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Safe Operation and Alignment of the Variable Pulse Width Laser at the US Army Research Laboratory

by Eric S Collins and Jennifer L Gottfried

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14. ABSTRACT
The variable pulse width laser at the US Army Research Laboratory can output a maximum of more than 5 J per pulse at pulse widths between 50 µs to 10 ms. Maximum energy output is only achieved by proper alignment and laser operation. This report provides tips for safe operation to avoid damage to parts within the laser and provides details of a technique to align the variable pulse width laser that are not included in the operator's manual.

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pulse width, laser energy, laser alignment, peak power, laser operation

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Disclaimer: The authors of this report are not responsible for personal injury or property damage when operating or aligning the variable pulse width laser.

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1. Introduction

The variable pulse width laser at the US Army Research Laboratory is an ND:YAG laser from MegaWatt Lasers (Model #R5X75-01) with a 1,064-nm wavelength. A flashlamp controller with an external capacitor box from Analog Modules (Model #8800V-334) is used to control the stored voltage and pulse width setting to adjust the energy output of the variable pulse width laser. The capacitors store voltages up to 700 V, and the laser has a pulse width range between 50 µs and 10 ms. Research in the Laser Ignition in Guns, Howitzers and Tanks program in the 1990's featured a variable pulse width glass laser,[1–4] and the variable pulse width ND:YAG laser used in this study was previously used for research in the US Army Environmental Quality Basic Research and Development program.[5,6] It has recently been revived for use in a new laser ignition project.[7,8]

2. Energy Output of the Variable Pulse Width Laser

Measured energy output data was acquired from the initial installation of the laser in November of 2002[9] and was compared with the laser output measured on 4 December 2015 (Fig. 1). At a 5-ms pulse width, the original and current measured energy outputs were the same at lower voltage levels, and the difference between the 2 increased to only 3.5% at the higher voltage levels.

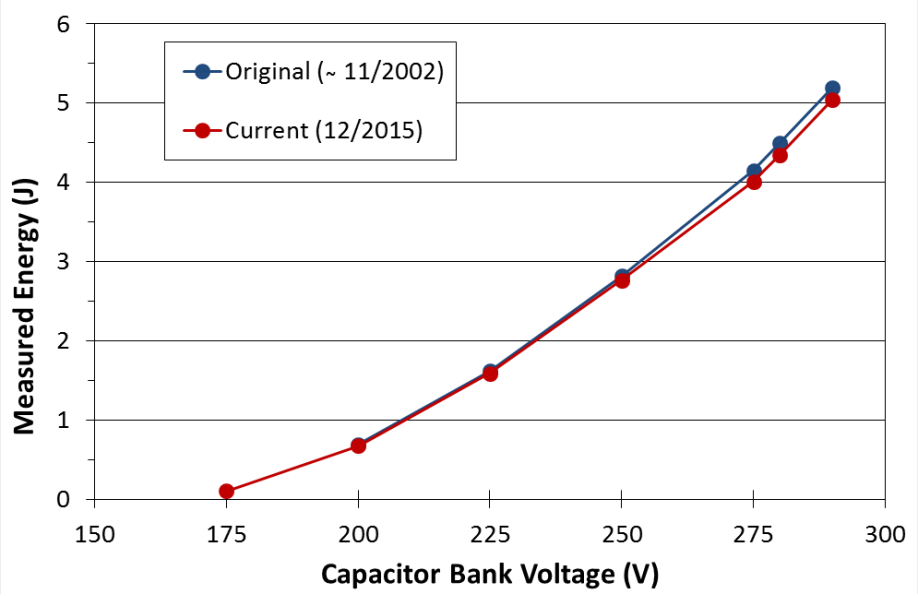

Fig. 1 Comparison of energy output of variable pulse width laser at its new and original state (approximately November 2002) and at its current state (December 2015)

The measured energy (Fig. 2A) and the peak power (Fig. 2B) with respect to pulse width are shown in Fig. 2 (as of 4 December 2015). Figure 2A shows that the maximum energy increased as the pulse width increased until 2.6 ms, at which point the energy decreased as the pulse width continued to increase. The maximum measured energy was 7.7 J at 2.6 ms. The peak power of each pulse was calculated by dividing the energy by the pulse width. The peak power increased as the stored voltage increased from 200 to 700 V.

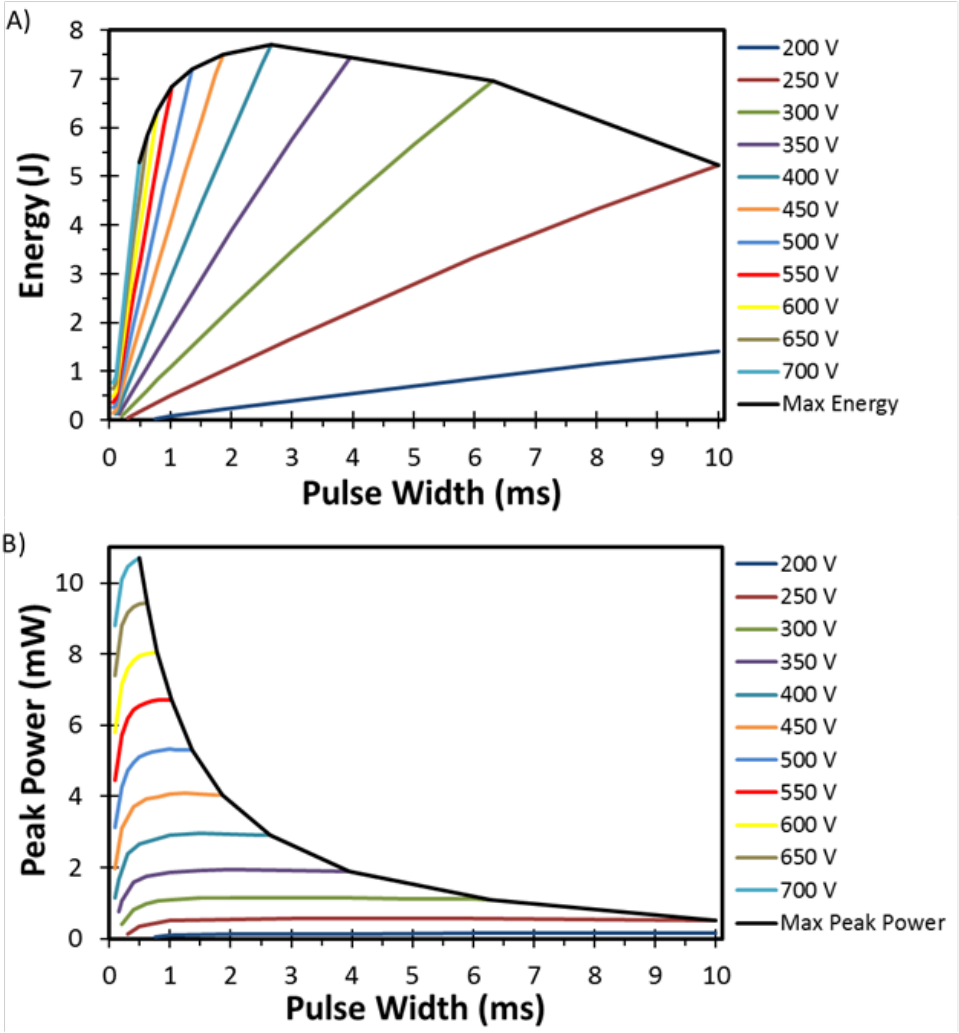

Fig. 2 Measured energy and peak power range of the variable pulse width laser

3. Operation of the Variable Pulse Width Laser

To operate the variable pulse width laser, turn the key switch to "ON" and wait for the 10-s audible delay period. From the main menu, press "D" to verify that the stored lamp parameters match the desired flashlamp operating parameters. Then go back to the main menu and press "B" to select the desired pulse rate mode and press

the letter corresponding to the desired mode, and then press the arrow up key to change that mode to “ON”. Press “A” to change the pulse rate if necessary. From the main menu, a preview of the laser settings can be displayed by pressing the “Previous Menu” key. In the Preview Menu window, the desired voltage and pulse width can be inputted by pressing “B”.

Press “RUN” to enable the system high voltage and wait a few seconds until the system has been fully charged and the display reads “HV fully charged…laser paused…press RUN to fire”. When RUN is pressed again, the laser will fire, and the display will read “Laser active…Press ‘RUN’ to pause”. When RUN is pressed again, the laser will stop firing but the charger will remain enabled. Pressing the RUN button will continue to toggle between the fire and pause modes. Pressing the “STOP” button will stop the laser and disable the charger. For more details on operating the laser, refer to “Section 3: Operating Instructions” of the operator’s manual.

4. Precautions for Using the Variable Pulse Width Laser

When operating at a high voltage, the flashlamp will break and/or the mirrors will become damaged if the voltage is decreased and the pulse width is increased simultaneously. After operating the laser at a high voltage, either press “STOP” on the flashlamp controller to discharge the capacitors or fire the laser a few times at the lower voltage setting to stabilize the voltage in the charged capacitor before increasing the pulse width.

Laser parts will become damaged if the voltage is deceased and the pulse width is increased because when the voltage is decreased, the capacitors are still charged at the higher voltage. Replacement part numbers for the flashlamp and the front and back mirrors are listed in the following Table. The front mirror from CVI is 1/4 inch thick, but the original front mirror in the laser was 3/8 inch thick. The energy output did not change when the 3/8-inch-thick mirror was replaced with the 1/4-inch mirror.

Table. Replacement parts for the items in the variable pulse width laser head

Item	PN	Description	Company
Flashlamp	EM1687	High performance	Fenix Technologies
Back mirror	Y1-0537-0-3.00cc	0.5-inch diameter, 3-m radius, 3/8 inch thick, 1,064 nm	CVI
Front mirror	PR1-1064-30-0525	0.5-inch diameter, 1/4 inch thick, R=30%, 1,064 nm	CVI

The flashlamp controller has an internal pump energy safety limit (set to 300 J), which was programmed into the controller to protect the flashlamp. If the safety limit is increased, the life expectancy of the flashlamp will decrease.

5. Alignment of the Variable Pulse Width Laser

The laser needs to be aligned regularly to ensure the energy output is maximized. Procedures for completing a coarse adjustment and a fine adjustment are outlined in Steps 1–5. First, in the flashlamp controller, set the pulse rate mode to "single shot" and set the laser voltage to 250 V and the pulse width to 10,000 μs. Place an energy meter in front of the laser, and fire the laser to observe the measured energy output. If the meter was not triggered, adhere to the following steps (beginning with Step 1) to conduct a coarse adjustment. If the meter was triggered, skip to Step 5 to conduct a fine adjustment to try to increase the energy output.

Step 1: Disconnect power

When aligning the variable pulse width laser, follow these first steps: 1) turn off the laser, 2) unplug the power cord to disable the flashlamp controller, and 3) disconnect the power cord to the laser head.

Step 2: Alignment of diode laser

Take out 4 screws to remove the plate located on the top of the laser head. Take out 4 more screws to remove the top piece of the pump chamber cover. As shown in Fig. 3, place a target directly in front of the variable pulse width laser and place a diode laser and iris directly behind the variable pulse width laser. Align the diode laser straight through the center of the ND:YAG rod and point it at the target. Make sure the laser spot on the target is at the same height as the diode laser (i.e., beam is horizontal). The purpose of the iris is to decrease the diameter of the diode laser beam, making it easier to visualize reflections.

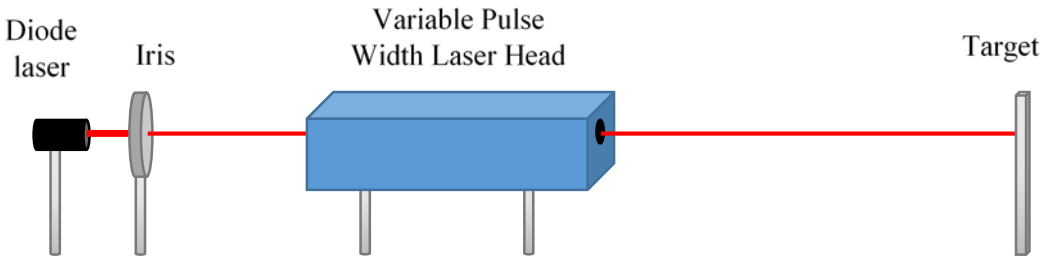

Fig. 3 Setup for alignment of variable pulse width laser

Step 3: Mirror adjustment

The front and back mirrors on the variable pulse width laser are aligned by adjusting the alignment screws on the mirror mounts to converge all reflections from the diode laser. Each mirror mount has 2 screws, one for vertical alignment and one for horizontal alignment. Place a beam block between the back mirror and the rod to observe reflections on the iris from the back mirror. Adjust the alignment screws on the back mirror such that all reflections are converged to the center hole of the iris. Then place the beam block between the rod and the front mirror and observe additional reflections that appeared on the iris. If additional reflections appeared on the iris, repeat Step 2 and Step 3 to make sure the diode laser is directed straight through the ND:YAG rod. Remove the beam block, and adjust the front mirror to converge all reflections to the center of the rod.

Step 4: Assemble laser

Once all reflections have been positioned to the center (in line with the diode laser), assemble the variable pulse width laser head by screwing in the pump chamber cover and the top plate. Plug in the flashlamp controller, and plug the power cord into the laser head and turn on the laser. Set the laser voltage to 250 V and the pulse width to 10,000 μs, and place the energy meter in front of the laser.

Step 5: Fine alignment

Fire the laser and observe the energy output on the energy meter. Make very small adjustments to one of the alignment screws and refire the laser. If the laser energy increased, continue rotating the screw in the same direction, making very fine adjustments (the energy is very sensitive to rotation of the screws). If the laser energy decreased, rotate the screw in the opposite direction. Continue adjusting the screw until maximum energy is observed by the energy meter. Repeat this process on the remaining 3 screws until the maximum energy has been attained for all 4 screws (2 on the back mirror and 2 on the front mirror). Refer to Fig. 2 to compare the energy output.

6. Conclusion

Safe operation tips were provided to prolong the life of the parts within the head of the variable pulse width laser. A technique was also provided to align the mirrors of the laser for maximum energy output. The maximum energy of the variable pulse width laser increased as the pulse width increased up to 2.6 ms, at which point the maximum energy decreased as the pulse width continued to increase. The maximum energy output of the laser, as of 4 December 2015 was 7.7 J.

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