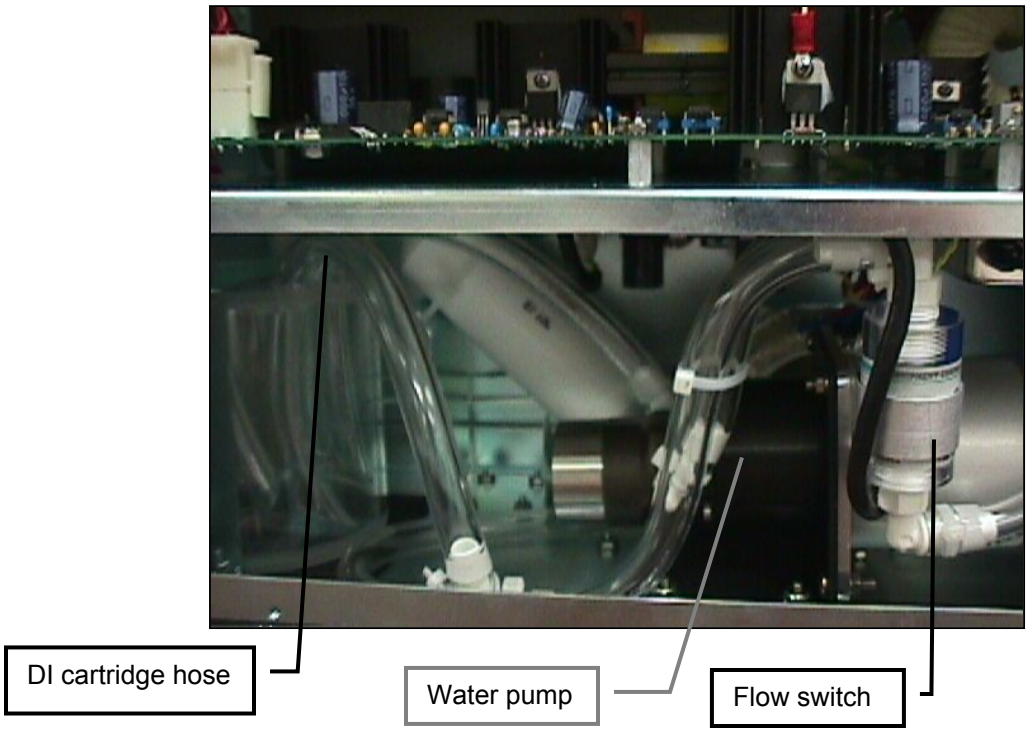


Figure 5-2. Deionization Cartridge and Water Reservoir

8) Refill the cooling system with a solution of 5% acetic acid in distilled water. Alternately, distilled white vinegar may be purchased at the grocery store and used. Start the power supply and add more of the solution to completely fill the system (reservoir about 80% full). See Chapter 2-2, Cooling System Installation.

9) Operate the power supply and cooling system for at least 6 hours with the acetic acid solution circulating through the laser head.

10) Completely drain the cooling system and blow the acetic acid solution from the system.

11) Completely refill the cooling system with pure deionized water.

12) Operate the system for at least 2 hours. The deionization cartridge is still bypassed. This flushes acetic acid and contaminants from the system.

13) Completely drain and refill the cooling system with new deionized or distilled water.

14) Operate the system for another two hours, then completely drain and blow the lines.

15) Completely fill the system again with pure deionized/distilled water. Reconnect the deionization cartridge to maintain the water purity. The laser is now flushed. Run the laser for thirty minutes, then optimize the system for laser output. Measured output should be back to normal.

Flashlamp Replacement

The flashlamp needs to be changed when the specified energy cannot be achieved or if the laser energy fluctuates significantly from shot to shot. This can be seen over the course of several hundred pulses. The flashlamp should be useful for at least 30 million shots. Use the following procedure to install a new flash lamp.

1) Place the power supply lower than the laser head.

2) Turn the power supply off with switch at the AC power entry module on the back of the power supply, and disconnect the AC power cord from the power supply.

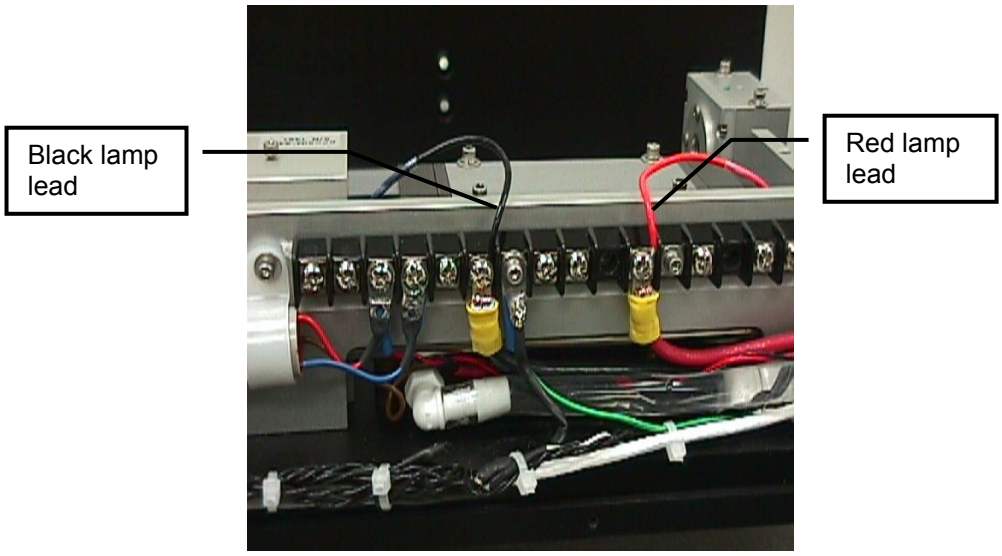


Figure 5-3. Removing Leads to Replace Flashlamp

3) Remove the RED and BLACK flashlamp leads from the terminal strip, Figure 5-3.

4) There are four screws, accessible from the top, that hold the pump chamber to the baseplate, Figure 5-4.

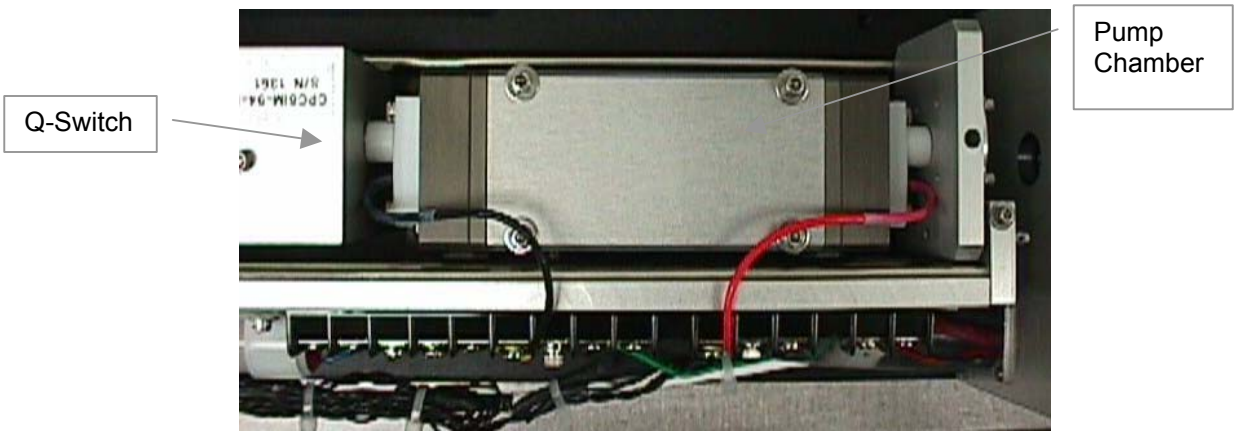


Figure 5-4. Pump Chamber Attachment Screws

5) Remove the pump chamber from the laser head and carefully place it on a clean surface.

6) Remove the pump chamber end caps that secure the flashlamp within the pump chamber, Figure 5-5.

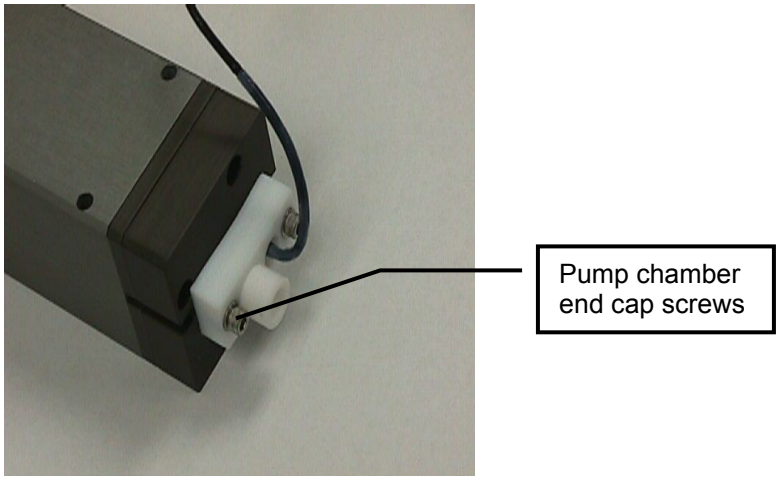


Figure 5-5. Removal of Pump Chamber Assembly End Cap

7) Carefully straighten the lamp leads and remove the flash lamp from the pump chamber. Note the position of the RED and BLACK lamp leads.

8) Install the new flashlamp with the RED and BLACK leads on the same side as the original lamp. Bend the lamp leads so that they are perpendicular to the lamp.

Do not touch the glass surface of the lamp with your bare fingers, or other skin. This may leave grease marks that will degrade lamp performance and may shorten lamp lifetime

9) Slide the o-rings over the flashlamp lead and into place using tweezers. Reinstall the pump chamber end caps and carefully tighten the screws to hold the lamp in place.

10) Carefully check the two o-rings on the resonator base plate, Figure 5-6. The o-rings seal the pump chamber against water leaks. Ensure that the o-rings are in place, before replacing the pump chamber in the resonator.

11) Check that the four ball bearings in the laser base plate are in place. The ball bearings locate the pump chamber with respect to the laser baseplate.

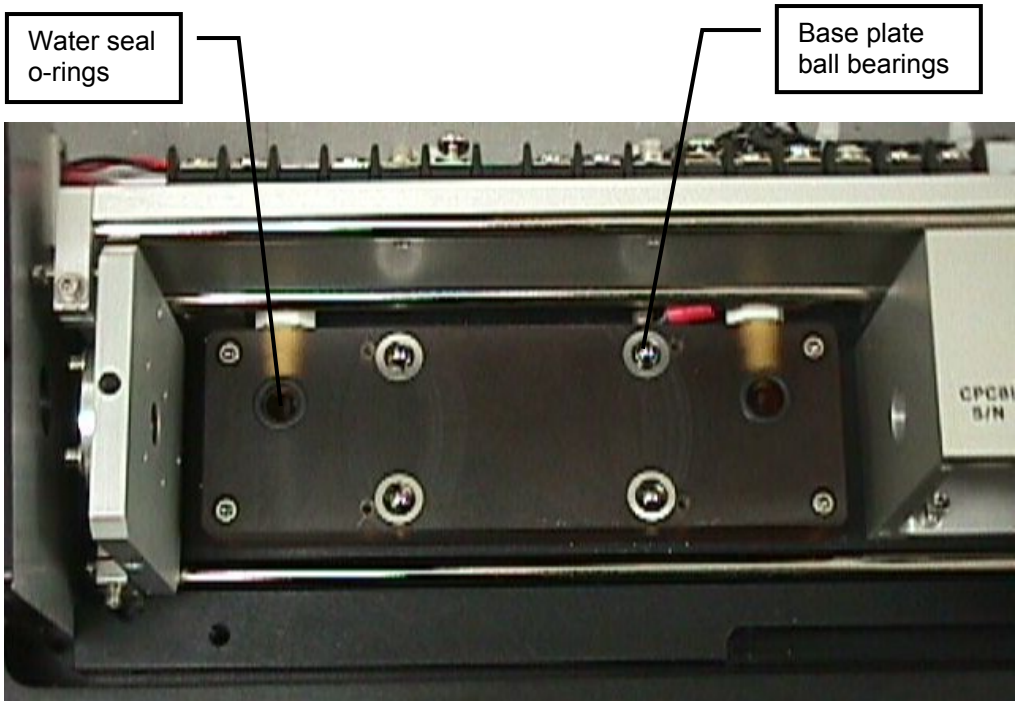


Figure 5-6. Pump Chamber Water Seal O-rings

12) Reinstall the pump chamber, observing that the Nd:YAG rod is in line with the mirrors and the black flashlamp lead is on the end by the Q-switch. Tighten the four screws to connect the pump chamber to the base plate.

13) Reconnect the RED and BLACK flashlamp leads, as shown in Figure 5-3.

14) Start the power supply and check the cooling system for leaks before replacing the laser head cover. Disconnect power before replacing the laser head cover.

Chapter Six,
Troubleshooting

Introduction

This chapter lists a number of conditions that may be observed during the lifetime of the Tempest Nd:YAG laser system. Following the list of conditions is a set of procedures that may be used for resolving specific conditions to improve laser performance.

Observed Conditions

To use this section, find the observed condition in this section that matches the condition of the laser. Follow the recommended procedure to correct the situation. If the problem cannot be resolved by following the procedure then phone New Wave Research at (510) 249-1550; FAX (510) 249-1551; or e-mail lasers@new-wave.com to get technical support for the laser.

Table 6-1: Observed Conditions

Observed Condition	**Recommended Procedure**
Laser does not start	Procedure 1
Laser starts, but no light is emitted	Procedure 2
Low output energy	Procedure 3
Unstable laser energy	Procedure 4
Clipped beam profile	Procedure 5
Low second harmonic energy	Procedure 6
Low third harmonic energy	Procedure 7
Low fourth harmonic energy	Procedure 8

Recommended Procedures

The following procedures should be followed to resolve the observed conditions listed in the section above. Please contact New Wave Research at Tel: 510-249-1550 FAX: 510-249-1551
for more detailed information regarding these procedures.

Procedure 1. Laser does not start

If the laser does not start, please check the following points.

- The laser AC power cord is plugged in and the outlet has power.
- The power switch on the AC power entry module is in the ON (I) position.
- The key switch on the power supply is turned to the ON position, and the AC power light is illuminated.
- The control panel flashlamp knob is rotated fully counterclockwise to the minimum start position.

- The water reservoir has been filled with distilled water.
- The umbilical from the laser head is securely attached to the power supply.
- The interlock shorting plug is secured in the socket on the back of the power supply.
- If the external interlock is utilized, ensure that the switch on the door interlock or other device is activated.

Procedure 2. Laser starts, but no light is emitted

When the laser is in the standby mode pressing the start button will cause the laser to begin firing. The LED above the fire button on the control panel should flash at the rep rate the laser is firing.

- Check that the mechanical shutter is open.
- Check that the flashlamp voltage is set to the maximum.
- For internal triggering, check that the flashlamp and trigger select switches on back of the power supply are both in the INT (up) position.
- For external triggering, check that the flashlamp and trigger select switches are in the desired positions. Check that TTL pulses are present at the BNCs. Check that the Q-switch delay is correct, typically 180 microseconds.

Procedure 3. Low fundamental output energy

If the laser output energy is low, please check the following points.

- The flashlamp voltage knob is rotated fully clockwise to the highest energy setting.
- If the optional attenuator is installed, ensure that the attenuator knob is rotated fully clockwise to the maximum energy/minimum attenuation setting.
- Check the optics to ensure that they are clean, and that none of the optics have any burn marks.

Procedure 4. Unstable laser energy

The pulse stability for the Tempest Nd:YAG laser is specified as ± 2% at 1064 nm for greater than 98% of pulses for 10,000 pulses after 30 min warm up. If the pulse stabilty at 1064 nm does not meet this specification then check the following.

- Check that the laser is running at full energy, with the lamp voltage is set to the maximum.

- Check the number of shots on the flash lamp. This can be estimated from the date of the last flash lamp change and the average usage per day. If the number of shots fired exceeds 30 million shots, change the flash lamp.

- For fluctuations in the laser energy in the harmonics check that the laser is running at full energy.

Call New Wave Research if it is not possible to increase the laser pulse energy by this procedure.

Procedure 5. Clipped laser beam

The output beam of the Tempest Nd:YAG laser should be round, symmetric with even energy distribution. An object in the beam path may clip the laser beamresulting in an output beam which appears asymmetric, with a sharp edge. If the output beam is clipped, check the following.

- Check the beam path to ensure that there are no foreign objects in the path.

- Turn the flashlamp voltage knob counterclockwise to reduce the energy to just above threshold. Trace the beam through the head examining the beam profile after each mount. Try to determine which mount is responsible for clipping the beam. Use an infrared card to view the beam before the harmonic generators.

- Check the dichroic mirrors and mounts to ensure that they are not clipping the beam.

- Check that the mechanical shutter is fully removed from the beam path and is not clipping.

- When you have found the object that is responsible for clipping the beam, correct the situation and ensure that the beam path is fully clear.

Procedure 6. Low second harmonic energy

If the second harmonic output energy is low, please check the following points.

- Check the dichroic mirrors to ensure that the SHG mirrors are installed, are clean and undamaged.

- Adjust the SHG crystal angle to maximize the output energy.
- Adjust the waveplate on the input to the SHG housing to maximize the energy.
- If the optional attenuator is installed, ensure that the attenuator knob is rotated fully clockwise to the maximum energy/minimum attenuation setting.
- Check the second harmonic crystal and housing to ensure that all surfaces are clean and undamaged.
- Check that the fundamental energy meets specifications. Ensure that the laser has been operating at least ten minutes to achieve an optimum operating temperature.

Procedure 7. Low third harmonic energy

If the third harmonic output energy is low, please check the following points.

- Check the dichroic mirrors to ensure that the THG mirrors are installed, and are clean and undamaged.
- Adjust the THG crystal angle to maximize the THG output energy.
- Adjust the waveplate on the input to the SHG housing to maximize the THG energy.
- Adjust the SHG crystal angle to maximize the THG output energy.
- If the optional attenuator is installed, ensure that the attenuator knob is rotated fully clockwise to the maximum energy/minimum attenuation setting.
- Check the harmonic crystals and housings to ensure that all surfaces are clean and undamaged.
- If none of the above work, check the 532 nm energy, then the 1064 nm energy.

Procedure 8. Low fourth harmonic energy

If the fourth harmonic output energy is low, please check the following points.

- Check the dichroic mirrors to ensure that the 4HG mirrors are installed, are clean and undamaged.

- Adjust the 4HG crystal angle to maximize the output energy.
- Adjust the wave plate on the input to the SHG housing to maximize the energy.
- Adjust the SHG crystal angle to maximize the output energy.
- If the optional attenuator is installed, ensure that the attenuator knob is rotated fully clockwise to the maximum energy/minimum attenuation setting.
- Check the harmonic crystals and housings to ensure that all surfaces are clean and undamaged.
- If none of the above work, check the 532 nm energy, then the 1064 nm energy.

Appendix A, Part Numbers

The following part numbers can be ordered by contacting the New Wave Research service department at Tel: 800-566-1743

Table B-1: Part Numbers for Laser Head

Flash lamp	0002-0036-1
Pump chamber	0002-6722
Q-switch/polarizer assembly	0002-6721
Simmer transformer	5600-6770
Nd:YAG rod	0002-0127-1
Mounted 1064 nm dichroics	0002-0526
Mounted 532 nm dichroics	0002-0516
Mounted 355 nm dichroics	0002-0527
Mounted 266 nm dichroics	0002-0528
Mounted SHG crystal	0002-6723
Mounted THG crystal	0002-6724
Mounted 4HG crystal	0002-6725

Table B-2: Part Numbers for Laser Power Supply

Deionization cartridge	1300-0001
Fan	2600-0004
Flow switch for pump	5200-0002
Water pump	5850-0003
Water reservoir	0002-0914

Appendix B, Limited Warranty

Tempest Nd:YAG Laser Operator's Manual

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