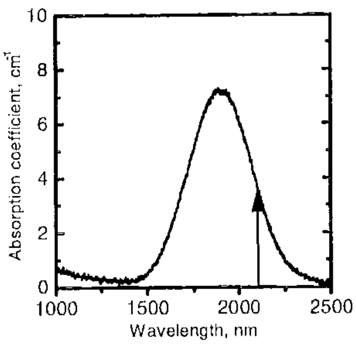

CThM5 Fig. 1. Absorption spectrum of Cr^{2+}:$Cd_{0.55}Mn_{0.45}Te$.

width of about 400 μs. Using the method of Avizonis and Grotbeck[2] the ground state absorption (GSA) cross section was estimated to be of 1.1×10^{-18} cm^2 at 2.09 μm. That was in satisfactory agreement with the results published in Ref. 3. The excited-state absorption (ESA) cross section did not exceed the value of 0.4×10^{-19} cm^2. Thus Cr^{2+}:$Cd_{0.55}Mn_{0.45}Te$ crystals look promising as passive *Q*-switches for 2-μm lasers due to high GSA cross section and negligible ESA losses. The *Q*-switching experiments were carried out with a flash-lamp-pumped Cr,Tm,Ho:YAG laser rod (∅5 × 100 mm). A laser cavity was formed with concave high reflector with a 1-m radius of curvature and a flat output coupler with 30% transmission at the laser wavelength. The saturable absorber was placed into the cavity between the laser rod and the high reflector at Brewster angle. A *Q*-switched pulse duration was measured with a InGaAsSb photodiode with a temporal response of 20 ns. We have obtained a passive *Q*-switching of Cr,Tm,Ho:YAG laser with a pulse width of about 200-ns FWHM and an output pulse energy of 8 mJ from 85-cm-long laser cavity using Cr^{2+}:$Cd_{0.55}Mn_{0.45}Te$ saturable absorber with small signal transmission of 70%.

In conclusion, saturation of absorption at 2.09 μm was measured in Cr^{2+}:$Cd_{0.55}Mn_{0.45}Te$ and GSA and ESA cross sections were estimated. Passive *Q*-switching of Cr,Tm,Ho:YAG laser was demonstrated with Cr^{2+}:$Cd_{0.55}Mn_{0.45}Te$ passive shutter and giant pulses with energy of 8 mJ and pulse duration of 200 ns were obtained.

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CThM6

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

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

$$\frac{\sigma_{gs}}{\gamma\sigma} \times \frac{A_g}{A_s} > 1, \qquad (1)$$

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 $\alpha \le 1$ 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 $A_s \approx A_g$.

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.

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. Figure 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:

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

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.

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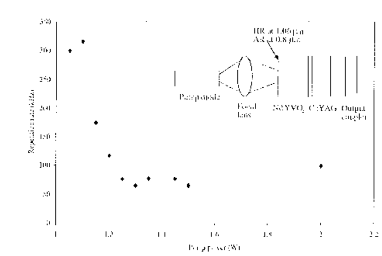
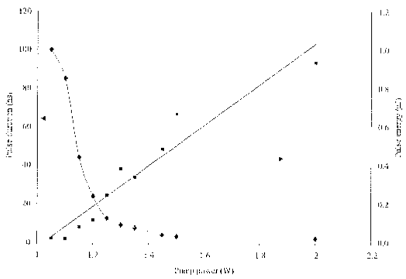
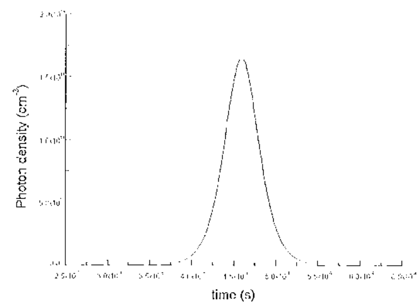


CThM6 Fig. 1. Cr:YAG passively *Q*-switched $Nd:YVO_4$ laser pulse repetition rate as a function of pump power. Inset shows resonator layout.



CThM6 Fig. 2. Cr:YAG passively *Q*-switched $Nd:YVO_4$ laser pulse pulse duration and energy as a function of pump power.



CThM6 Fig. 3. Temporal pulse profile for a passively *Q*-switched microlaser with $\alpha = 0.65$.

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