

# High Repetition Rate Passive Q-Switched Er:Glass Laser Using $U^{2+}$ :CaF<sub>2</sub> Saturable Absorber

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## **Abstract:**

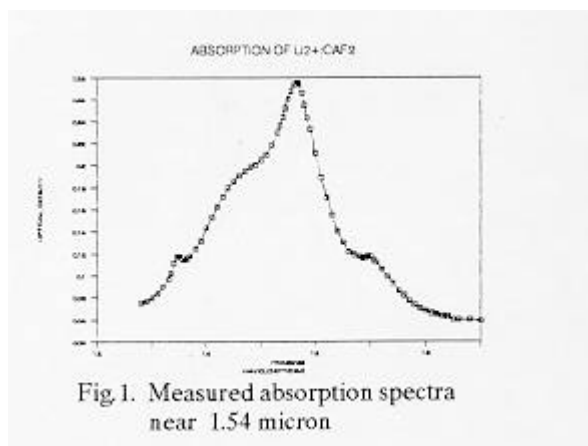
1.54  $\mu$ m laser output with 10 mJ of energy and a 60ns pulse width was demonstrated at 8.5Hz by using  $U^{2+}$ :CaF<sub>2</sub> as a saturable absorbing Q-switch. The laser media is an experimental Er:Glass designated QX/ER.

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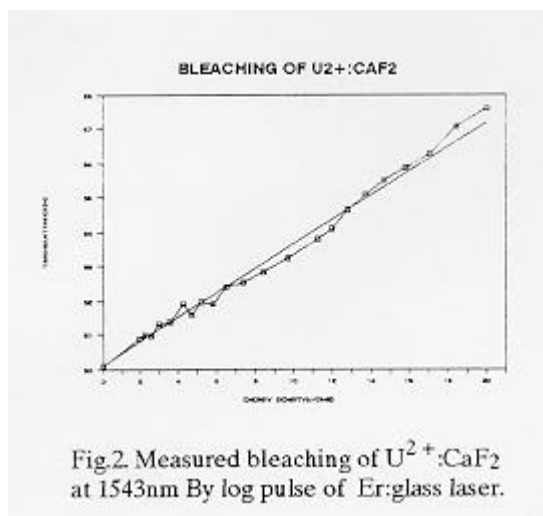
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Recently, interest in higher repetition Q-switched Er:Glass lasers has increased. This is primarily due to new Q-switch and base glass technology. <sup>[1-3]</sup> Applications include ranging, target designation, laser radar, communications, environmental sensing, collision avoidance, law enforcement, and wind shear detection. Several laboratories have been conducting basic research involving different methods of Q-switching Er:Glass lasers at reasonably high repetition rates. <sup>[1-8]</sup> Because passive Q-switches are compact, simple, and reliable, they are utilized as the Q-switch of choice for most Nd:YAG rangefinding transmitters. Scientists have searched for many years for an acceptable passive Q-switch for Er:Glass lasers. Recently, researchers at the University of Southern California have reported Passive Q-switching of Er:Glass using  $U^{4+}$  doped fluoride crystals (9). Kigre has demonstrated passive Q-switching in  $U^{2+}$  doped CaF<sub>2</sub> and glass. <sup>[10,11]</sup> In more recent conversations with the researchers at the University of Southern California, it appears that the active valance was  $U^{2+}$  and not  $U^{4+}$  <sup>[12]</sup>. Based upon the saturable absorbing Q-switch and high average power glass technology, a higher repetition rate transmitter was designed and demonstrated.



The spectral characteristics of  $U^{2+}$ ,  $U^{3+}$ , and  $U^{4+}$  were carefully analyzed. The absorption spectra near 1540 nm was measured and is illustrated in figure 1. The absorption cross section at 1535 nm was calculated to be  $7 \times 10^{-20}$  [10]. Bleaching experiments were conducted and the results are shown in Figure 2. The  $CaF_2$  samples were doped with 0.5 atom% uranium. The measured absorption curves indicate the uranium in the sample to be divalent.

Due to the large absorption cross section at  $1.54 \mu$  of  $U_2:CaF_2$  in comparison to the stimulated emission cross section of  $Er^{3+}$  in phosphate glass, intra-resonator focusing was not necessary. The first Q-switch experiment was conducted using a normal Er:glass laser resonator, in which the HR mirror is 60 cm concave and the output coupler is 300 cm concave. The 0.5 mm diameter of the  $TEM_{00}$  mode was nearly constant over the entire cavity length.



Q-switch sample #1 had an initial transmission of 82.9%. Output energies of 2mJ and about 60ns pulse widths were obtained in both  $TEM_{10}$  and  $TEM_{00}$  modes with 33J of pumping. Decreasing the initial transmission to 64%, in sample #2 yielded a higher output energy of 6.9mJ with higher transverse modes and a pulsewidth of 27ns with an 87J pump. Adjusting the resonator alignment produced very clear mode patterns such as  $TEM_{00}$ ,  $TEM_{10}$ ,  $TEM_{20}$ ,  $TEM_{30}$ ,  $TEM_{40}$ ,  $TEM_{50}$ ,  $TEM_{60}$ , as well as some cylindrical modes. For certain modes, the output energy was found to be quite stable: for example 1.6mJ in  $TEM_{00}$  and 2.5mJ in  $TEM_{10}$ . The maximum output energy was achieved with a combination of  $TEM_{00}$  and cylindrical  $TEM_{08}$  modes. This combination of modes has a maximum mode volume and produces output energies up to 6.9mJ. An interesting observation was that the bleaching times for the  $TEM_{00}$  mode and the cylindrical  $TEM_{08}$  mode are slightly different and a double pulse output was observed. The delay between the two pulses varied from 50ns to 400ns. We are convinced that this kind of double pulse behavior is completely different from the normal meaning of “double pulse” in saturable absorber Q-switch lasers.

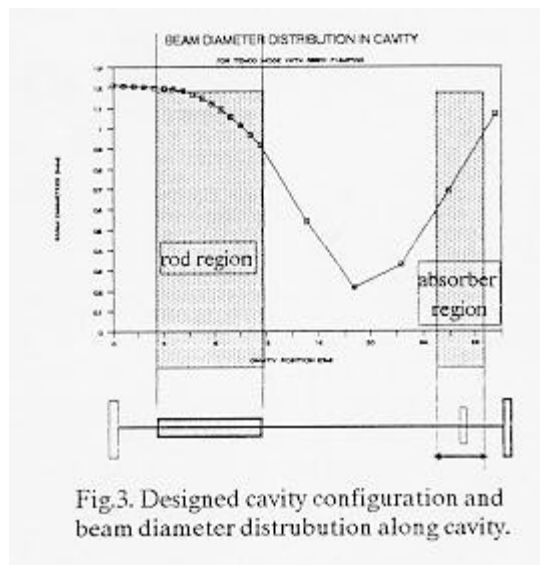
**Table 1. Summarized Data of Q-switch Experiments**

CAVITY	SAMPLE	BEAM@ SIZE	RATIO*	INPUT ENERGY	REP. RATE	OUTPUT ENERGY	PULSE WIDTH	MODE STRUCTURE
	82.9%	0.5	1:1		33J	1HZ	2.0mj	55ns
TEM30	1	64.0%	0.5	1:1	33	1	1.6	27 TEM00
		64.0%	0.5	1:1	87	1	6.9	27 TEM00+ High
	82.9%	1.04	1.08	53	1	6.4	60	CYL01
	82.9%	0.92	1.21	53	1	8.2	55	CYL01
II	82.9%	0.92	1.21	36	1.5	7.5	65	CYL01
	82.9%	0.53	1.37	33	3.0	6.2	65	MIXED MODE
	82.9%	0.72	1.41	40	1.5	7.6	65	CYL01
	82.9%	0.75	1.47	38		8.5	10	60 MIXED MODE
III	82.9%	0.88	1.25	38		8.5	5	65 CYL01

@ Beam size was calculated according TEM<sub>00</sub> mode  
 . Ratio of beam size (TEM<sub>00</sub> mode) in rod to absorber

In order to further increase the Q-switched output, a new laser resonator was designed with a variable diameter of mode volume along the axis of the resonator. In this resonator, the influence of the mode size upon the saturable absorber could be easily observed. 8.2mJ of energy with a 55ns pulse width was obtained when the saturable absorber sample #1 was moved to the smallest beam diameter with a pump of 53J at 1 Hz. Table 1 summarizes the results of this experiment illustrating that the control of the beam size in the saturable absorber is very important.

Finally, with Kigre's newly developed QX/ER high average power Er:glass exhibiting a maximum thermal loading three times greater than standard QE-7S or about 370W for a 3X75mm rod, we were able to operate the laser at 10 Hz with a 35J pump. The thermal lensing produced by pumping the rod at repetition rates was matched in the resonator design to optimize the spot size in the U<sup>2+</sup> CaF<sub>2</sub> passive Q-switch for a single pulse output. Accounting for the thermal lensing in the laser rod, the resonator design produced a high order mode output of 10mJ at 8 Hz utilizing Q-switch sample # 1. This resonator is illustrated in figure 3.



All Q-switch samples that were not anti-reflection coated exhibited poor surface figure and optical quality. We believe that considerable performance improvements are possible; however, this is the first reported operation of a flashlamp pumped, Q-switched, Er:Glass laser operating in excess of 4 Hz.

## References:

1. Shibin .Jiang, John D. Myers, Dan Rhonehouse, M.J.Mvers, R.Belford, Scott J.Hamlin, in Proceedings of SPIE Vol. 2138 (1994)
2. K.Sparious, P.D.Stultz, M.Birnbaum, T.H. Allik, and J.A.Hutchinson.Appl.Phy.,Lett. **62** 2736(1993).
3. T.H.Allik, J.B.Gruber, M.D. Seltzer, M.E.Hills, K.S.Sparious, R.D.Stultz, M.Birnbaum, C.A. Morrison, B.H.T.Chai, J.A.Hutchinson and L.D.Merkel, in AOSA Proceedings on "Advanced Solid State Lasers", Vo1.15 pp246(1993).
4. Scott J. Hamlin, John D. Myers, Michael J. Myers, in Proceedings of SPIE Vol. 1419, pp 100-105.
5. B.I.Denker, G.V. Maksimova, V.V. Osiko, S.E. Sverchkov, YU E. Sverchkov, Sov. J. Quantum Electron. **20** (8)877(1990).
6. B.I.Denker, G.V. Maksimova, V.V. Osiko, S.E. Sverchkov, YU E. Sverchkov, Sov. J. Quantum Electron. **21** 774(1991).
7. B.I.Denker, G.V. Maksimova, V.V. Osiko, S.E. Sverchkov, YU E. Sverchkov, Sov. J. Quantum Electron. **22** (6)500(1992).
8. Kaoru Asaba, Jun Ohta, Tetsuo Hosokawa, and Yoshio Hatsuda, NECRESEARCH & DEVELOPMENT, No.93, pp21-37.
9. R. D. Stultz, M. B. Camargo, S.T. Montgomery, M. Birnbaum, in "Advanced Solid State Laser" 1994 Technical Digest, ATHC3-1.
10. Yasi Jiang, Ruikun Wu, Daniel Rhonehouse, Michael J. Myers, John D. Myers, to be published in Photonics West95, SPIE's International Symposia.
11. Yasi Jiang, Ruikun Wu, Daniel Rhonehouse, Michael J. Myers, John D. Myers, to be sent to Advanced Solid State Laser Conference, 1995
12. M.Birnbaum, University of Southern California, private conversation, August 1994.