1KHz BBO E/O Q-Switched Diode Pumped Er:Glass Laser Experiment

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Introduction

BBO is a popular nonlinear optical crystal typically used for frequency conversion. Recently, BBO was also used as electro-optic Q-Switch material. BBO was chosen as a good candidate material for use as an E-O Q-Switch for Er:Glass lasers because of it's low insertion losses at 1.54um and high laser damage threshold ($5GW/cm^2$, 10 ns). Traditional materials such as KD*P or $LiNbO_3$ exhibit high insertion losses and/or low damage thresholds at 1.54um. As an added benefit, BBO does not exhibit a piezoelectric effect. All of these advantages make BBO an attractive Er:Glass E/O Q-switch for high peak and high average power applications.

Experimental set-up

The BBO E-O Q-Switch under test were manufactured by Inrad. The laser beam travel along optical axis and the electrical field were transversely to the beam. The transverse field BBO Pockel's cell design was used to help keep the hold-off voltage down to an acceptable range. The specified quarter wave voltage for BBO at 1.54um is 5.5 KV. Our 4 mm aperture, AR coated, BBO E/O Q-Switch cell package size was 1-5/8" long and 1" diameter.. Both ends was sealed with AR coated window.

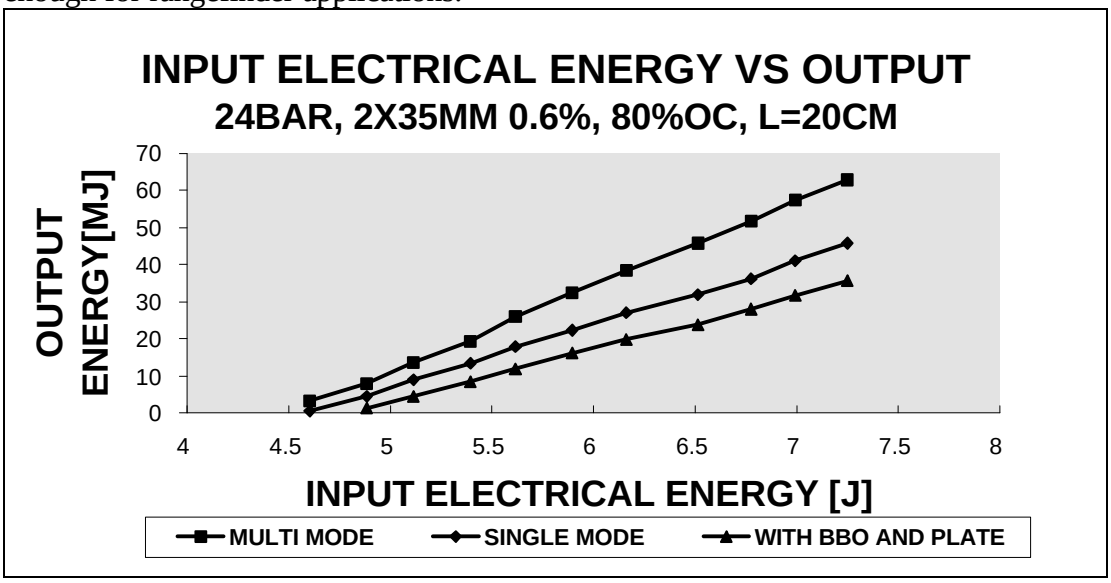
Two different diode pump setup , 24 bar and 16 bar diode pump system manufactured by Paradigm Lasers, were used for pumping. The 24 bar system consisted of three eight bar segments arranged symmetrically about 6 mm diameter and provide 35 mm pump length. The 16 bar system consisted of a single sixteen bar segment arranged symmetrically about 6 mm diameter and provide 11 mm pump length. The laser diode bar had centre pump wavelength about 930 nm.

Calcite and sapphire polarizer elements were tested and compared. A sapphire plate was chosen for further experimentation as it exhibited lower insertion losses and a better output beam quality. An uncoated Brewster angle sapphire plate was found to provide enough losses for resonator hold off during Q-Switch operation. This is due to the low gain of Er:Glass. We found that the specified BBO quarter wave voltage was not required for

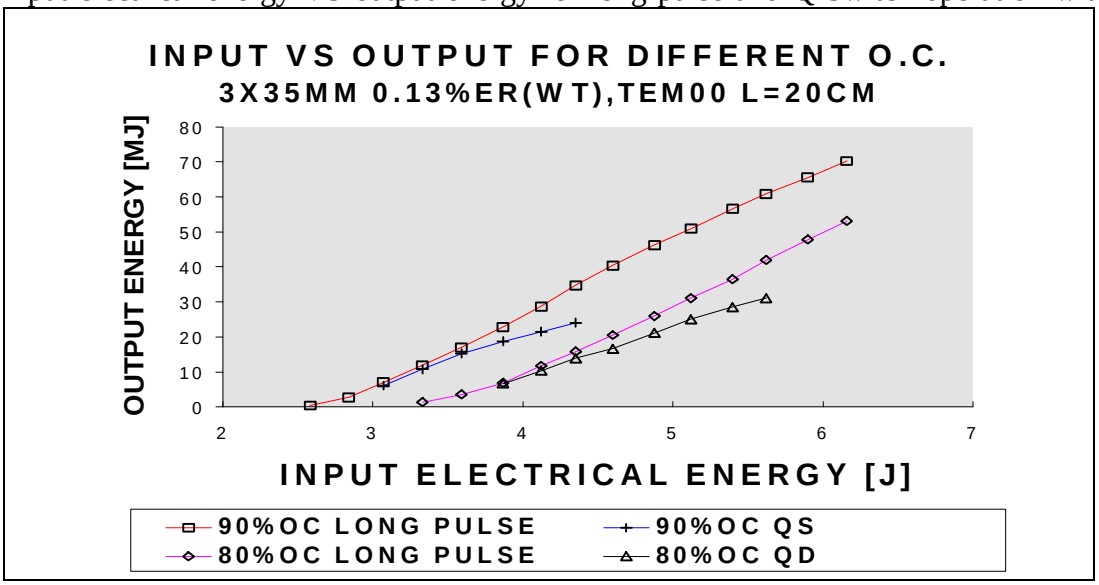
resonator hold off. We readily demonstrated reliable E/O Q-switched Er:Glass laser performance of 1 MW @ 1.54um, TEM_{oo}, 30 mj, and 30 ns.

Experimental Results

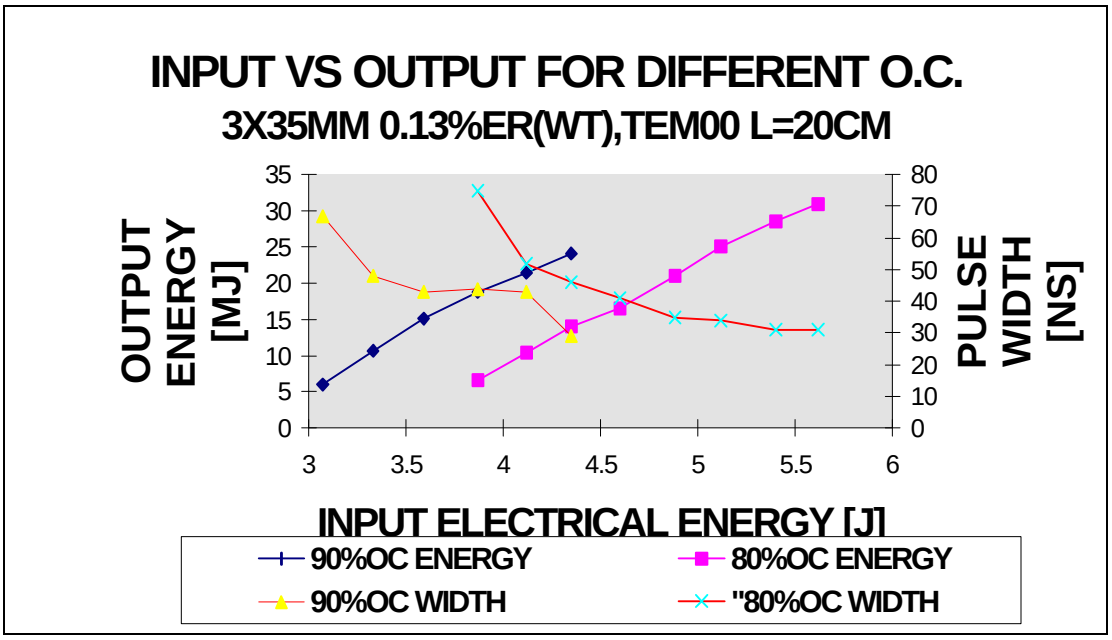
Fig.1 shows the input electrical energy VS output energy with 80% reflectivity output coupler for multi-mode and single mode operation. Even running in multi-mode only lower cylindrical mode exist because the rod diameter is only 2 mm. Fig.1 also shows the influence of introducing the BBO Q-Switch and polarizer. The calcite block and sapphire plate been tested as polarization component. with sapphire plate the insertion loses is lower and output beam quality is better. But with such combination the resonator keep hold off with voltage for pumping energy less than 6 joules which is enough for rangefinder applications.



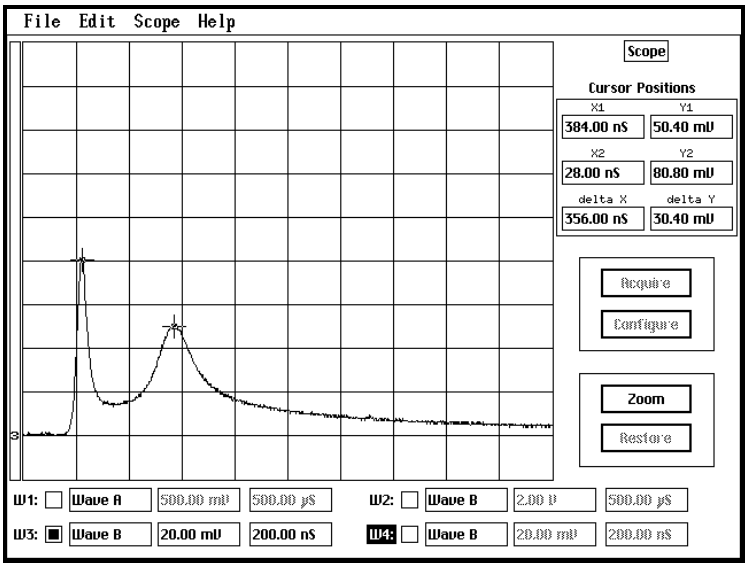
We test the BBO Q-Switch with 0.13% (wt) erbium doping rod. Fig. 2. shows the input electrical energy VS output energy for long pulse and Q-Switch operation with



different output coupler. Fig. 3 shows the pulse width and pulse energy changes with input electrical pumping energy under Q-Switching operation. The 30 mj energy with 30 nsec pulse width which corresponding 1 MW peak power was demonstrated.

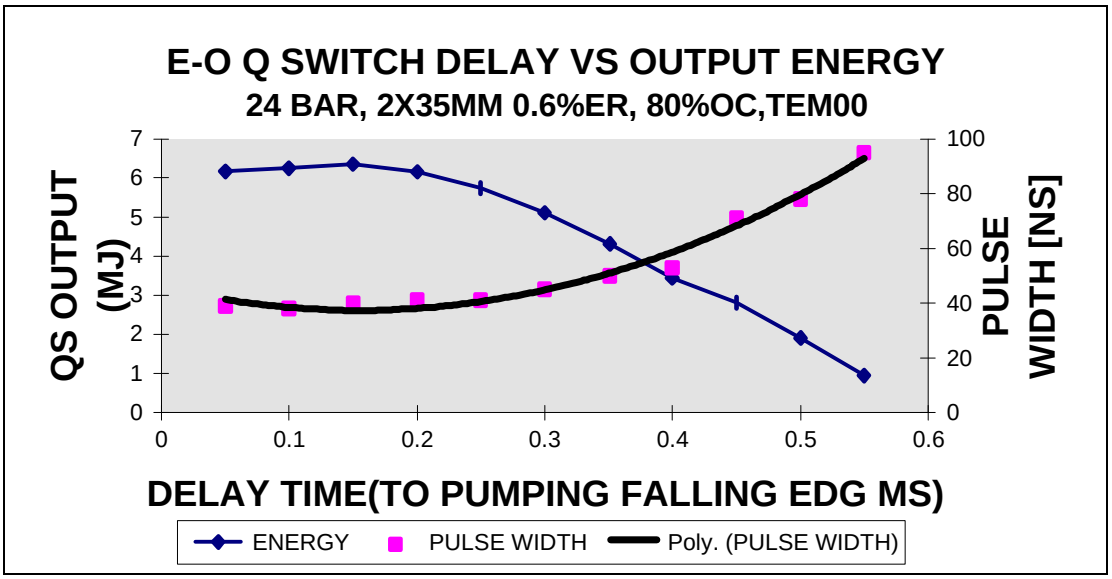


For the multi-mode operation the Q-Switching output always appears as double pulse even at pumping energy near threshold as Fig. 4 shows. The first narrow pulse is



come from the centre TEM_{00} mode volume while the second pulse is from the other mode which have slightly different gain and different pulse generate time. For rangefinder application such behaviour is not allowed. Single mode operation is needed.

Fig. 5 shows the Q-Switching pulse energy and pulse width change with the delay time. The zero point is corresponding to falling edge of pumping pulse. Such decay are expected because the pumping level is only 10% above threshold although the 8 ms long fluorescence live time of erbium ions. The curves show the Q-Switching pulse width is very sensitive to the gain. Further increasing pumping level will result much narrow pulse width.

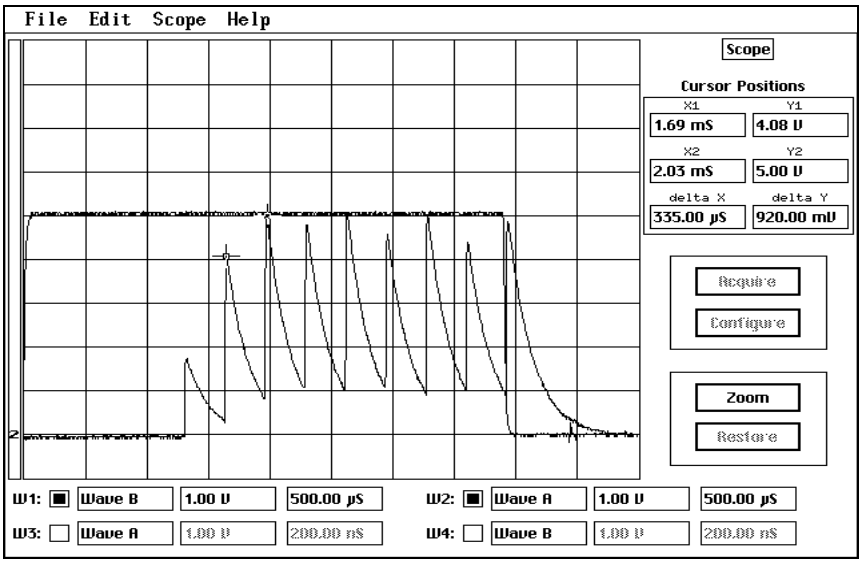


To compare with passive Q-Switch, the BBO E/O Q-Switch have better performances, more output energy and shorter pulse width. The comparison data were summarised in table I.

Table I. Comparison Results Of E-O and Passive Q-Switch

Q-S Meth.	Diode Array	Pump Current	Pump Width	Pump Energy	Length of Res.	Output Energy	Pulse Width	Rise Time
	(bar)	(A)	(ms)	(J)	(cm)	(mj)	(ns)	(ns)
Passive	48	50	1.00	4.67	10	3.5	43	42
Passive	24	50	2.45	6.34	10	4.0	42	42
Passive	24	50	2.50	6.52	7	3.5	36	32
E-O	24	50	2.10	5.39	20	8	35	20

In order to demonstrate the high repetition rate Q-Switching capability, up to 3 khz Q--Switch experiments were conducted. Due to the limitation of laser diode the laser



diode was running in single short with 4 msec pump width. Fig. 6 shows the pumping pulse and laser output in the integrated mode in which the amplitude is proportional to

pulse energy. The total energy output of 9 pulses is 60 mj which corresponding 7 mj for each pulses. The 4 ms pump energy is 6.8j.

Conclusion

By using BBO E-O Q-Switching 1 MW peak power output, 30 mj with 30 nsec pulse width in TEM_{00} mode, was demonstrated in Erbium glass laser at 1535 nm. Only moderate high voltage about 3 kv applied to the BBO crystal. There are big potential to further decrease the pulse width because the pumping level only about 10% higher than threshold for the high doping rod. To compare with passive Q-Switch, the E/O Q-Switch Erbium glass laser output higher energy, slightly shorter pulse width with less pumping energy. Up to 3 KHz high repetition rate Q-switching was demonstrated