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50Hz Diode Pumped Er:Glass Eye-Safe Laser

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ABSTRACT

A high repetition rate diode pumped Erbium glass laser was demonstrated at 50Hz with Q-switched outputs up to 15mj by various Q-switch methods.

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Diode pumping technology has opened up many new possibilities for Erbium glass lasers for use in eye-safe radar and rangefinding applications. For most radar applications high pulse repetition rates are required. The low thermal conductivity of Erbium glass is a key limiting factor for laser operation at high repetition rates. When compared with traditional flashlamp pumping, the diode pump is more efficient and produces less heat. Diode pumping allows the Er:glass laser to operate at higher repetition rates. In this paper we report on a continuous duty 50Hz diode pumped Erbium glass laser.

The basic pumping method used in this investigation is side pumping. We evaluated two different liquid cooled 940nm diode radial array pumping heads manufactured by the Cutting Edge Optronics. One head is a "Y" configuration that provides 3.3cm of pump gain length. The other head is a pentagon configuration that provides 6.5cm of pump gain length. In "Y" shaped head there are three 1 cm diode bars arranged in a single line to provide 3.3cm of pump length. Three such linear 3 bar units pump a 2.5mm diameter and 33mm long Er:glass rod from side in a "Y" configuration. The "Y" laser head contains a total (9) 25 watt diode bars. The pentagon pumping head contains 6 bar linear units that each provide 6.5 cm gain length. Five of these linear 6 bar units pump the rod from the side in pentagon shaped configuration. The pentagon head contains a total of (30) 25 watt diode bars. The pentagon head provides up to 750 watts of peak power in up to a 5ms pump pulsewidth.

Each 1cm long diode bar is rated at 20W for CW output. Test data shows that each bar's output may reach peak pump powers of ~25 W at 35A pump current. The 9 bar "Y" pump head was pulsed at up to 5msec pump pulsewidth and 35 A current at 50 Hz. In other testing, the same set-up was operated at up to 70 A and 3msec at 50 Hz. At the higher currents the peak output power of each bar doubled and reached 50 W . Diode bar life testing at the 70 A pumping level has yet to be completed.

The data in Tab.1 shows the laser output performance under above two different pumping conditions. Pumping with shorter pump pulsewidth yields higher output energy and higher efficiency especially at the higher repetition rates. The higher peak power diode pumping produces better results for the laser's output. However, this factor needs to be carefully considered with regards to the diode's life time and the laser's overall performance parameters and design goals.

Table 1. QS output Energy with Different Pump Width

R.R	Pump current	Pump width	Pump energy	QS output	Pump current	Pump width	Pump energy	QS output
10	35A	5ms	1.13J	11mj	60A	2.5ms	0.96J	12.3mj
20				10.8				11.9
30				10.5				11.2
40				10.5				11.2
50				4.5				10.5

Erbium glass is low gain laser material that operates under a quasi-three level working principle. It is very important to having no unpumped gain length in the laser head design. Just a few millimeters of unpumped region will introduce absorption losses into the oscillation beam. In order to compensate for this sensitivity, three different rod designs were tested. These were thermal fused, chemical fused (glued), doped and undoped rod regions and metal tube rod collar extensions.

The round trip gain was measured at different pump energies and plotted in Fig.1. The threshold pump energy was measured with different output coupler reflectivity values and also plotted in Fig.1. In earlier experiments it was demonstrated that the Er:glass laser's output is shifted toward shorter wavelengths when the reflectivity of output coupler is decreased. This phenomenon is due to the fact the Er:glass 1.54um absorption and emission bands overlapped each other.[1] The measured gain corresponds to different wavelengths which is determined by the output coupler reflectivity value. This association accounts for the irregular appearance of the double pass gain curve for different output coupler reflectivity values.

Fig.2 displays the long pulse output verses repetition rate with different rod and rod treatment conditions. Variations in the laser rod treatment and dopant concentration produce different performance curves. For example, the long pulse energy output is reduced with increasing repetition rate settings for an unstrengthened rod while an ion-exchanged strengthened laser rod maintains the same output energy with increased repetition rate settings. This indicates that the ion-exchange process may produce a degree of pre-stress intensity in a given rod. Variation in dopant concentration is also shown to influence the laser's output energy with respect to the pulse repetition rate.

Another important characteristic is the de-polarization caused by the thermal stress. Fig.3 gives some long pule output results with and without a glass polarization plate in the laser resonator. The figure shows that the de-polarization is limiting factor for polarization sensitive Q-switched methods. The more insensitive a particular Q-switch is to polarization the greater the Q-switched energy output extraction at higher repetition rates.

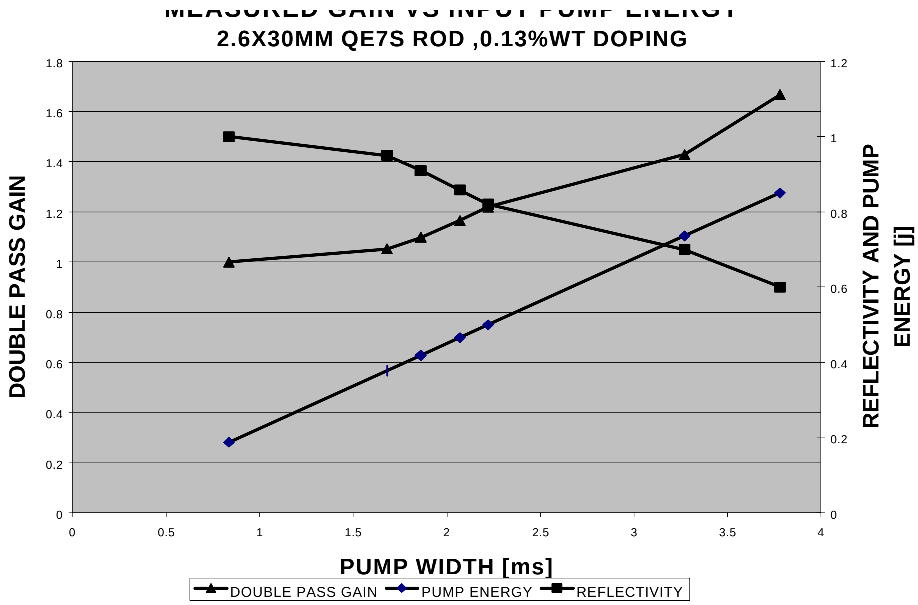
Fig. 3 also shows the long pulse and Q-switched output verses the repetition rate for the FTIR Q-switch. The Q-switched output maintains the same ratio of long pulse to QS output from l0 to 50 Hz. The working principle of the FTIR Q-switch does not theoretically rely on polarization. However, when the FTIR is activated the transmission for Tp and Ts are not identical depending the design parameters. Differences in the s and p polarization transmission cause the QS output to be polarized and this is reflected in a diminished output energy caused by de-polarization. Experimental results confirm that the FTIR QS output is polarized with the Ts component. When compared to a conventional E/O Q-switch, the QS output energy of the FTIR is not influenced by de-polarization to a significant degree. There are additional details that need to be further investigation regarding this matter.

Using the above mentioned pump heads long pulse outputs of up to several hundred milli-Joules and Q-switched outputs of up to 20~30 mJ are demonstrated. Repetition rates from 1 to 50 Hz with different Q-switch methods are reported.

Reference

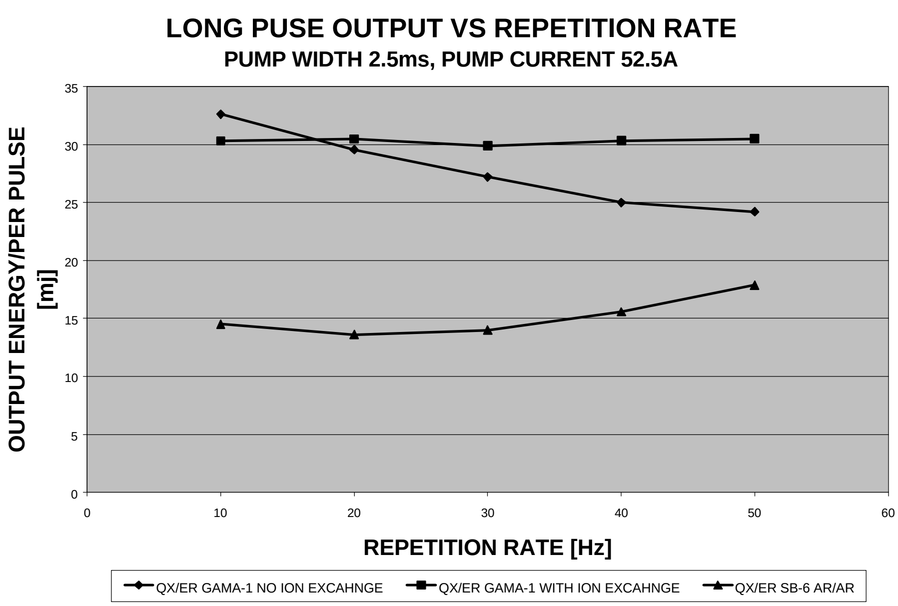
[1] J. Sandos, P. Sarkies and S. Parke “Variation of Er3+ cross section for stimulated emission with glass composition”, J Phys, D:Appl. Phys., Vol.5, pp1788, 1972

[2] S. Jiang, J. Myers, D. Rhonehouse, G. Bishop, M. Myers, S. Hamlin, “Further investigation of 1.5um $Er3^{+}$ doped novel phosphate glasses and lasers”, Conference on Lasers and Electro-Optics, (CLEO) 1995.



MEASURED GAIN VS INPUT PUMP ENERGY
2.6X30MM QE7S ROD ,0.13%WT DOPING
DOUBLE PASS GAIN
REFLECTIVITY AND PUMP ENERGY [j]
PUMP WIDTH [ms]
DOUBLE PASS GAIN
PUMP ENERGY
REFLECTIVITY

FIG. 1



LONG PUSE OUTPUT VS REPETITION RATE
PUMP WIDTH 2.5ms, PUMP CURRENT 52.5A
OUTPUT ENERGY/PER PULSE [mj]
REPETITION RATE [Hz]
QX/ER GAMA-1 NO ION EXCAHNGE
QX/ER GAMA-1 WITH ION EXCAHNGE
QX/ER SB-6 AR/AR

FIG. 2

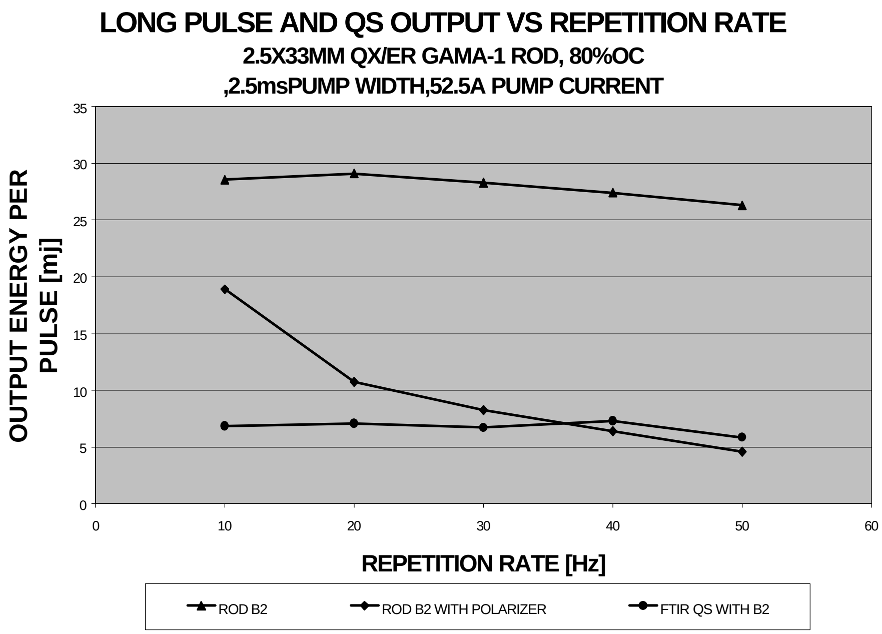

LONG PULSE AND QS OUTPUT VS REPETITION RATE
2.5X33MM QX/ER GAMA-1 ROD, 80%OC
,2.5msPUMP WIDTH,52.5A PUMP CURRENT
OUTPUT ENERGY PER PULSE [mj]
35
30
25
20
15
10
5
0
0
10
20
30
40
50
60
REPETITION RATE [Hz]
ROD B2
ROD B2 WITH POLARIZER
FTIR QS WITH B2

FIG. 3