

## Evaluation Study of an Electro-Optics Q-Switched in End Pumped Nd: YAG Laser System

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**Abstract:** We evaluation the operation of 1064 nm electro –optically Q-switched Nd: YAG rod laser that is end pumped by laser diode. The width of 400 ns, 350 ns and 250 ns were obtained at reflectivity of output coupler mirror of 99, 98 and 95%, respectively and also observed the optical resonator ( L= 70-90 mm) and input optical power (350-430 mW) is effective in the value of energy per pulse (6-23  $\mu$ J) and pulse width (250- 600 ns). The optimum switching time of Q-switching is obtained at 750  $\mu$ s and the beam that a near-diffraction-limited quality.

**Keywords:** Active Q-switch, beam quality, diode pump

### INTRODUCTION

Diode-laser-pumped solid state lasers such as neodymium yttrium aluminum grant (Nd: YAG) are prime candidates for lasers light sources for used in deep-space optical communications and other applications (Jeff *et al.*, 1999; Ifflander, 2001). Due to the long upper-state lifetimes of the Nd<sup>3+</sup> into YAG crystals, the energy storage capacity of such as materials is quite high. Using a technique such as Q switches or cavity dumping, the stored energy can be extracted in the form of short laser pulses with high peak power (Koechner, 2006; Jassim *et al.*, 2014). Q-switched laser can be produced by using electro-optic mechanism. Pockels cell effect is used to modulate or compress the beam (Furata, 2005). The loss in modulation beam will be manipulated to produce powerful Q-switched laser. In the most common implementation of the Q-switch, an electro-optical crystal in combination with a linear polarizer is used. Initially, the voltage on the electro-optical crystal is set to the quarter-wave voltage. That is, the applied voltage induces a birefringence in the electro-optical crystal (Pockles cell) such that a linearly polarized beam passing trough it becomes circularly polarized (quarter wave phase delay between the orthogonal polarization components) (Nisperuzaa *et al.*, 2010). With the quarter-wave voltage on, the cavity is open, both linear polarization states (vertical or horizontal) cannot propagate trough the cavity (a double pass in the electro-optical crystal amounts to a 90 degree of rotation of the initial polarization state). The high voltage is kept until the population inversion above threshold is achieved. Then the voltage across the Pockles cell is dropped and the birefringence of the crystal is removed (Abd Rahman *et al.*, 2009). The

vertical polarization state is allowed to oscillate in the cavity (closed cavity). Lasing builds up and a high power nanosecond pulse is formed. In a Q-switch laser system, the time delay between flash lamp trigger and Pockels Cell (PC) switching is very important (Salvestrini *et al.*, 2004; Molina *et al.*, 2001). In this present paper the optimization of Q-switched Nd: YAG laser output is discussed based on the performance of all parameters of this system.

### EXPERIMENTAL SETUP

A schematic set-up of the passive Q-switched device is shown in Fig. 1 it consists of the driver unit, the laser head, which contains the pump diode laser emitting optical power about 0.5 W of 808 nm wavelength and a collimator for collimating the beam by a focusing lens of 238  $\mu$ m focal length in the active medium, type (Nd: YAG). One end has a high-reflection coating for the 1064nm wavelength to function as a mirror for the resonator and an Antireflection (AR) coating for the 808nm wavelength to allow the pump beam to enter the rod. The other end has an AR coating for the 1064nm. The stimulated emission cross section equal to ( $2.5 \times 10^{-18}$  cm<sup>2</sup>) and spontaneous fluorescence lifetime equals to (230 $\mu$ s) (Dharmadhikari *et al.*, 1998; Sipes, 1985). A nonlinear optic LiNbO3 crystal was employed as Pockels cell. The dimension of the Pockels cell was 6 $\times$ 6 $\times$ 30 mm<sup>3</sup>. The cell was provided with adjustable DC high voltage power supply with maximum voltage of 2 kV. The quarter-wave voltage of the crystal is normally greater than 0.75 kV (Fulkerson *et al.*, 1997). The Pockels cell was interposed in the laser resonator associated with a thin film polarizer. And the output-coupling mirror with a radius of curvature of

800 mm with 5% transmission at 1064 nm. This mirror with another plane mirror constructs the optical resonator of hemispherical type having a length of 60

mm with a beam waist of 265  $\mu\text{m}$ . In the experiments, the output power was measured and analyze by a power meter (UP19K-50L-H5), CCD camera (BEAMAGE-CCD12) and storage Oscilloscope (ADS1202CML with bandwidth of 250 MHz).

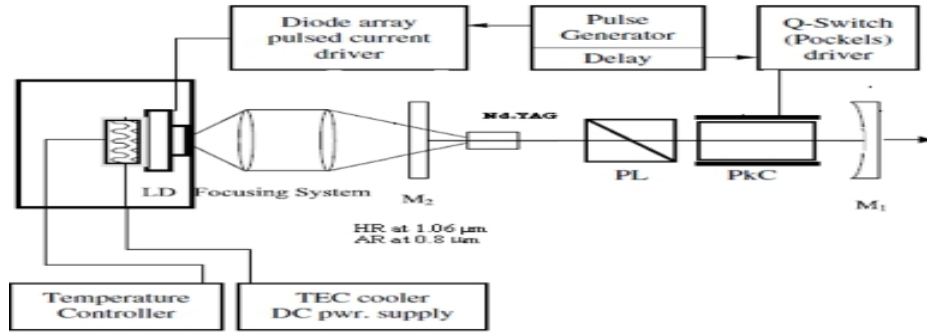


Fig. 1: Experimental setup of electro-optics Q-switch for solid state laser system

## RESULTS AND DISCUSSION

**Laser output energy:** In electro-optically Q-switched operation with LiNbO3 Pockels cell, the output pulse energy as a function of input optical pump energy is plotted in Fig. 2.

For various values of output coupler reflectivity ranging from  $R_{O.C.} = 95\%$  to  $R_{O.C.} = 99\%$  at a cavity length  $L = 70\text{mm}$ . Here, output pulse energies up to 23.1  $\mu\text{J}$  can be obtained for 380 mW incident optical pump power by using a  $R_{O.C.} = 99\%$  output coupler mirror, while an optical slope efficiency  $\eta_{opt} = 27\%$  is derived from the corresponding linear data fit.

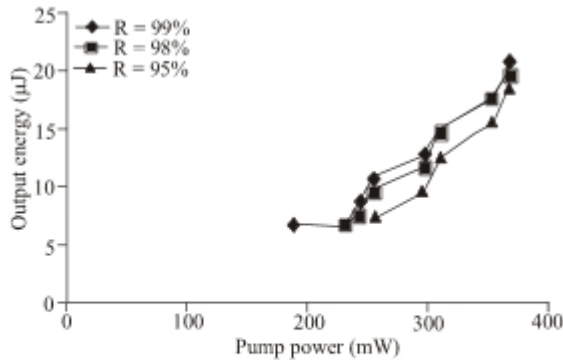


Fig. 2: Laser output energy in multimode Q-switched operation vs. optical input pump energy, for several output coupler (O.C.) mirror reflectivities

**Time delay:** Figure 3 shows the output energy Q-switched laser distribution for delay time between 50  $\mu\text{s}$  to 1000  $\mu\text{s}$ . This time delay is called as an “optimum time delay”. An appropriate time delay for Q-switching is expected to be within 5% of the optimum delay (Tamuri *et al.*, 2008). In this particular experiment the time delay to optimize the production of Q-switched laser beam is realized to be in the range between 500  $\mu\text{s}$  to 850  $\mu\text{s}$ . The maximum output energy occurs at a time delay of 700  $\mu\text{s}$ .

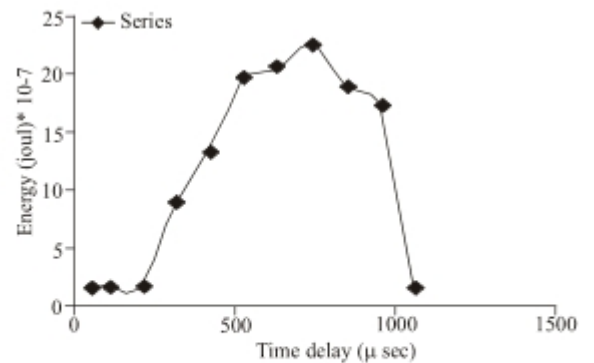
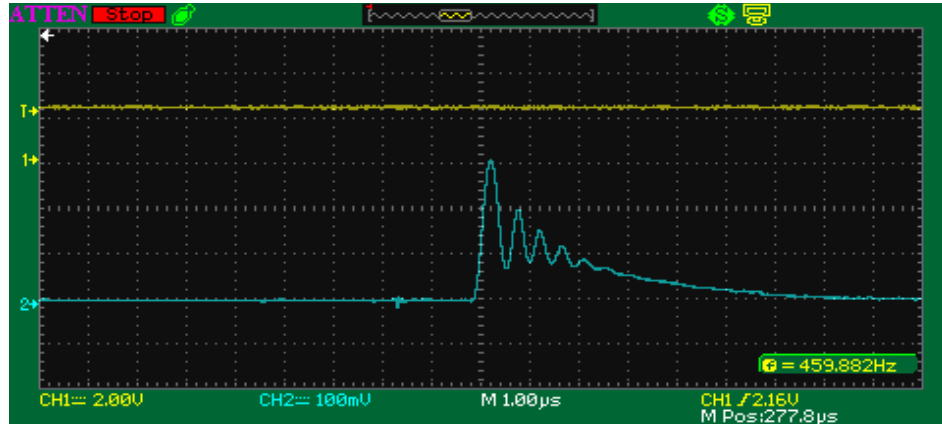
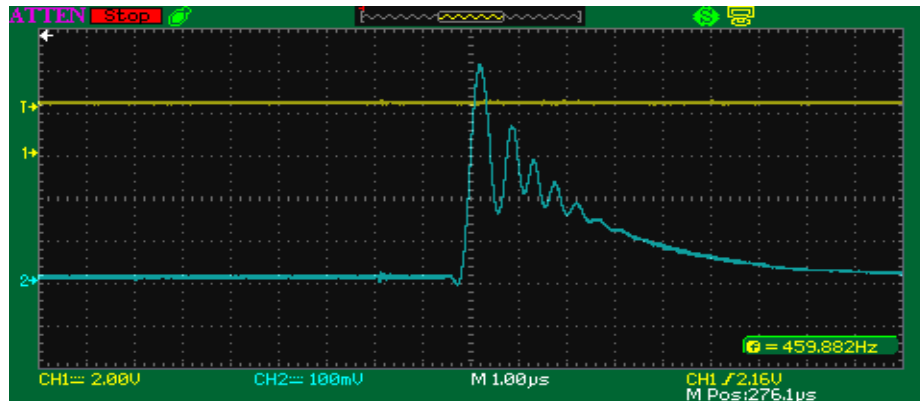


Fig. 3: Distribution of output Q-switched laser based on time delay

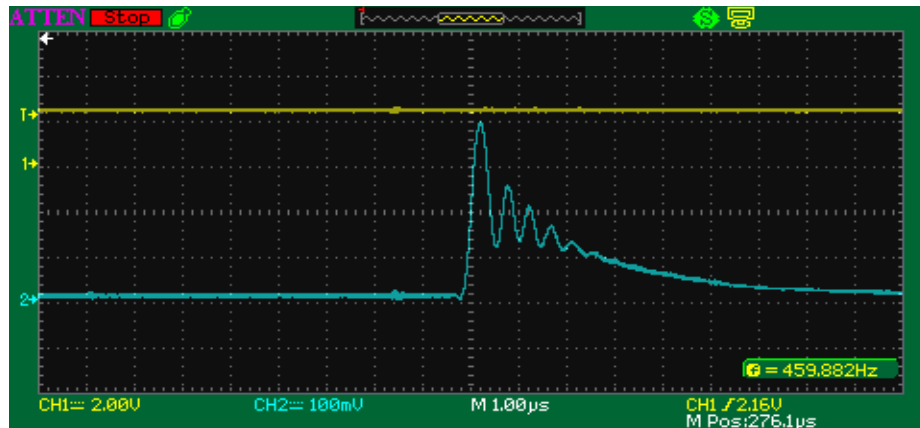
**The relationship between the pulse width and the reflectivity of the output mirror:** Figure 4 (a to c) shows the relation between the pulse duration for



(a)



(b)



(c)

Fig. 4: The relation between the pulse duration for different reflectivity of output mirror (a, R = 99%, W = 400 ns, b-R = 98%, W = 300 ns and R= 95%, W = 250 ns)

different reflectivity of output mirror @ at fixed value of (Pin = 450 mW and L = 70 mm). The pulse duration decreases less than (250ns) when the reflectivity is decreased less than (95%). Normally when the generated pulse has narrow duration, this pulse has a peak power.

**Relationship between the Pulse Width with the Optical Resonator Length:** Figure 5 (a to c) shows the relation between the pulse duration for different values of optical resonator length, of fixed values of (Pin = 450 mW and R = 95%). The pulse duration decreases less than (250 ns) when the optical resonator length is decreased less than (70 mm).

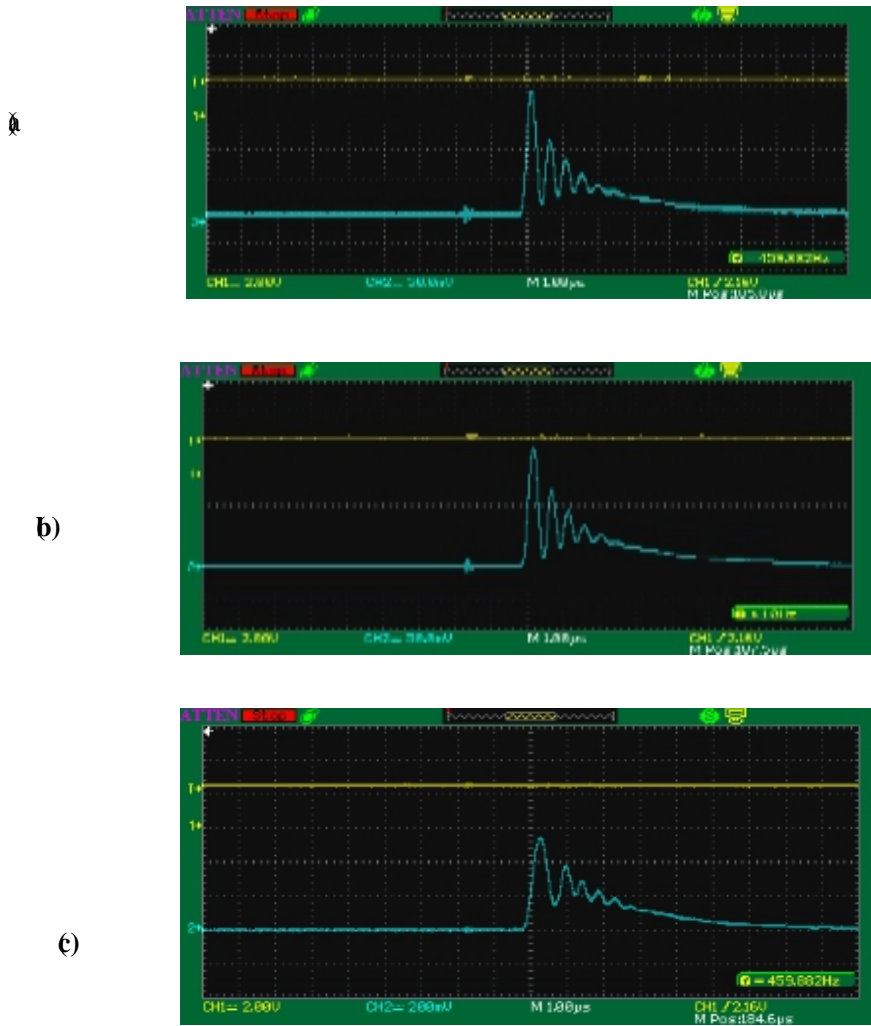


Fig. 5: Shows the relation between the pulse duration for different values of optical resonator length (a- L= 70 mm, W= 250ns, b- L = 80 mm, W= 300ns and c- L= 90 nm W= 370ns)

**Relationship between the pulse width with the input optical power:** Figure 6 shows the relation between the pulse duration for different values of input optical power, of fixed values of (L = 70 mm and R = 95%). The pulse duration decreases less than (330 ns) when the input optical power is increased than (450 mW).

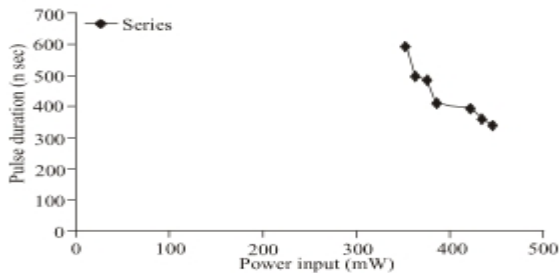


Fig. 6: The relationship between the pulse duration and different value of input optical power (a- Pin = 350mW, W = 600 ns, b- Pin = 383mW, W = 420ns and c- Pin = 442mW, W = 350ns).

**Beam quality:** The beam quality of the Q-switched, green laser was measured and analyze by using CCD camera While the Nd: YAG laser was operating at the maximum pump power level with approximately 23.1  $\mu$ J of pulse energy at 250 nm laser output, the beam quality was measured as  $M^2_x = 1.2$  and  $M^2_y = 1.15$ , as shown in Fig. 7 was detected. The results revealed that a near-diffraction-limited laser beam was achieved [12].

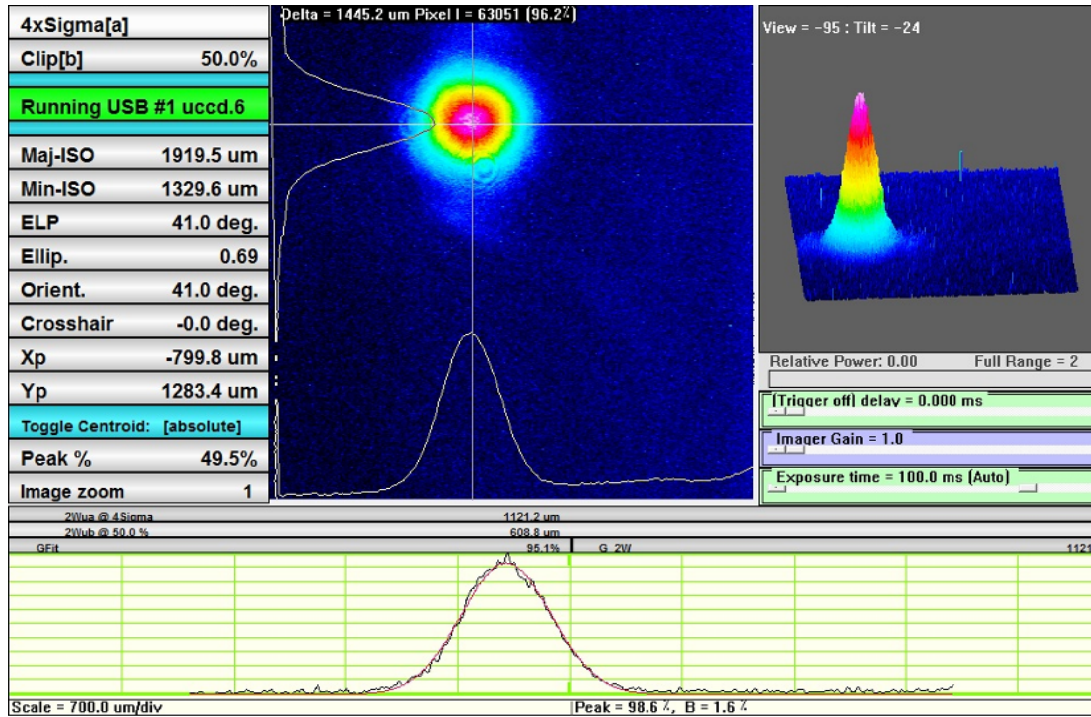


Fig. 7: Beam quality

## CONCLUSTION

- This system provides almost independent adjustments of pulse duration and energy and has the capability of variable ns-pulsewidth operation in the infrared spectrum.
- The optimum time delay was obtained at 184  $\mu$ s with the corresponding maximum energy of 40 mJ. The pulse duration of Q-switched Nd: YAG laser was 250 ns.
- The increasing the power of input happens decrease impulse width, in case of reducing the length of resonator occurs decrease impulse width and also in the case of the use of reflectivity few mirror happens decrease impulse width.

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