Co^{2+}:$Y_3Sc_2Ga_3O_{12}$ (YSGG) Passive Q-switch for Infrared Erbium Lasers

by:

Marly B. Camargo, Robert D. Stultz,[a] and Milton Birnbaum
Center for Laser Studies
University of Southern California
DRB 17, University Park
Los Angeles, CA 90089-1112,
and
Milan Kokta
Union Carbide Corp.
750 South 32nd Street
Washougal, WA 98671

Co:YSGG possesses a very broad absorption band from 0.9 to 1.8 μm (see Figure 1) which is characteristic of transition-metal-ion-doped materials. Co^{2+} in various crystal hosts[1-3] has been used as a tunable laser source from 1.5 – 2.3μm. We have investigated Co^{2+} in YSGG as a possible saturable absorber Q-switch for 1.5 μm lasers. The Co:YSGG crystal was grown in the <111> direction using the standard Czochralski method. The Cobalt concentration was 2% at. wt. and Silicon was added to the melt for charge compensation.

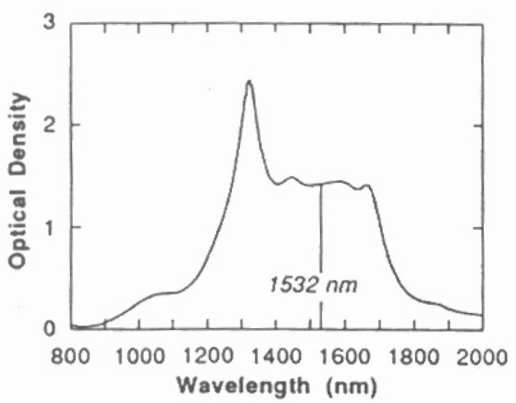

Figure 1. Room temperature absorption of Co:YSGG near 1.5 μm.

The saturation fluence of the Co:YSGG was measured using a Raman-shifted Nd:YAG laser at 1543 nm. The 1543 nm light had a pulsewidth of 15 nanoseconds and was focussed to a 0.5 mm spot diameter. The Co:YSGG crystal used in the bleaching experiment was 1 cm thick with an internal small-signal transmittance of about 4%. The 1.54 μm beam was aligned parallel to the <111> crystallographic direction in the crystal. The results of this experiment are plotted in Figure 2.

We analyzed the bleaching data, assuming a four-level, slowly relaxing absorber model. The following equation was derived using Avizonis and Grotbeck methods.[4] If σ_g is the ground-state absorption cross-section and σ_{ESA} is the excited-state cross-section, then the fluence E as a function of the position z along the crystal, varies according to:

$$\frac{dE}{dz} = -h\nu N_0 \left\{ \left(1 - \frac{\sigma_{ESA}}{\sigma_g} \right) \left[1 - \exp\left(-\frac{\sigma_g E}{h\nu} \right) \right] + \frac{\sigma_{ESA} E}{h\nu} \right\}$$

where N_0 is the absorber ion concentration and hν is the photon energy of the bleaching light. It is assumed, in order to use the above equation, that the pulse duration of the bleaching light is short compared with the excited-state relaxation time for Co^{2+}:YSGG. A very good fit to the experimental data is obtained by using $\sigma_g = 5.2 \times 10^{-20}$ cm^2 and $\sigma_{ESA} = 0$ (see Figure 2). The cross-section (σ_g) at the Q-switched Er:glass laser wavelength of 1532 nm should not be significantly different (see Figure 1).

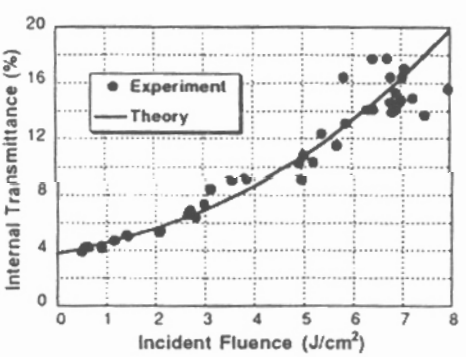

Figure 2. 1543 nm bleaching of 1 cm thick Co:YSGG crystal. Solid curve is from Avizonis-Grotbeck model.

The Q-switching results were obtained using a Kigre 4 x 76 mm QE-7S Er:glass rod. The rod was pumped with a flashlamp pulse of about 600 μsec pulsewidth. The pump cavity used in this experiment was designed for a much larger laser rod and therefore was not an optimized system. Threshold was 40 J and 27 J for the Q-switched and free-running laser, respectively. The outcoupler had a curvature of 2.5 cm and a reflectivity of 94%. An intracavity lens with a 5 cm focal length was used to focus the light into the Q-switch.

The Q-switch thickness was 0.5 mm with internal transmittance of 85%. It was cut with the faces perpendicular to the crystallographic direction <111>. The Q-switch was polished flat with parallel surfaces and was used uncoated in the laser experiments.

A typical Q-switched pulse is shown in Figure 3 (4 mJ, 20 nsec). The wavelength of the Q-switched output was 1532 nm, measured using a 1/4 meter Jarrell-Ash monochromator. This was about 2 nanometers less than the peak of the emissions of the free-running laser (1534 nm).

We numerically solved saturable absorber Q-switch rate equations[5,6] using cross-sections of 0.8×10^{-20} cm^2 and 5.2×10^{-20} cm^2, respectively for the Er:glass and Co:YSGG. Slowly-relaxing Q-switch theory predicts that Q-switching with this material should occur even without intracavity focussing, although experimentally no Q-switching was observed without focussing. The reason for this discrepancy may be due to a short relaxation lifetime of the Q-switch which was not included in the theoretical model. With focussing included in the theory, a 28 nanosecond pulsewidth was calculated (reasonably good agreement with experiment).

In conclusion, we have demonstrated a new passive Q-switch material for the Er:glass laser. The very broad absorption band may permit its use as a Q-switch for a variety of lasers in the 1 – 2μm wavelength range. Future research in this area will include spectroscopic measurements (including fluorescence lifetime).

M. B. Camargo, thanks the Brazilian Institute of Energetical and Nuclear Research (IPEN-CNEN/SP) and also the Brazilian National Science Foundation (CNPq/RHAE Program) for her financial support.

a) also with Hughes Aircraft Co. at El Segundo, CA.

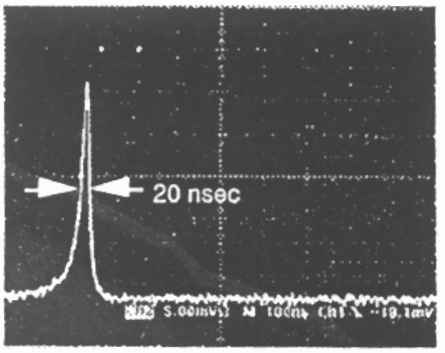

Figure 3. Output pulse from Er:glass laser Q-switched using Co:YSGG.

References

[1] P. F. Moulton, IEEE J. Quantum Electron. **QE-21**(10), 1582 (1985).

[2] D. Welford and P. F. Moulton, Opt. Lett. **13**(11), 975 (1988).

[3] W. Kunzel, W. Knierim, and U. Dürr, Opt. Commun. **36**(5), 383 (1981).

[4] P. V. Avizonis and R. L. Grotbeck, J. Appl. Phys. **37**(2), 687 (1966).

[5] A. Szabo and R. A. Stein, J.Appl.Phys. **36**(5), 1562(1965).

[6] A. Siegman, Lasers (University Science Books, Mill Valley, California, 1986), chapter 26.