Q-SWITCHING OF A Nd:YLF PULSED LASER USING F_2^- COLOR CENTERS IN LiF[+]

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Q-SWITCHING THEORY

Considering that the $LiF:F_2^-$ centers changes fast their absorption properties during laser pumping the peak output power is given by:

$$Pp = \frac{Vh\nu}{2Tr} \ell n(1/R) \left[n - n_T (1 + \ell n \frac{n}{n_T} \right]$$

Where $h\nu$ is the photon energy, T_R is the cavity round trip time, R is the mirror reflectivity n is the maximum population inversion and n_T is the cavity threshold inversion population in the absence of the absorber. The maximum gain is a measurable quantity given by: $G_M = \sigma_e RL$ where σ_e is the emission cross section L is the active medium lenght and G_T is the threshold gain. We can maximize the peak power that is a funcion of the output mirror reflectivity by imposing:

$$\frac{G_M - G_T}{G_T} = \ell n \left(\frac{G_M}{G_T} \right)^2$$

and in order to achieve the maximum possible inversion population we must have an initial saturable absorber transmission given by:

$$To = \exp \left[G_T - G_M \right]$$

EXPERIMENTAL PROCEDURE

Ultra pure (U.P.) crystal were grown in our laboratory by Czochralski method from zone refined material treated under HF atmosphere. Nd:YLF laser rods were also produced in our laboratory from Nd:YLF single crystals grown from U.P. starting YF_3, NdF_3 and LiF materials. These reagents were sinthetized and zone refined under HF. The Nd:YLF laser is pumped by a Xe flash lamp in a tight coupling pumping cavity; the ressonator cavity is plane parallel; the rod is 7 cm long by 6 mm ϕ, π polarized, with an output energy of (free running) of 300 mJ.

F_2^- CENTERS IN LiF CRYSTAL

F_2^- color center consists of two adjacent anion vacancies shared by three electrons. They are efficiently produced by γ-ray irradiation, at room temperature in U.P. LiF crystal. The fundamental F_2^- absorption peaks at 960 nm. These centers are room temperature stable and can stand high peak powers in the absorption region. LiF:F_2^- centers created as described above have a decay time of 100 ns at room temperature.

Inserting the LiF:F_2^- crystals in the laser resonator with an unsaturated absorption of 48%, we obtained a pulse width of 9 ns (FWHM). The length of the cavity, for this operation, is 40 cm, the shortest possible for achieving optimum Q-Switching, as shown in fig. 1. By increasing the cavity length above 100 cm, we observed complete mode-locked regime, as is shown in fig. 2.

CONCLUSIONS

As we increase the initial absorption, of the saturable absorber, the pulse width becomes narrower and the number of pulses smaller, as we expected. The highest output peak power

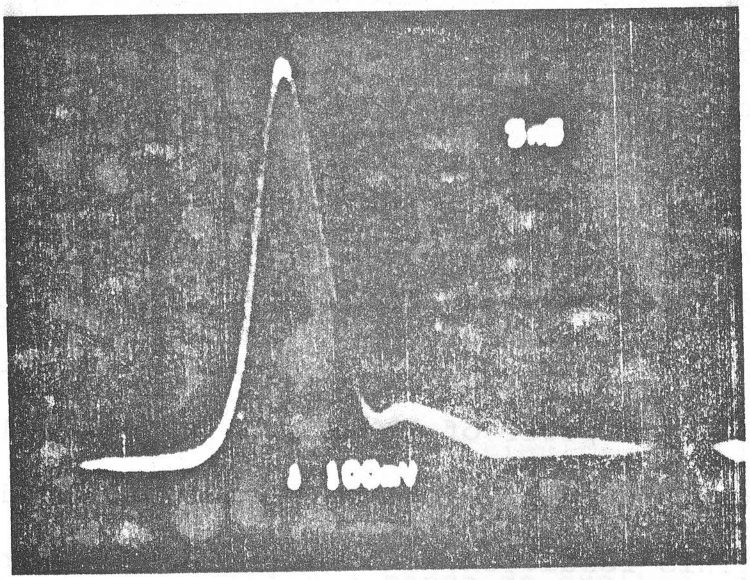

Figure 1. Laser pulse using an F_2^- initial absorption of 48% and an output coupling of 58%. The pulse energy is 110 mJ.

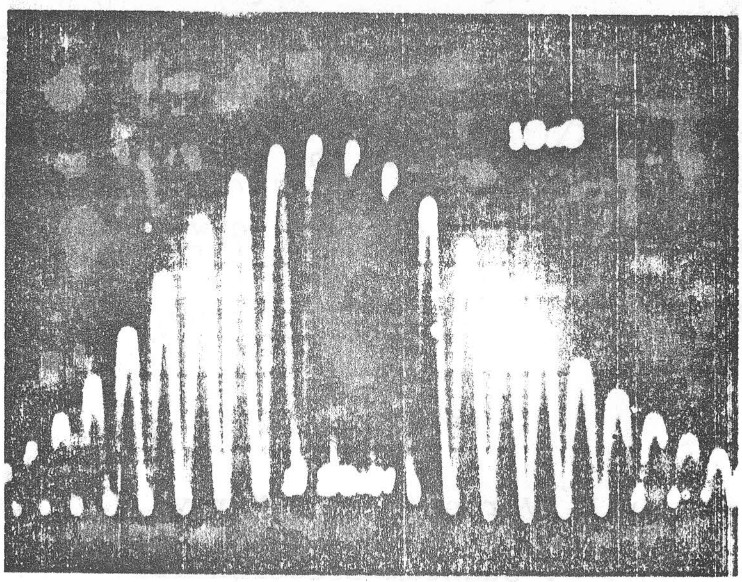

Figure 2. Full mode-locked train of pulses obtained with 48% initial F_2^- absorption and 13% output coupling (cavity length 50 cm).

obtained was 12 MW. For our laser conditions, the maximum gain is 1.25, so according to the theory, in order to have the very best conditions we need an output coupling of 51% (considering that there are no losses in the resonator). The initial trans mission of the saturable absorber for optimum performance,would be T_O = 41% and therefore the output peak power would be 30 MW. For our best experimental conditions (initial absorption 48%), we estimate an output power of 22 MW.This is relatively close to 12 MW because the LiF crystal was uncoated, introducing some re sidual losses. This result exceeds our expectation because the F_2^- centers have a much faster decay rate than the gain medium pump rate, providing an efficient loss for the laser. The absen ce of this effect is due to the stimulated emission induced by the Nd emission line of the F_2^- centers, behaving as a two level system and contribuiting to the laser field. This is a conserva tive mechanism for the laser output energy.The stimulated decay in the saturable absorber also populates much faster the ground state of the F_2^- centers providing a very fast gate during the intense burst of the pulse. This explains why we obtained mode locking operation by stretching the cavity length, in spite of the saturable absorber long decay time with respect to the cavi ty round trip time.

REFERENCES

1. T.T. Basiev, Yu K. Voronko, S.B. Mirov, V.V. Osiko and A.M. Prokhorov - Sov. J. Quantum Electron 12(4) 530 (1982).

2. Toshio Kurobori, Nobuyuki Shoumura and Nozomu Takeuchi - Optics Commu. 58 409,1986.