# Diode-end-pumped 1D top-hat $Nd:YVO_4$ slab laser

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A one-dimensional (1D) top-hat, diode-end-pumped, electro-optically $Q$-switched $Nd:YVO_4$ slab laser is demonstrated. Under the pump power of 175.5 W, 26.3-W output power is obtained with the repetition rate of 5 kHz and the pulse width of 4.3 ns. The output beam has a good top-hat beam profile in both the near field and the far field.

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Diode-pumped solid-state laser (DPSSL) has attracted much attention since it was invented because of its high output power, high efficiency, small size, and reliability[1]. Laser beam with top-hat profile has been widely used in laser processing, pumping dye laser, and inertial confinement fusion. Reshaping of Gaussian beam with a group of optical lenses has been proved to be an efficient way to get laser with one-dimensional (1D) top-hat beam profile[2]. But it cannot keep the beam profile as a 1D top-hat during the whole propagation especially near the focus due to laser spatial coherence and the Fresnel number of the beam in propagation[3]. A stable resonator can also be used to generate laser with a 1D top-hat beam profile as a result of multiple transverse modes with partial spatial coherence, which is a more effective method to generate laser beam with 1D top-hat profile in both the near field and the far field.

In 2007, Li *et al.* got 1D top-hat output beam by using diode-stack-end-pumped Nd:YLF slab crystals[4]. The output power of 60 W at 5 kHz was measured with the pump power of 210 W. Compared with other common laser crystals such as Nd:YAG and Nd:YLF, $Nd:YVO_4$ has been proved to be one of the best working materials for a high power, high repetition rate, and narrow pulse width laser for its relatively higher stimulated emission cross section and shorter upper state lifetime at 1064 nm[1,5−10]. In order to generate 1D top-hat laser beam with shorter pulse width, $Nd:YVO_4$ slab was used in our experiment. At the repetition rate of 5 kHz, 26.3-W $Q$-switched output was obtained with a pulse width of 4.3 ns under the pump power of 175.5 W. The output beam in the horizontal direction had a good top-hat profile for both the near field and the far field, and in the vertical direction, it was a good Gaussian profile.

The experimental setup is shown in Fig. 1. The central emission wavelength of the laser diode (LD) stacks was around 808 nm. Radiation from each diode laser bar was individually collimated by microlens. The pump coupling system was the same as that used in Ref. [11]. A homogeneous pumping line was generated by the coupling system inside the $Nd:YVO_4$ crystal with the size of $12 \times 10 \times 1$ (mm). The laser crystal was mounted between two water-cooled heat sinks with two large faces $12 \times 10$ (mm). M1 and M2 were resonator mirrors. M1 was a concave mirror with the radius of 3 m, which was coated for high reflection (HR) at 1064 nm and high transmission (HT) at 808 nm. M2 was a flat mirror with HR coating at 808 nm and transmission $T = 70\%$ at 1064 nm. The distance between M1 and M2 was 95 mm.

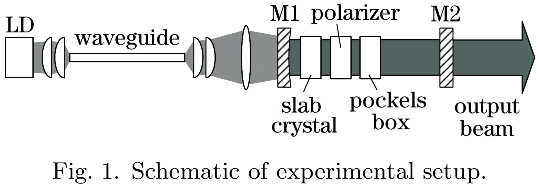


Fig. 1. Schematic of experimental setup.

The output characteristics of the partial diode-end-pumped $Nd:YVO_4$ slab laser are shown in Figs. 2 – 4.

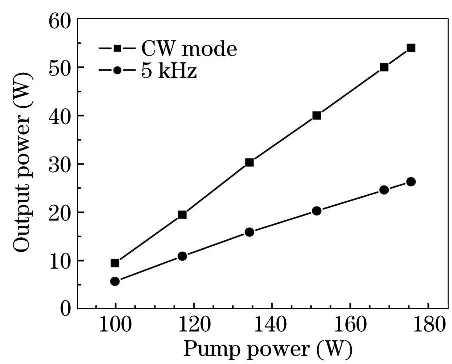


Fig. 2. Output power versus pump power.

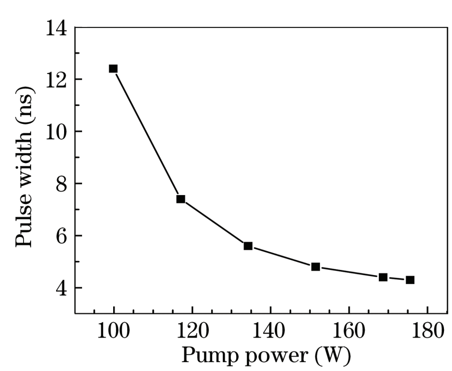


Fig. 3. Pulse width versus pump power.

 

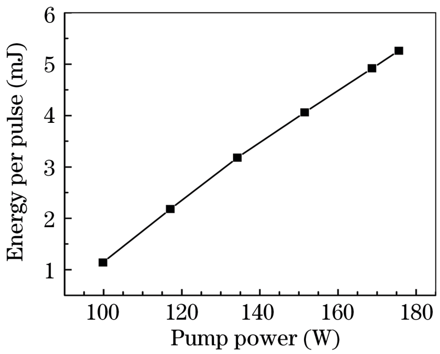


Fig. 4. Energy per pulse versus pump power.

Under the pump power of 175.5 W, the continuous-wave (CW) output power of 54 W was obtained. At the same time, the average power of 26.3 W with the repetition rate, pulse width, and energy per pulse of 5 kHz, 4.3 ns, and 5.26 mJ, respectively was got in $Q$-switched situation. The pulse energy stability was 1.44%. With the same output power, in Ref. [4] the pulse width obtained at 5 kHz was 22 ns, which is much wider. The main reasons are as follows. Firstly, Nd:$YVO_4$ has larger cross-section and shorter upper state lifetime than Nd:YLF. Secondly, the output mirror has the transmission of 70% which is much more than that used in Ref. [4]. At last, the cavity length in this experiment is 110 mm compared with 130 mm in Ref. [4].

A lens ($f$ = 300 mm) and a charge-coupled device (CCD) camera were used to measure the output beam intensity distribution. Figure 5 shows the intensity distribution of output beam in the near field. The lens was put at the position where the spot was imaged with the rate of 2:1. In the horizontal direction, the output beam has a good top-hat profile due to multiple-transverse-mode operation. In the vertical direction, a Gaussian

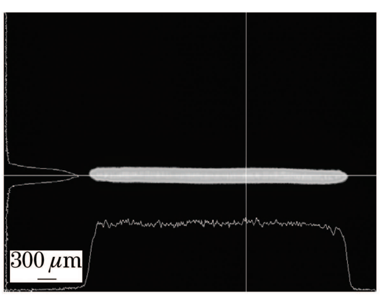


Fig. 5. Near-field intensity distribution.

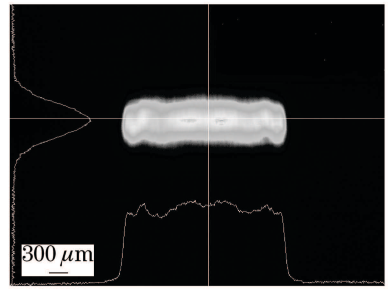


Fig. 6. Far-field intensity distribution.

profile was obtained as a result of good mode matching. Figure 6 shows the intensity distribution of output beam in the far field.

In conclusion, a high power partial diode-end-pumped Nd:$YVO_4$ slab laser with 1D top-hat output beam was demonstrated. CW output power of 54 W and $Q$-switched output power of 26.3 W with the repetition rate of 5 kHz and the pulse width of 4.3 ns were obtained when the pump power was 175.5 W. The output beam in the horizontal direction had a good top-hat profile for both the near field and the far field, and a good Gaussian profile was obtained in the vertical direction.

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