Atypical behavior of Cr:YAG passively Q-switched Nd:YVO_4 microlasers at high-pumping rates

M.A. Jaspan and D. Welford
Q-Peak, Inc., 135 South Road, Bedford, MA 01730
Phone (781) 275-9535, Fax (781) 275-9726, E-mail mjaspan@qpeak.com

G. Xiao and M. Bass
School of Optics/CREOL University of Central Florida Orlando, FL 32816-2700
Phone (407) 823-6977, Fax (407) 823-6880 E-mail: bass@creol.ucf.edu

Abstract: We present confirmation of passive Q-switching in microlasers with a cross section ratio, α, less than or near unity. Unlike large-α systems, pulses in small-α systems shorten in duration and increase in energy with increasing pump power.

OCIS Codes: (140.3540) and (140.3430)

Introduction

Passively Q-switched microlasers are an elegant means to generate sub-nanosecond duration pulses with moderate energies. Earlier work on these devices [1,2,3] has emphasized that the following criterion must be met to ensure Q-switching:

$$\frac{\sigma_{gs}}{\gamma\sigma} \times \frac{A_g}{A_s} > 1, \tag{1}$$

where, σ_{gs} is the saturable absorber ground–state absorption cross section, σ is the gain medium emission cross section, γ is the gain medium degeneracy factor, and A_g and A_s are the laser beam areas in the gain medium and saturable absorber, respectively.

Eq. 1 suggests that the ratio $\sigma_{gs}/\gamma\sigma$, α [1] or α' [2], must be greater than unity for a passively Q-switched microlaser to work with a plano-plano cavity structure, e.g. when A_g and A_s are equal. In Ref. 3 a Nd:YVO_4/Cr:YAG microlaser failed to operate and $\alpha \leq 1$ was cited as the reason. Yet, in this work we present Nd:YVO_4/Cr:YAG microlaser Q-switching data for small-α, i.e. near one, with $A_s \approx A_g$.

Experimental results

We assembled and characterized a cw-pumped Nd:YVO_4/Cr:YAG microlaser, as shown in Fig.1. The Cr:YAG unsaturated transmission was 80% and the output coupler reflectivity was 85%. Total cavity length was 3 mm of which 1 mm was 3% Nd-doped YVO_4. The microlaser was pumped with a 100-μm diameter beam from a fiber-coupled diode laser. Despite having small α, this laser Q-switched reliably.

Referring to Fig. 1 it can be seen that the initially high pulse rate rapidly decreases asymptotically to 50 kHz with increasing pumping rate. This behavior starkly contrasts with large-α systems, such as Nd:YAG/Cr:YAG, where pulse rate increases linearly with pumping rate. Additional atypical behavior for small-α systems is shown in Fig. 2, where the pulse duration and energy improve with pump power in contrast to the invariance seen in systems with large α.

Numerical simulations

When cw pumping at high rates a laser with small α, the derivations of Degnan and others [1,2] require the addition of pumping and spontaneous loss terms to render a new set of rate equations that we solve numerically. Fig. 3 shows a temporal pulse profile for a passively Q-switched laser, obtained from the numerical solution to the rate equation model, for $\alpha = 0.65$.

We apply Siegman's second threshold condition [4] to extract a new criterion for passive Q-switching:

$$\alpha \geq 1 + \frac{1}{(\eta_i - 1)} - \frac{\eta_{cw} - \eta_i}{(\eta_i - 1)\tau_a \Phi_i}, \tag{2}$$

where η_i is set by Siegman's first threshold condition to the value for which the gain balances the saturable losses and other cavity losses.

This criterion includes the effects of pumping rate for the first time. The second term reduces the limiting value on α for large initial inversions thereby improving Q-switching for large stored energy [3]. Additionally, the third term decreases the limiting value on α at high-pumping rates thereby enabling Q-switching.

References

1 J. J. Degnan, *IEEE J. Quantum Electron*., **31**, 1890-1901, (1995).
2 Guohua Xiao and Michael Bass, *IEEE J. Quantum Electron*., **33**, 41-44, (1997).
3 Y. Bai, N. Wu, J. Zhang, J. Li, S. Li, J. Xu, and P. Deng, Applied Optics, 36, 2468-2472, (1997).
4 A. Siegman, Lasers, 1st ed., p1026, (1986).

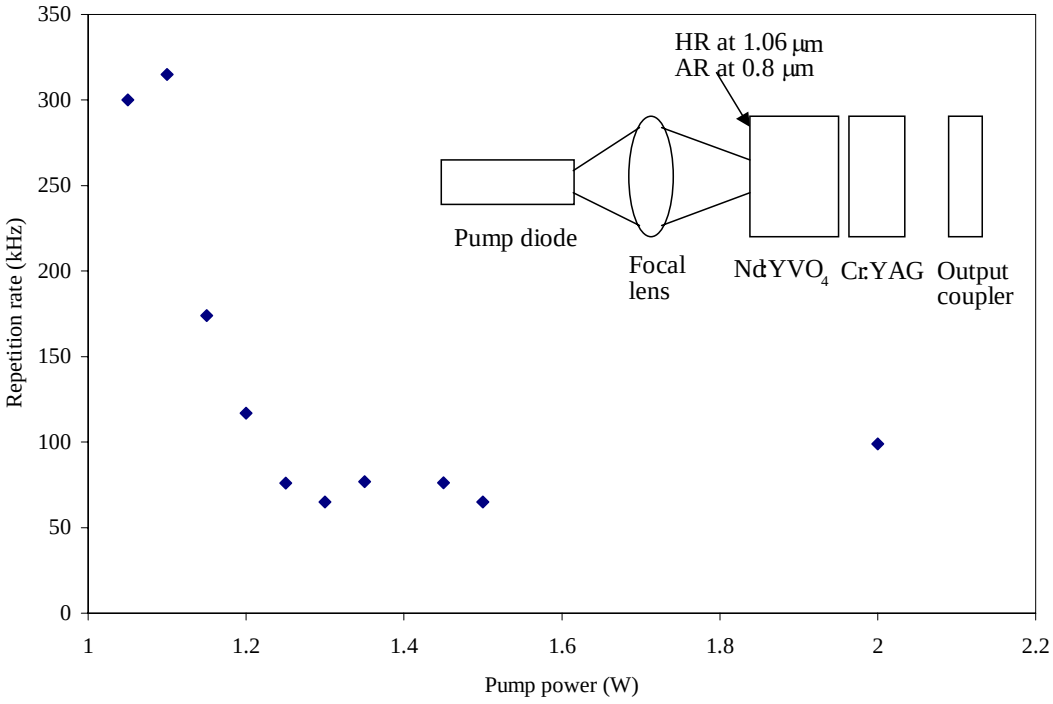

Fig. 1. Cr:YAG passively Q-switched Nd:YVO_4 laser pulse repetition rate as a function of pump power. Inset shows resonator layout.

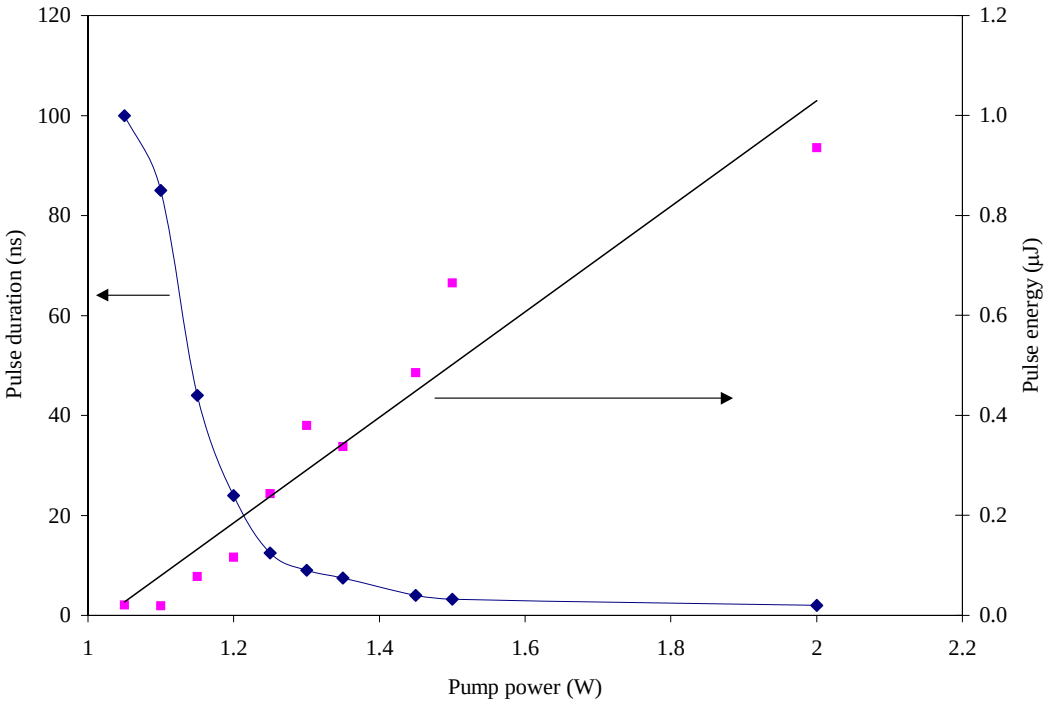

Fig. 2. Cr:YAG passively Q-switched Nd:YVO_4 laser pulse pulse duration and energy as a function of pump power.

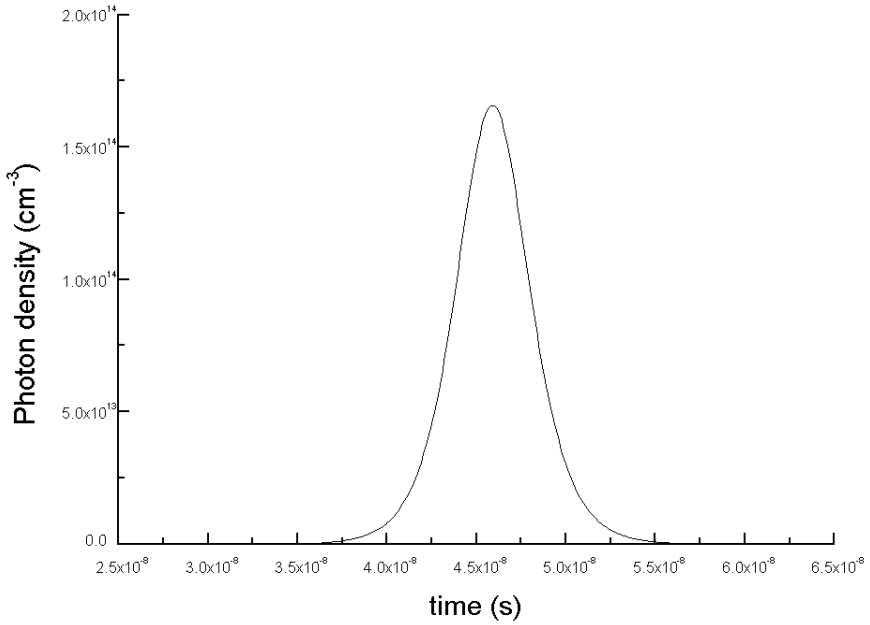

Fig. 3. Temporal pulse profile for a passively Q-switched microlaser with α=0.65.