Passive Q-Switching of an Erbium Fiber Laser Using Uranium-Doped Fluoride Crystal Q-Switches

Robert D. Stultz
Hughes Electro-Optical Systems
2000 E. El Segundo Blvd., E1/D109, El Segundo, CA 90245-0902
Ph: (310) 616-4963, Fax: (310) 616-4468

Hans Bruesselbach and David S. Sumida
Hughes Research Laboratories
3011 Malibu Canyon Road, MS RL65, Malibu, CA 90265-4799
Ph: (310) 317-5204; Fax: (310) 317-5679

Marly B. Camargo* and Milton Birnbaum
Center for Laser Studies, University of Southern California
DRB 17, University Park, Los Angeles, CA 90089-1112
Ph: (213) 740-4230, Fax: (213) 740-8158

Abstract

20 μJ, 200 ns passively Q-switched pulses with a repetition-rate of 1 kHz were obtained using a uranium-doped saturable absorber and a CW-pumped erbium-doped fiber.

Key Words

Fiber optics-amplifiers and oscillators, Rare earth and transition metal solid state lasers, Infrared and far-infrared lasers, Passive Q-switching.

Introduction

Uranium-doped difluoride crystals have recently been used to passively Q-switch flashlamp-pumped Er:Yb:glass lasers [1,2]. The pulse repetition rates of these lasers have been severely limited by the poor thermal conductivity of glass, and the high thermal loads that result from flashlamp pumping. We now show that high pulse repetition rates can be obtained using uranium saturable absorber Q-switches with a CW-pumped Er-fiber laser.

The absorption spectrum for one of our $U:SrF_2$ crystals is shown in Fig. 1. Some controversy has surrounded the valence identification of the uranium ion responsible for 1.5 μm saturable absorber Q-switching, however, the current thought [3] is that it is U^{4+}. All of our U-doped Q-switches also contain U^{3+} (see Fig. 1).

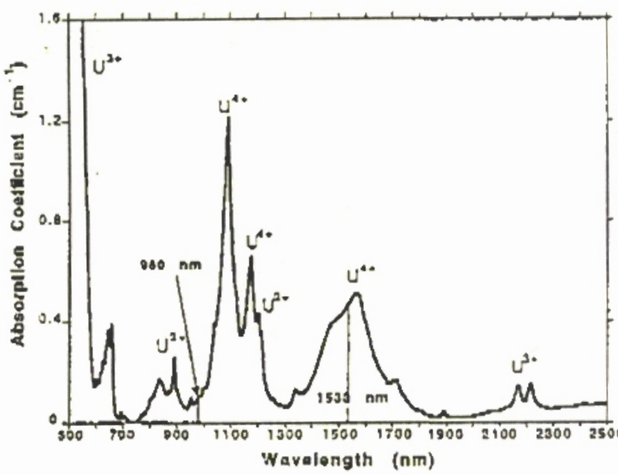

Figure 1. $U:SrF_2$ absorption spectrum.

Experimental Set-up

A diagram of the Q-switched fiber laser is shown in Fig. 2. The Er-doped fiber used was 63 cm long with a core diameter of 75 μm, and a nominal Er concentration of 2700 ppm by weight (2.1×10^{19} ions cm^{-3}).

The resonator output mirror had a concave radius of curvature of 2.5 cm, and its position was fine-tuned for best performance at near 2.5 cm from the end of the fiber. The second resonator mirror was placed as close as practical to the end of the fiber as shown in Fig. 2, and was coated for high reflectance (HR) at the Q-switched laser wavelength (1.5 μm), and high

OSA TOPS on Advanced Solid-State Lasers, 1996
Vol. 1, Stephen A. Payne and Clifford Pollock (eds.)
©1996 Optical Society of America

IPEN / CNEN - SP
BIBLIOTECA
... Científica
IPEN-DOC-4736

transmittance (HT) at the pump (979 nm) wavelength. A CW $Ti:Al_2O_3$ laser, tuned to 979 nm, with an incident power of 1.2 W, pumped the Er-fiber through the second (HT at 979 nm) mirror. A compound 12-mm focal length lens was used to couple the pump light into the fiber.

A 1-mm thick $U:SrF_2$ Q-switch was used in this experiment. The internal transmittance (unbleached) was 89% at 1533 nm. As shown in Fig. 1, the Q-switch absorption is relatively low at the pump wavelength (979 nm); nevertheless, the U-doped crystal was positioned near the output end of the fiber in order to avoid any pump losses through the absorber (Fig. 2).

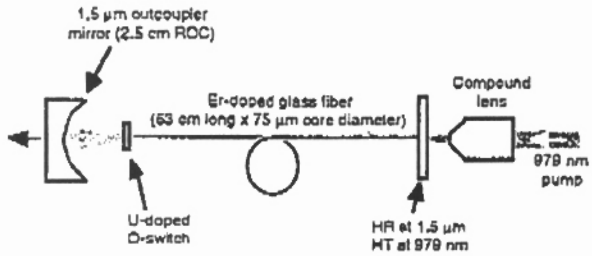

Figure 2. Diagram of Q-switched fiber laser.

Results and Discussion

The output of the fiber laser, with the uranium-doped saturable absorber, typically consisted of a repetitive train of Q-switched pulses. Pulse energy, width, and repetition rate could be varied by translating the Q-switch longitudinally along the beam axis. 20 µJ pulses, with 200 ns full-width at half-maximum (FWHM) pulse durations, at a repetition rate of 1.07 kHz were observed with an 85% reflectivity resonator output mirror. The input pump (979 nm) power was 1.2 W; approximately two hundred milliwatts of this emerged at the output end of the fiber unused. No provision was made to redirect this unused pump back into the fiber. A typical 1.5 µm Q-switched output pulse is shown in Fig. 3. An example of a Q-switched pulse train having a repetition rate of >7 kHz, from which the pulse-to-pulse timing and energy jitter can be observed, is shown in Fig. 4. The FWHM of the individual pulses in this case was about 3.5 µs.

The conventional passive Q-switch rate equations [4,5] were numerically solved using prior measured spectroscopic parameters for $U:SrF_2$ [6]. The nonsaturable loss was varied in the model such that the FWHM of the output pulse matched experiment. As shown in Fig. 3, the theoretical pulse shape (3% nonsaturable loss) is identical to experiment, with the exception of the tail on the experimental pulse. The model predicts that in order to obtain shorter pulses, more saturable loss is required.

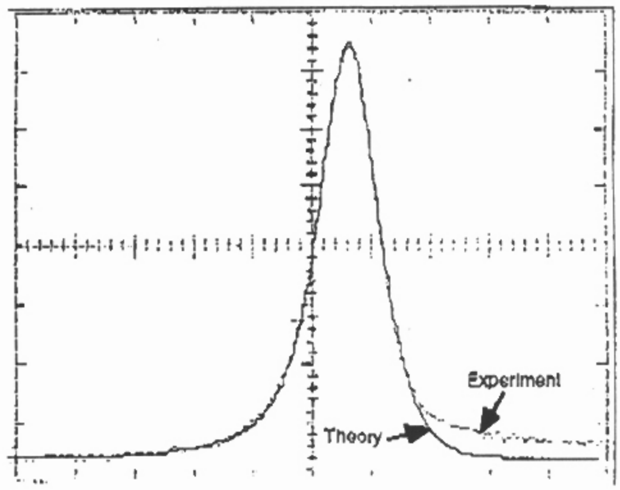

Figure 3. Typical Q-switched pulse (200 ns per division). Tail on experimental trace is an artifact of the detector.

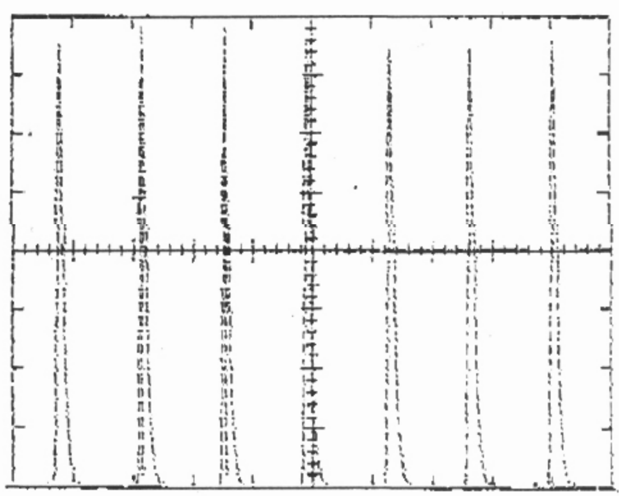

Figure 4. 7 kHz pulse train (100 µs per division), showing small pulse energy and timing jitter. The pulse durations in this figure are determined by the decay time of the integrating detector, and do not represent the duration of the optical pulses.

Conclusions

We have demonstrated passive Q-switching with an Er-fiber laser for the first time, to the best of our knowledge, for this type of saturable absorber. Our modeling, with which our present results agree, predicts significantly shorter Q-switched pulses will be obtained by increasing the saturable loss of the U-doped passive Q-switch and using a shorter fiber/resonator length. We have also demonstrated Q-switching with U:CaF_2, but the results are preliminary.

* *Present address: Instituto de Pesquisas Energéticas e Nucleares - MMO, Travessa R, 400, CEP 05508-900, S. Paulo, SP, Brazil. Financial support: CNPq/RHAE and FAPESP.*

References

1. R. D. Stultz, M. B. Camargo, S. T. Montgomery, M. Birnbaum, and K. Spariosu, Appl. Phys. Lett. **64** (8), 948 (1994).
2. R. D. Stultz, M. B. Camargo, and M. Birnbaum, J. Appl. Phys. **78** (5), 2959 (1995).
3. A. O. Wright, M. D. Seltzer, J. B. Gruber, and J. A. Hutchinson, 1995 IEEE LEOS Proceed., paper SSL3.4.
4. A. Szabo and R. Stein, J. Appl. Phys. **36**, 1562 (1965).
5. A. Siegman, Lasers, (University Science Books, Mill Valley, California, 1986), Chap. 26.
6. R. D. Stultz, M. B. Camargo and M. Birnbaum, OSA Proceed. on Advanced Solid-State Lasers **24**, 460 (1995).