Comparative results of diode pumped Er:Glass lasers Q-switched with BBO Pockel's cell and FTIR methods

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Abstract

Erbium doped phosphate glass lasers, utilizing both BBO Pockel's cell and FTIR Q-switching methods have achieved operation up to 3 KHz.

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Laser radar has numerous military, industrial, and commercial applications including flight control, obstacle avoidance, target detection, fire control, and law enforcement. For many military and most civilian applications, the laser transmitter is required to be eyesafe. Q-switched Erbium glass lasers, operating at 1535 nm, have attracted considerable attention due to their direct laser output in the "eyesafe" wavelength range.

We have been investigating high repetition rate Er:glass lasers lately for optical radar applications. The common method of Q-switching an Er: glass laser is with a rotating porro prism. As the synchronization of rotating prisms is difficult, we have been investigating different methods. Passive saturable absorbing Q-switches are very simple in design and capable of KHz operation; however, the timing and synchronization of passive Q-switches are even more difficult to control. Additionally, the peak and average output power is limited by the material constraints of the saturable absorber. Two methods that appear attractive for high repetition rate Er:glass Q-switching include electro-optical Pockel's cells and Frustrated Total Internal Reflection (FTIR) devices.

In this paper, we compare the results of both BBO electro-optical Q-switches and frustrated internal total reflection (FTIR) Q-switches. Both Q-switch methods are capable of exceeding kilohertz repetition rates and are directly controllable by external electronic signals.

BBO was chosen as a good electro-optic candidate for us as a Pockel's cell for Er:glass lasers because of its low insertion loss at 1. 54μm and high laser damage threshold (5 GW/cm^2, 10 ns). As an added benefit, BBO does not exhibit piezoelectric effects. All of these attributes make BBO an attractive electro-optical Q-switch material for high peak and high average power Er:glass laser applications.

Two different laser diode-pumping configurations were utilized. The first consisted of 24 1 mm laser diode bars configured in three 8 bar segments. The 8 bars were spaced symmetrically about a 6.1 mm diameter. The three segments were spaced about 1 mm apart to pump a 35mm long laser rod. The second configuration used 16 bars in a single segment that was also spaced about a 6.1 mm diameter. The second configuration was used to pump 12 mm laser rods.

For the BBO Q-switch experiments, an uncoated sapphire plate was oriented at Brewster's angle to function as the polarizing element for the electro-optic Pockel's cell. The loss induced by the single Brewster plate was more than sufficient to hold off the low gain Er: glass laser rod. Figure 1 illustrates the pump energy vs. output energy for both quasi-CW and Q-switched operation with different output coupling. Figure 2 illustrates the relationship the pump energy has upon the pulse duration and output energy when Q-switched. 30 mJ output with a pulse duration of 30 ns was produced for a peak output power of 1 MW.

The use of FTIR Q-switching was demonstrated in the 1960's. Applications of this method were limited because of its slow switching time. Because Er:glass has such a low gain, the pulse build up is relatively slow and slow switching does not influence the efficiency very much. The particular FTIR Q-Switch used for our experiments was provided by Prof. B. I. Denker oft the General Physics Institute.

Prior to the actual Q-switch laser experiments, dynamic characteristics of FTIR were characterized using a HeNe laser. The rise time of the FTIR was about 300-500 ns, depending upon the driving conditions, and open period was approximately 2-3 @s. The peak transmission at 632.8 nm was about 90 %. For the FTIR Q-switched experiments, no additional elements, such as polarizers, were added to the resonator. Figure 3 illustrates the FTIR Q-switched laser performance in both quasi-CW and Q-switched modes. Figure 3 also illustrates the pulse duration as a function of pumping.

Figure 4 compares the performances of both FTIR and BBO Q-switching methods in the same resonator configuration and pumping conditions. For this experiment, the 16 bar radial array was used to pump a 3 mm x 12 mm QE7N rod doped with 0.6 % wt-% Er2O. The resonator was forced to operate in TEM$_{00}$ and the output reached about 2 MW with an 18 ns pulse width for the FTIR Q-switched method. From Figure 4, it is evident that the FTIR Q-switch method is more efficient than the electro-optical method. Measurement and analysis indicate the double pass losses of the BBO and Brewster plate assembly is approximately 5%. We believe this suggests the intra-resonator losses, introduced by the FTIR Q-switch, are even less than 5 %. The FTIR method does not require linear polarization; so, it may be a better choice for higher average power lasers where thermally induced birefringence may become an issue.

In order to demonstrate the potential of high repetition rate 3 KHz Q-switched experiments were conducted with a BBO electro-optical Q-switch. The BBO QS was switched at 3KHz and the Er:glass rod was pumped with a 4 ms, 50 Amp pump pulse. For each single pump pulse, the 3 KHz output consisted of 8 pulses of 7 mJ each, with a pulse duration of 3- 5 ns.

References:

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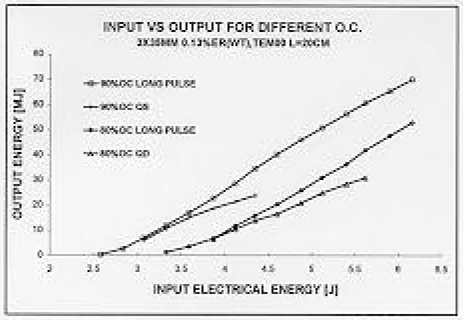

Figure 1

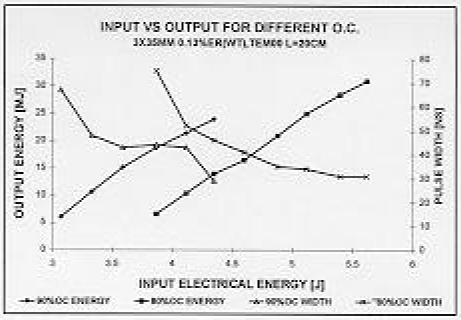

Figure 2

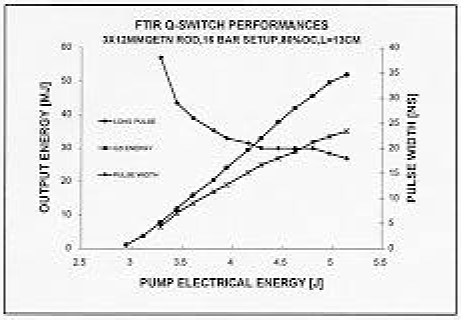

Figure 3

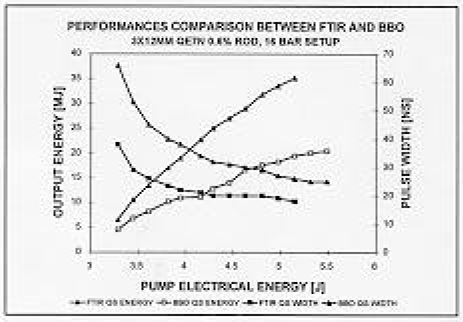

Figure 4