BLEACHING AND Q-SWITCHING OF DIVALENT URANIUM DOPED GLASS AND CRYSTAL AT 1535nm

Yasi Jiang*, Ruikun Wu, Daniel Rhonehouse,

Michael J. Myers, Scott J. Hamlin and John D. Myers

Kigre Inc., Hilton Head, SC 29926, U.S.A.

(803) 681-5800, Fax: (803) 681-4559

***Also with Shanghai Institute of Optics & Fine Mechanics,**

Chinese Academy of Sciences, Shanghai 201800, P.R. China

INTRODUCTION

Laser emission at 1535nm from Er^{3+}:glass is interesting due to its eye-safe wavelength, high transmission through the atmosphere, and silica fiber optics. E^{3+}:glass lasers are used for rangefinding, lidar, communication and atmospheric data measurement etc.. A Q-switched pulse is necessary for many of these applications [1]. Mechanical and electro-optical Q-switches have commonly been utilized for Er^{3+} glass lasers. Compared to active Q-switching, passive Q-switching is advantageous due to its simplicity, compact dimensions and lack of auxiliary electronics. Recently, Er^{3+}: CaF_2, Er^{3+}:Yb^{3+} :FAP and U^{4+}:SrF_2 were experimentally employed for passive Q-switches by researchers at The University of Southern California[2,3]. In this paper, bleaching of divalent uranium glass

and CaF_2 are investigated and these solid materials are used for Q-switching Er^{3+} :phosphate glass lasers.

ABSORPTION SPECTRA

Uranium has an electronic shell of 5e6d7S2 and forms valences of U^{2+}, U^{3+} ,U^{4+} , and U^{6+} in ionic crystals. Spectroscopic studies of different uranium valences in fluoride crystals were performed by Hargreaves [4,5]. Divalent uranium in CaF_2 exhibits a board absorption band centered at 1.58mm and a metastable energy level of $^5L_7$ with a fluorescence emission at 2600nm. A relatively large absorption cross section at a 1535nm and a moderate metastable lifetime of CaF_2 meet the requirements for a saturable absorber. Based on the similarity of the spectra of U:glass samples to U:crystals, it appears that divalent uranium glass is also a suitable saturable absorber material for Er^{3+} :glass laser at 1535nm.

Various uranium doped fluoride, fluorophosphate, and phosphate based glasses were melted under oxidizing or reducing atmosphere. The reduced glasses typically exhibit absorption bands in the vicinity of 1535nm and 2300nm that are similar to that in U^{2+} :CaF_2. The peak wavelengths appear at 1500nm and 2200nm in phosphate glass and 1400nm and 2120nm in zirconium fluoride glass. In U:barium metaphosphate based glass, the spectra appear similar to that of U^{2+}:BaF_2 crystal. Glasses melted under oxidizing conditions have an absorption shoulder at 2120nm caused by U^{3+} along with a strong UV absorption edge at 400nm caused by U and U . Strongly reduced glasses produce high UV transparency indicating that a majority of uranium dopant existing in the divalent state.

The optical densities of U^{2+}: phosphate glass and U^{2+} :CaF_2 in the vicinity of the 1.5mm erbium glass laser wavelength are shown in Fig.1 and Fig.2. Strongly reduced U^{2+} :phosphate glass has a cross section of 5.56 x 10^{-20}at the laser wavelength of E^{3+} :phosphate glass. This value is much larger than the stimulated emission cross section of 0.8 x 10^{-20} cm^2 of Er^{3+}:phosphate laser glass and smaller than U^{2+} :CaF_2 value of 7 x 10^{-20} cm^2.

BLEACHING -SATURATION INTENSITY

Bleaching experiments were carried out by comparative measurements of transmission versus energy density. A Kigre Er^{3+}:phosphate glass laser operating at 1535nm was focused into each of the glass and CaF_2 samples. Energy densities of up to 30j/cm^2 were obtained by changing the position of the sample relative to the focal point. The measured transmittance percentage through a U^{2+}:glass and U^{2+}:CaF_2 are shown in Fig.3 and Fig.4 The transmittance of the glass sample increased quickly from 57.2% to 60.3% at energy densities from 0 to 4J/cm^2, and increased slowly from 60.3% to 63.6% at energy densities of 4J/cm^2 to 30J/cm^2 . The transmittance of CaF_2 increases continuously with energy density.

Q-SWITCHING RESULTS WITH U:GLASS

Q-switching experiments of uranium glasses were carried out using Kigre's Er^{3+}:glass laser, utilizing a plano-plano resonator, and 95% output reflector operated at lms, lHz. An uncoated uranium glass sample polished flat-flat, with a transmittance of near 70% was inserted into the resonator. The typical result was approximately one very strong Q-switched pulse followed by several small free running spikes, which were shown in Fig.6. The total energy was less than lmj.

Q-SWITCHING RESULTS WITH U^{2+}:CaF2

With U^{2+}:CaF2 samples, very good Q-S results were obtained . Due to the large absorption cross section at 1535nm 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 Q-switch experiment was conducted using a normal Er:glass laser resonator, in which the HR

mirror is 60cm concave and output coupler is 300cm concave. The 0.5mm diameter of the TEM_{00} mode was nearly constant over the entire cavity length.

Q-switch sample #1 of U^{2+}:CaF_2 had an initial transmission of 82.9%. Output energies of 2mj and about 60ns pulse widths in single pulse were obtained in both TEM_{10} and TEM_{30} modes with 33J of pumping. Decreasing the initial transmission to 64%, in sample #2 of U^{2+}:CaF2, yielded a higher output energy of 6.9mj with higher transverse modes and a pulsewidth of 27ns with an 87J pump.

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 pulsewidth was obtained when the saturable absorber sample #1 was moved to the smallest beam diameter with a pump of 53J at lHz. The results of experiment show 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 37OW for a 3X75mm rod, we were able to operate the laser at 1OHz 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^{2+}:CaF_2 passive Q-switch for a single pulse output. Accounting for the thermal lensing in the laser rod, the resonator design produce a high order mode output of 10mj at 8.5Hz utilizing Q-switch sample #1. This resonator is illustrated in figure 5. Table 1 summarized the results of all experiments.

All Q-switch samples were not anti-reflection coated and 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 4Hz.

References

[1] S.J. Hamlin, J.D. Myers and M.J. Myers, SPIE Processing 1419, 100, (1991).

[2] M.B. Camargo, R.D. stultz, M. Birnbum and K. Spariosu, CLEO 194 Technical Digest, 115(1994).

[3] R.D. Stultz, M.B. Camargo, S.T. Montgomery, M. Birnbum and K. Spariosu, Advanced Solid State Laser, 1-994 Technical Digest, 348 (1994).

[4] W.A. Hargreaves, Physcal Rev., 156, 331(1967).

[5] W.A. Hargreaves, Physcal Rev., B2, 2273(1970).

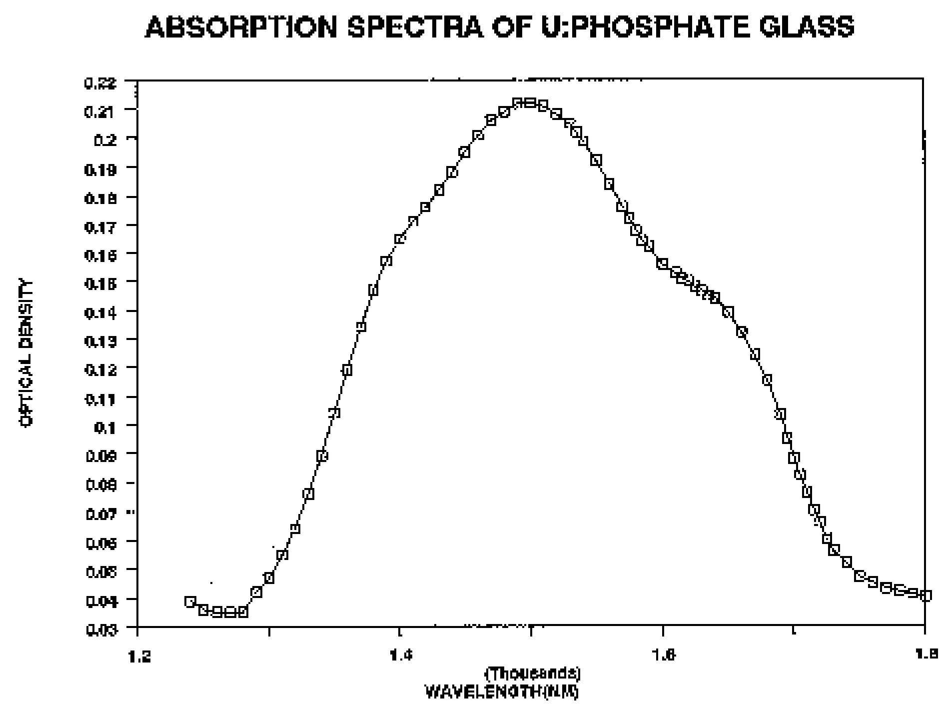


FIG.1 ABSORPTION SPECTRA OF U:GLASS

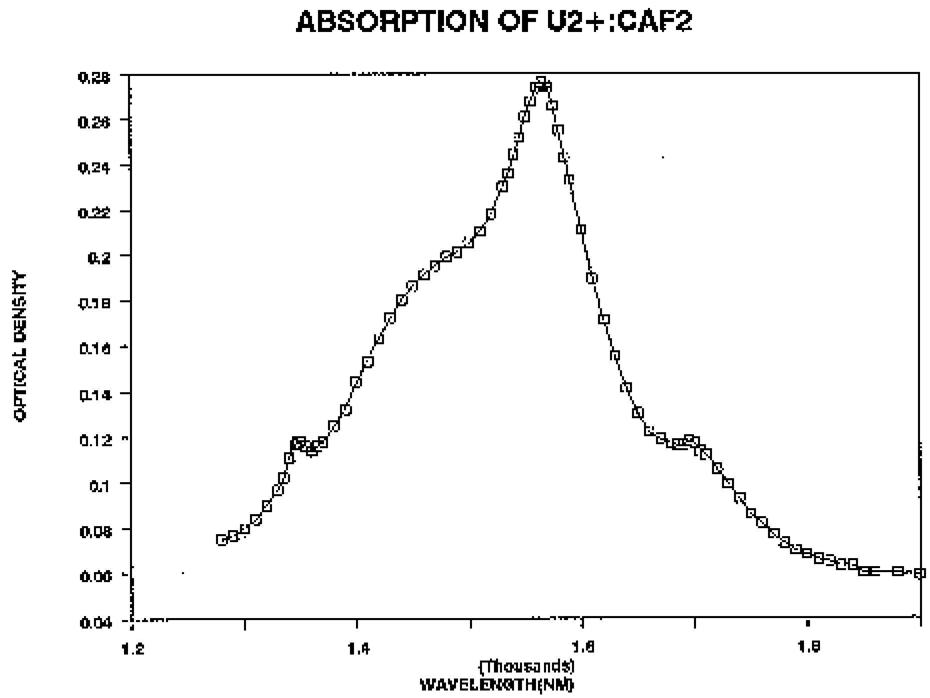


FIG.2 ABSORPTION SPECTRA OF U^{2+}:CaF_2

BLEACHING OF U:PHOSPHATE GLASS UP3

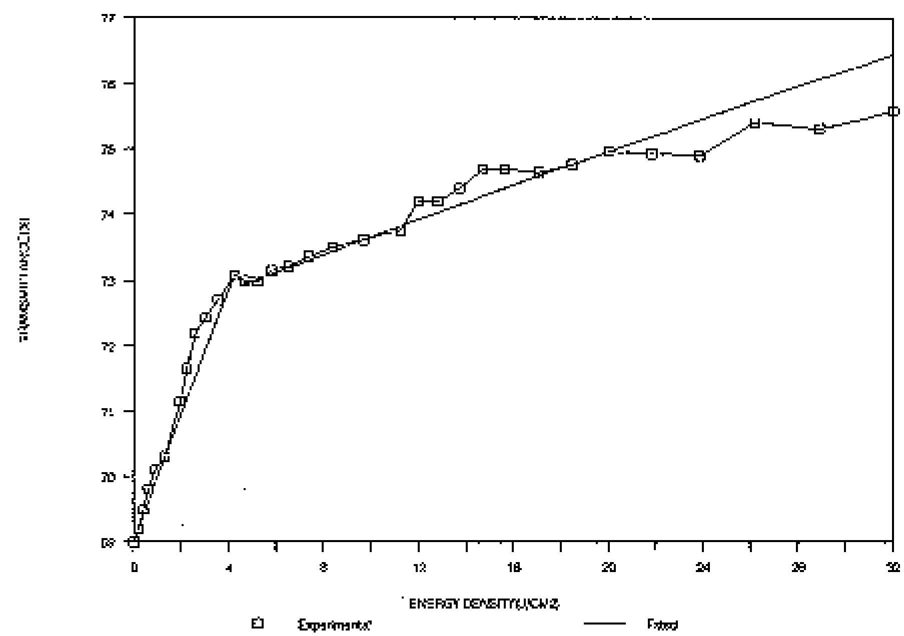


FIG. 3 BLEACHING OF U:PHOSPHATE GLASS

BLEACHING OF U2+:CAF2

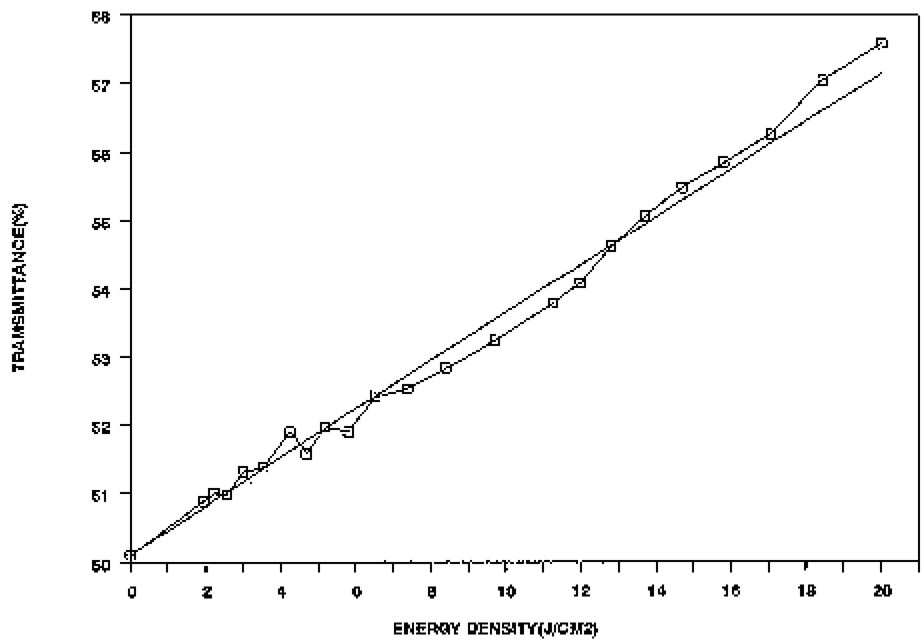


FIG. 4 BLEACHING OF U^{2+}: CaF_2

Table I. Summarised 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
I	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	CYL.01
	82.9%	0.92	1.21	53	1	8.2	55	CYL.01
II	82.9%	0.92	1.21	36	1.5	7.5	65	CYL.01
	82.9%	0.53	1.37	33	3.0	6.2	65	MIXED MODE
	82.9%	0.72	1.42	40	1.5	7.6	65	CYL.01
	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	CYL.01

@Beam size was calculated according TEM_{00} mode
* Ratio of beam size (TEM_{00} mode) in rod to absorber

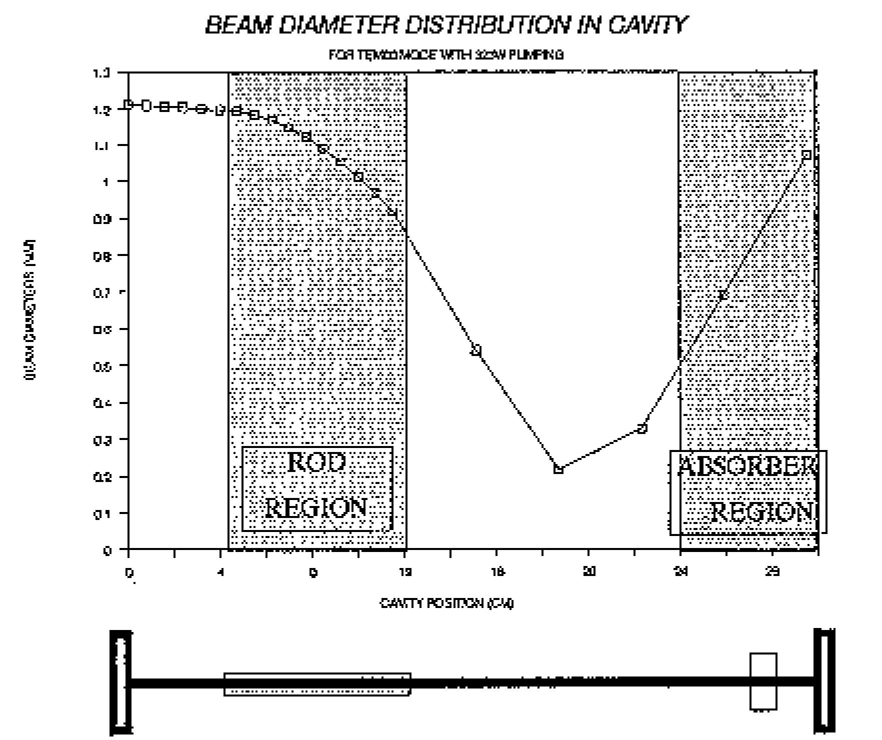


Fig.5 Designed cavity configuration and beam diameter distrubution along cavity

95ASSLC URANIUM DOPED PASSIVE Q-SWITCH KIGRE,INC.

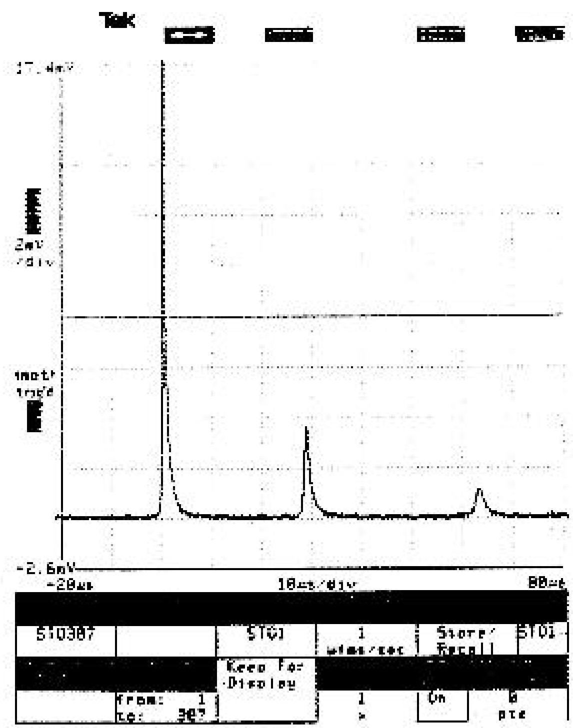


FIG. 6 Q-SWITCHING OUTPUT OF URANIUM DOPED GLASS

95ASSLC URANIUM DOPED PASSIVE Q-SWITCH KIGRE,INC.

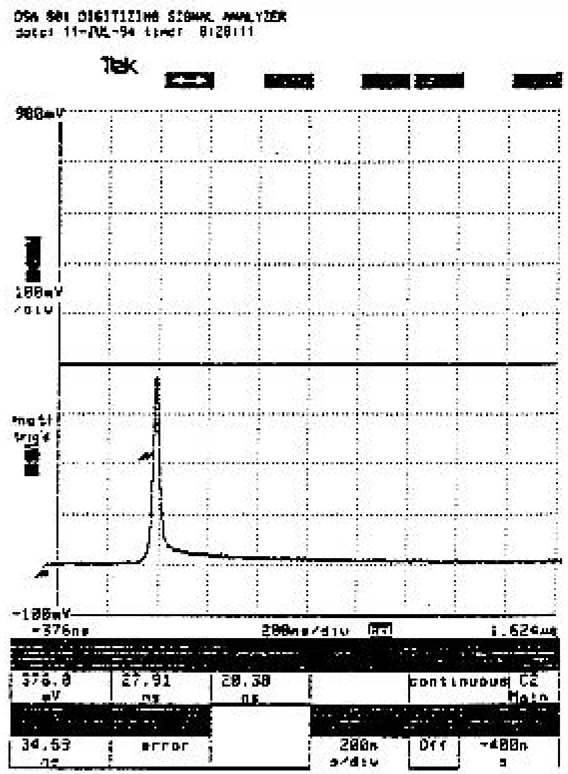


FIG. 7 Q-SWITCHING OUTPUT OF U^{2+}:CaF

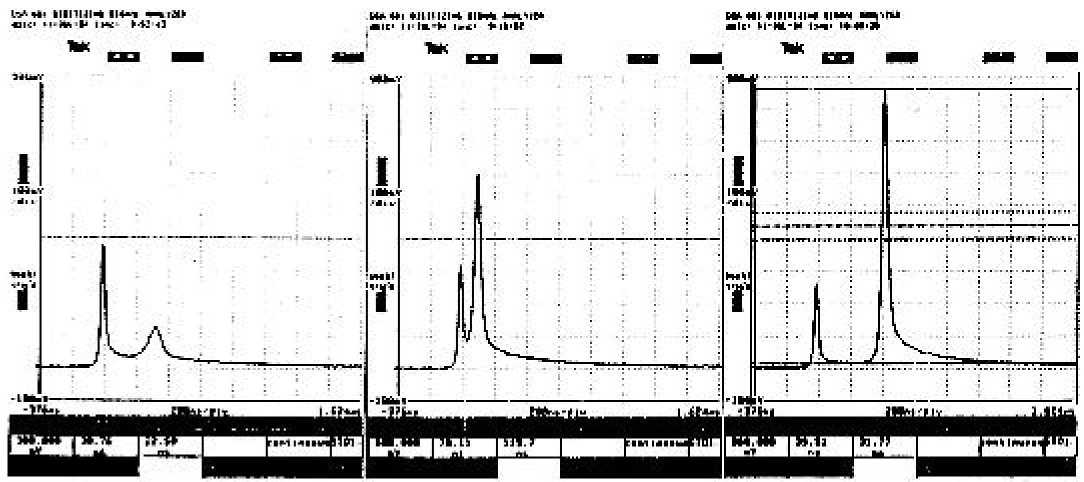
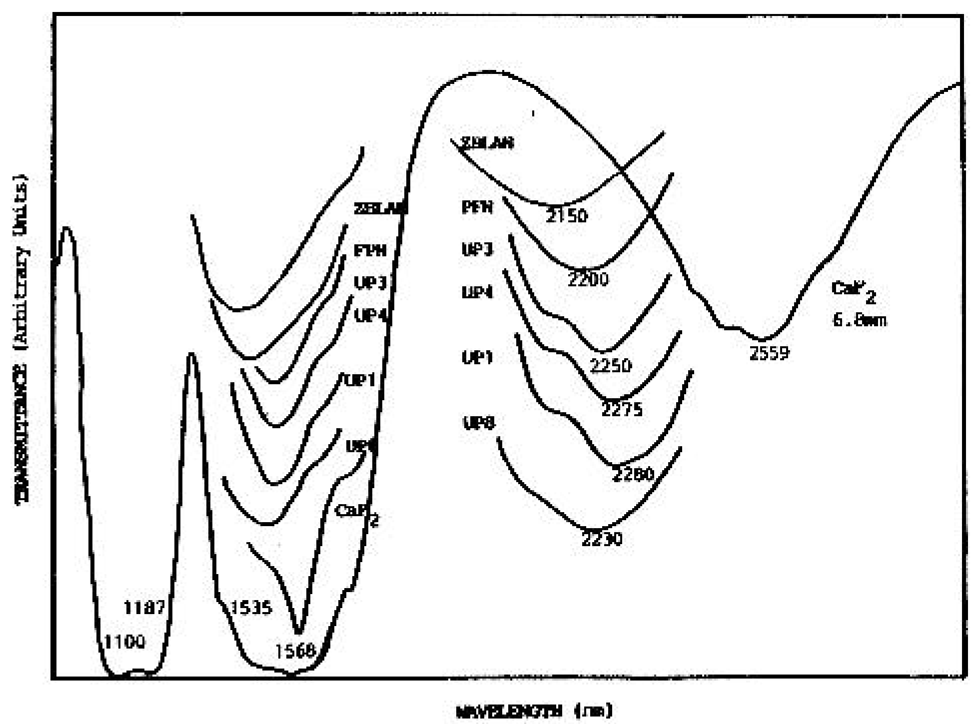
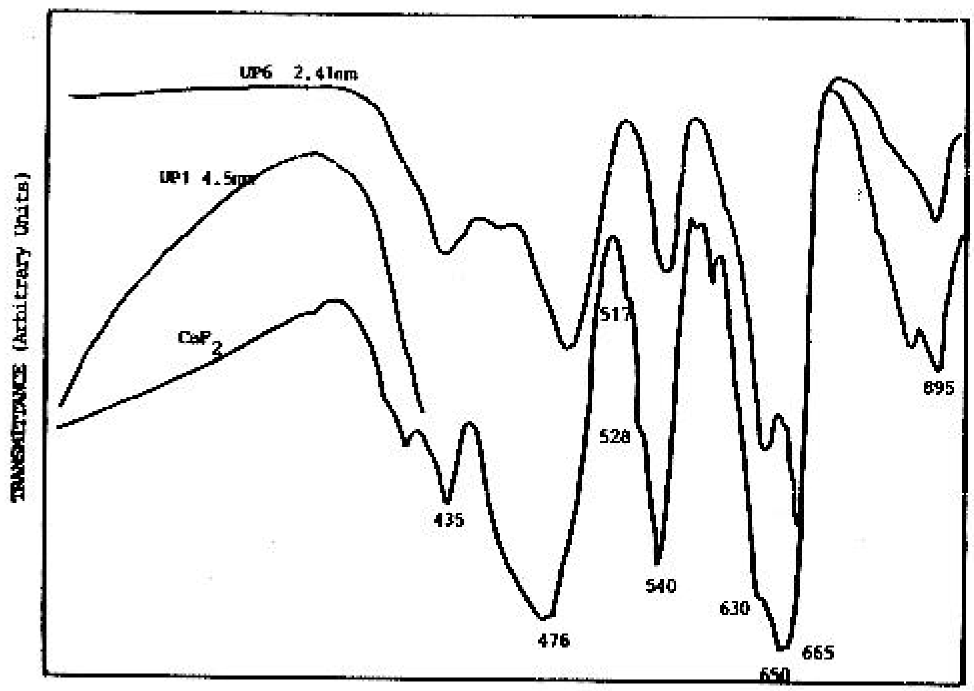


FIG. 8 Double Pulses Behaviour due to the multi-mode structure.

95ASSLC **URANIUM DOPED PASSIVE Q-SWITCH** **KIGRE,INC.**



IR Spectra of U^{4+} Doped Glasses and CaF_2



The Visible Spectra of U^{4+} Doped Glasses and CaF_2