CW-pumped, Repetitively Q-switched Operation of a Ti:sapphire Laser

A. Finch, P.F. Moulton and G.A. Rines

Schwartz Electro-Optics, Inc.
Research Division
45 Winthrop Street
Concord, MA 01742
508-371-2299

We report the first, to our knowldege, data on Q-switched operation of a cw-pumped Ti:sapphire laser, in which we observe generation of 140-W peak-power, 40-ns-duration pulses at a 100 kHz rate.

CW-pumped, Repetitively Q-switched Operation of a Ti:sapphire Laser

A. Finch, P.F. Moulton and G.A. Rines

Schwartz Electro-Optics, Inc.
Research Division
45 Winthrop Street
Concord, MA 01742
508-371-2299

The enhancement in output power provided by Q-switched operation of a cw-pumped laser is proportional to the ratio of the laser upper-level lifetime to the laser-cavity lifetime. For many systems the latter is on the order of tens of ns and thus solid state lasers such as Nd:YAG, with a 240-μs upper-level lifetime, can produce peak powers 10^3-10^4 times greater than the cw levels. On the other hand, there is no benefit to Q-switching conventional dye lasers, which have nanosecond upper-level lifetimes. The Ti:sapphire laser is an intermediate case, as the laser transition has a room-temperature lifetime of 3.2 μs, and some enhancement would be expected for sufficiently short cavity lifetimes.

In the experiments reported here, we present the first data, to our knowledge, on a cw-pumped, repetitively Q-switched Ti:sapphire laser. We observed operation over a wide range of repetition rates, with peak powers of nearly 140 W in 40-nsec-duration pulses at pulse rates up to 100 kHz and peak powers of 20 W in 100-nsec pulses at a 900 kHz rate, all at a 800-nm wavelength. The laser system studied was capable of 2.3 W of cw output and thus we obtained a peak-power enhancement of over 60. In one application of the Q-switched laser we generated 1.7 W and 4.9 mW of peak and average second-harmonic power at 400 nm through the use of a BBO external doubling crystal. In all cases the Ti:sapphire laser operated on the TEM_{00} mode.

The Ti:sapphire laser consisted of a 0.75-cm-long Brewster-angle Ti:sapphire crystal placed in an 4-mirror, astigmatically compensated, X-configuration cavity. Also in the cavity was a 3-plate birefringent crystal and a Brewster-angle acousto-optic Q-switch driven at 24 MHz. The total cavity length was 72 cm and the output coupler-transmission was 24%. The pump source was an all-lines argon-ion laser and the threshold pump power was 1.6 W. The data presented was taken at a pump power of 8.8 W. The level of enhancement is, to some extent, due to the use of a heavily doped crystal and a small pump-beam spot size, which leads to high gain and the ability of the laser to operate well over threshold with a relatively high level of output-mirror transmission.

We measured the peak power, pulsewidth and average power as a function of pulse repetition rate. At the highest rate, the average power was 1.8 W. As a check on our results we compared the data with the Q-switching theory of Chesler *et al.*[1]. The latter is a simplification that omits the effects of a finite pulse buildup time. In fact, we were limited to a maximum repetition rate of 900 kHz by the buildup time, which increased to over 650 ns at the highest pulse rate. Figure 1 shows the measured and calculated pulsewidths of the laser, while Figure 2 presents the measured and calculated peak powers, respectively, also as a function of pulse rate. The agreement with theory is reasonably good, considering that the theory also asumes the inversion density and cavity modes to be spatially uniform in the gain medium, as distinguished from the actual case of three-dimensionally varying pump and laser-mode intensities.

In harmonic-generation experiments, we focused the laser output, run at a 100-kHz pulse rate, into a pair of BBO crystals, each 6 mm long and cut for Type I SHG phasematching at an angle of 27.2 degrees (normal incidence phasematching for 860 nm). The resultant 1.7 W and 4.9 mW peak and average powers represented a conversion efficiency of 0.9%. In contrast, with the system run at a 2.3-W cw level, we were only able to observe 170 μW of 400-nm output. As the cavity lifetime in our system was determined almost entirely by the cavity length and output coupling we expect that even higher power enhancements and shorter pulses would result from the use of shorter cavities and/or higher levels of output-mirror transmission. Besides the application to improved harmonic generation, one may also be able to pump parametric oscillators based on non-critically phasematched KTP (and isomorphs) and generate pulses in the 1-3-μm wavelength region.

[1] R.B. Chesler, M.A. Karr and J.E. Geusic, "An experimental and theoretical study of high repetition rate Q-switched Nd:YAlG Lasers," Proc. IEEE **58**, 1899 (1970).

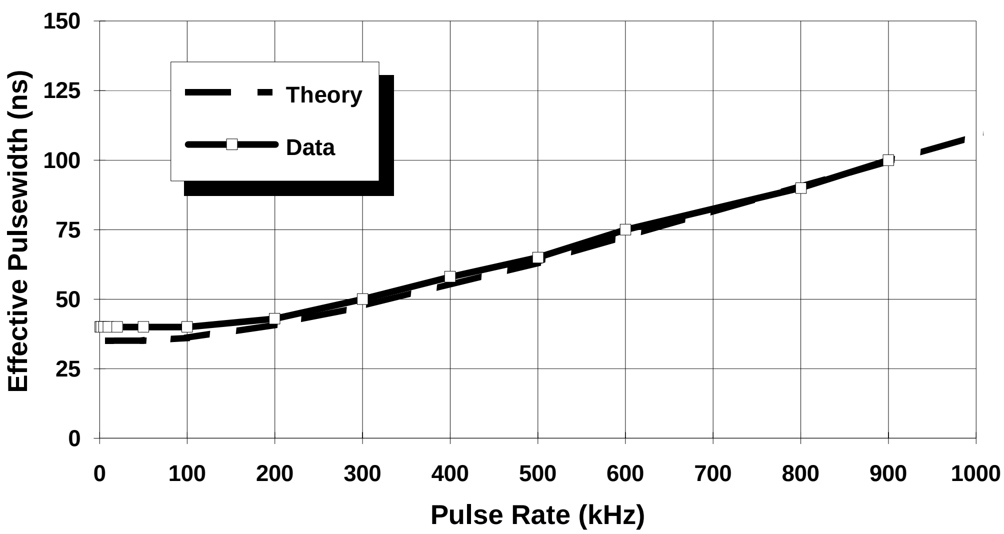

Figure 1. Pulsewidth vs. the pulse repetition rate.

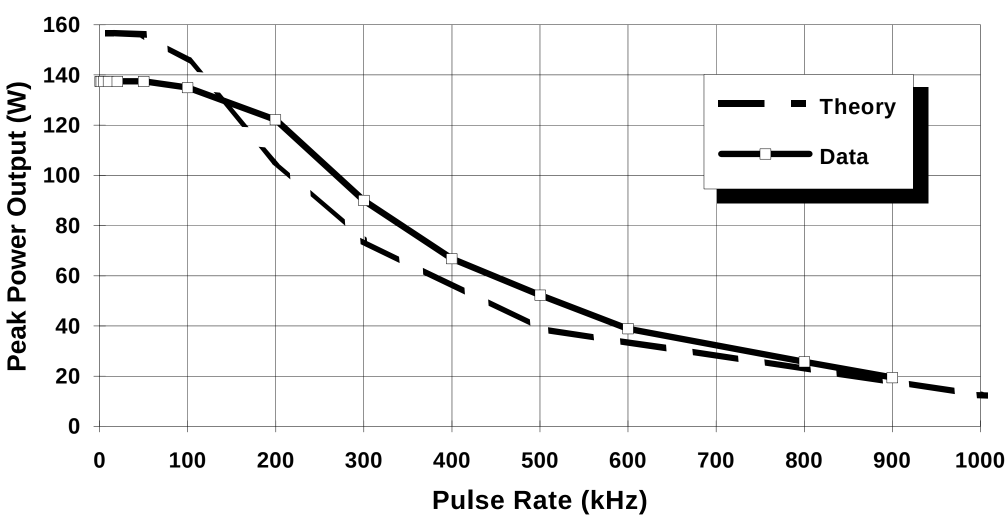

Figure 2. Peak output power vs. pulse repetition rate.