CW AND Q-SWITCHED OPERATION OF A HIGH-GAIN DIODE-END-PUMPED Nd:YLF OSCILLATOR USING THE BEAM SHAPING TECHNIQUE

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We report the development and characterization of a high-gain diode-laser-pumped Nd:YLF oscillator. The cavity fundamental mode has an enhanced overlap with the transversally symmetric pumping beam transformed by the beam shaper. In CW operation, the double-pass small-signal gain was 4.2, with optical efficiency of 45%. In Q-switched operation, using a $LiF:F_2^-$ ***saturable absorber, pulses as short as 2.5 ns were obtained, in a highly stable regime.***

Nd:YLF is a laser medium with highly favorable characteristics for longitudinal laser pumping. For an available pump source, there is a broad range of laser beamwaists that lead to almost the same (maximum) laser output power.[1] However, when high values of the small-signal gain are needed, high brightness pump laser beams and proper design of the laser system are required.

We report the development and characterization of a high-gain diode-laser-pumped Nd:YLF oscillator. We have used a 4 W c.w. diode-laser (DL), operating at 792 nm. The emission area is 1 µm x 500 µm, and $M_y^2 \approx 1$ and $M_x^2 \approx 100$ (*SDL-2382-P1*). The beam was collimated by a diffraction-limited, f = 8 mm objective, and corrected by a 3x anamorphic prism pair (*Melles Griot*). We have used the two-mirror beam-shaping technique to produce a nearly circular beam, as described by Friel et. al.[2] By defocusing the objective, a beamwaist of $w_x \approx 1$cm, $w_y \approx 100$µm was produced at the beam shaper mirrors, placed at 30 cm from the DL output. The two silver-coated mirrors were conveniently configured to chop up the incident beam (in the x direction) into 10 adjacent beams, and to re-arrange the relative positions so that the beams are stacked one above the other (see Figure 1).

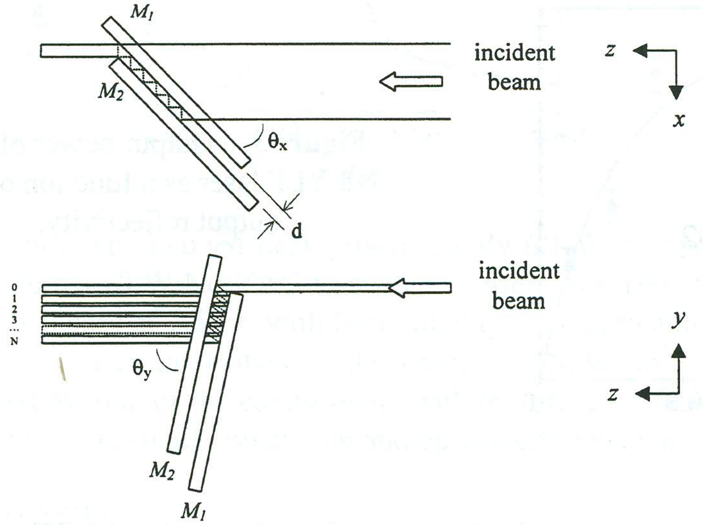

Figure 1 - Two mirror beam shaping technique

The general setup of the laser system is shown in Figure 2. After the beam shaper, the beam was focused by a 50 mm spherical lens, producing a nearly circular beamwaist, $w_{x,y} \approx 60$ µm, with $M^2 \approx 21$, in the 19-mm-long home-grown Nd:YLF crystal. In our case, the beam shaper transmission was 75%, and the power incident at the laser crystal was 2.2 W. M_1 and M_2 are plane mirrors, and the folding mirror M_3 has $R=1$m; $L_1 \cong 50$ cm and $L_2 \cong 25$ cm. The laser crystal, at Brewster angle, was positioned close to the mirror M_1 (HT at 792nm, and HR at 1047nm).

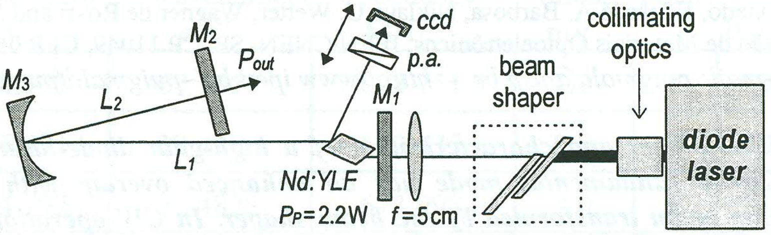

Figure 2 - Diode-pumped Nd:YLF laser

As shown in Figure 2, the residual beam reflection at the end of the laser crystal was used to monitor the quality, dimensions and polarization properties of the cavity mode, using a CCD camera and a polarization analyzer (p.a.). By modulating the DL pump duty cycle, a beamwaist of $w_L \approx 120\mu$m was kept constant.

By changing the output mirror (M_2) reflectivity and measuring the output power, we could obtain the double pass small-signal gain, Γ^0, and the cavity losses, L, modeling the system with the well known laser oscillator expression:[3]

$$P_{out} = [AI_s(1-R)/2][\Gamma^0/(L-\ln R) - 1]$$

The measured data as well as the laser parameters are shown in Figure 3. The obtained gain, $\Gamma^0 = 4.2$, brings interesting possibilities for the efficient operation in the Q-switching or mode-locking regimes

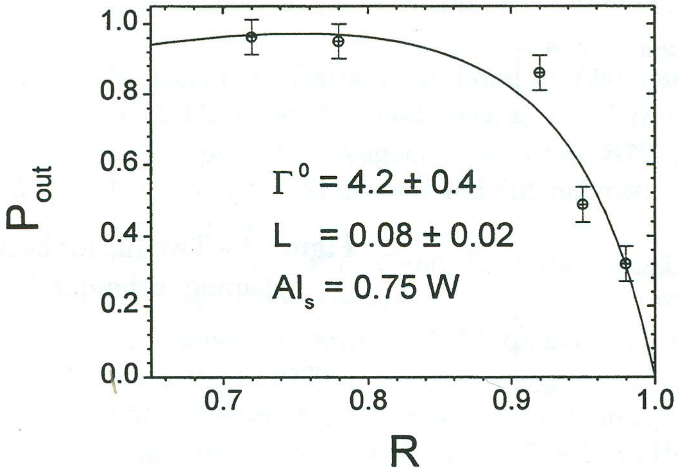

Figure 3 - Output power of the Nd:YLF laser as a function of the output reflectivity.

We have studied the Q-switched pulse generation in this system by using a slightly different laser resonator, with length shortened to 2 cm, and with the insertion of a LiF:F_2^- saturable absorber (SA) in the cavity, as shown in Figure 4. The initial absorption of the SA was 15% and the output mirror reflectivity was 92%.

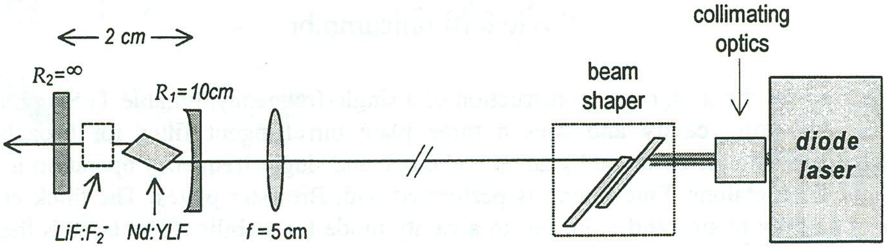

Figure 4 - Experimental setup for the passive Q-switching of the diode-pumped Nd:YLF laser

The laser produced Q-switched oscillations that could be stabilized and optimized, leading to the generation of 2.5 ns pulses, as shown in Figure 5, at a repetition rate of 10 KHz and average output power of 150 mW. We used an InGaAs ultrafast photo-detector (*Opto-Electronics*, model PD50) with response time of 50 ps, and a digital scope (*Tektronics*) with response time of 700 ps and sampling rate of 5 GHz. The pulse train showed a pulse-to-pulse amplitude variation of the order of 10%, and period variation of 5% (time jitter). However, as the diode laser current was electrically chopped, and adjusting its frequency and duty cycle, it was possible to produce a single Q-switched pulse for pumping cycle. In this regime, the time jitter was below the measurable limit, and the amplitude fluctuations were below 1%. The beam quality was around $M^2 \approx 1.2$.

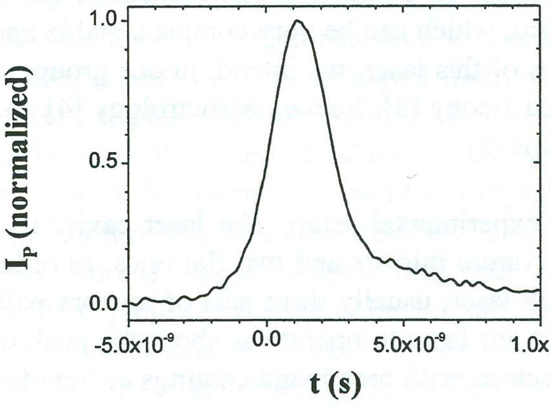

Figure 4 - Laser pulse obtained by passive Q-switching of the diode-pumped Nd:YLF laser.

Despite the obtained peak power is only 6 KW, compared with 50 KW typically obtained for 1 KHz, 200 ns, 10 W Nd:YAG Q-switched lasers, we have demonstrated an all-solid-state system that produces pulses of 2.5 ns with beam quality enough to attain near diffraction-limited beam size, thus capable to attain intensities of the order of 1GW/cm^2. These features were obtained due to the enhanced overlap of the cavity mode with the pumping beam transformed by a beam shaper, that has leaded to a high small-signal gain and optical efficiency of 45% in the CW regime.

REFERENCES

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[2] G.J.Friel, W.A.Clarkson, D.C.Hanna, in *Conference on Lasers and Electro-Optics*, 1996 OSA Technical Digest Series (Optical Society of America, Washington, DC, 1996), p.144.

[3] E.P.Maldonado, G.E.C.Nogueira and N.D.Vieira Jr., *IEEE J.Quantum Electron.*, Vol. **29**, p.1218 (1993)