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# Experimental study of high-power pulse side-pumped Nd:YAG laser

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**Abstract**

The paper reports on the characterization of a compact and simple side-pumped 0.538 J × 100 Hz pulse Nd:YAG laser. A side-pumping configuration with 100 laser diode bars is used in the laser head. We also experimentally studied the laser performance of the diode-pumped Nd:YAG laser head in the free running and Q-switched operation under different repetition rates.


*Keywords:* Nd:YAG laser; Side-pumped lasers; Solid-state lasers

## 1. Introduction

Diode-pumped solid-state laser (DPSSL) has been recognized as far back as the initial stage of laser development in the late 1960s and early 1970s as a particularly attractive laser excitation scheme [1,2]. As compared with the lamp-pumped laser designs in current widespread use, the all-solid-state concept assumes additional importance in areas which put a premium on ruggedness, size and reliability, for example, in military, communications and industrial and medical applications [3,4].

In order to improve the output power, the pumping efficiency and the beam quality of DPSSL, several different pump configurations and several techniques have been proposed in delivering pumping power [5–7]. These lasers are high priced, complicated and less stable. To obtain the higher output power, multi-modules diode-pumped are inserted into the oscillation or the amplifier configuration through the complicated MOAP (master-oscillator/power-amplifier) system.

In this paper, we present our compact and simple side-pumped pulse Nd:YAG laser generating about 0.53 J × 100 Hz in the near IR by one diode-pumped laser head, corresponding to average power on the scale of tens of Watts. Then in the free running and Q-switched operation, the laser performances under different repetition frequencies will also be presented in this paper.

## 2. Side-pumping configuration of the laser

A schematic drawing of the pump head is shown in Fig. 1. It consists of five modules arranged in a fivefold symmetry around the laser rod. Twenty 1-cm-long linear pulse diode bars are arranged on each module, in which the cooling water flows parallel to the bars. A Nd:YAG rod (7 mm in diameter, 88 mm in length, with 0.7% Nd doping) is surrounded by a flow tube and a circular reflector. Pump light is coupled into the Nd:YAG rod directly. O-Ring of $\Phi = 7$ mm is used to seal the cooling water of the crystal.

To match the Nd:YAG absorption band near 808.5 nm, we carefully selected the 100 bars at a given diode drive current, a given repetition rate and a given cooling temperature to obtain the lowest spectral dispersion. The laser diode bars are operated with a pulse duration of 250 μs. The threshold and slope efficiency of the laser diode bars are about 10 A and 1 W/A, respectively. Each bar's maximum peak output power and energy of single pulse is 60 W and 15 mJ at 70 A maximum input current, respectively.

Fig. 2 is a schematic drawing of the experimental arrangement in the free running operation. In the Q-switched operation an acousto-optic (AO) Q switch is requisite between the laser module and the output coupler.

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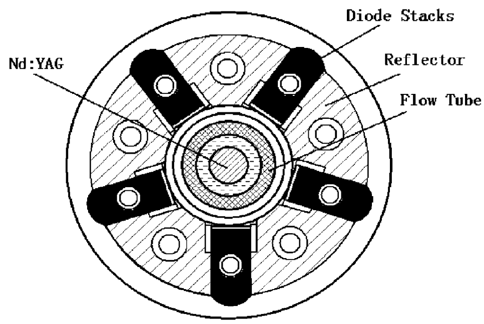


Fig. 1. Schematics of the diode-pumped laser head.

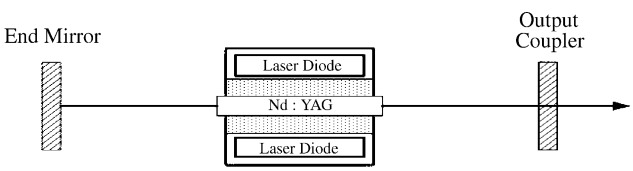


Fig. 2. The schematic drawings of the experimental arrangement.

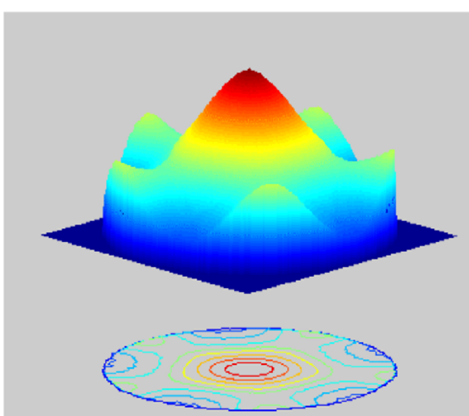

Fig. 3. Pump energy distribution for a 7-mm-diameter Nd:YAG rod.

## 3. Studies on laser performance

Fig. 3 shows the calculated pump energy distribution inside the Nd:YAG laser rod obtained from a ray trace analysis which takes into account the spectral and spatial properties of the laser diodes and the spectral absorption by the laser material [7]. The absorption coefficient $\alpha$ used in our calculation is 4 $cm^{-1}$. As is seen, the pump energy distribution at the center of the laser rod is similar to a Gaussian energy distribution. This profile also represents the radial gain profile. Such a pump energy distribution matched with the oscillation beam profile helps to increase the gain extraction in the medium [8].

The focal length of the thermal lens effect depends on both temperature gradients and stresses in the laser rod. In order to measure the focal length of the thermal lens, we design an experiment according to Ref. [6]. The higher the average input pump power, the shorter the focal length of the thermal lens measured. When the laser diode bars are operated at a 100-Hz repetition rate with a 70 A maximum input current and the cooling water is 30°C, the minimum focal length of the thermal lens measured is about 4.5 m. In our experiments, the thermal lens effect is negligible.

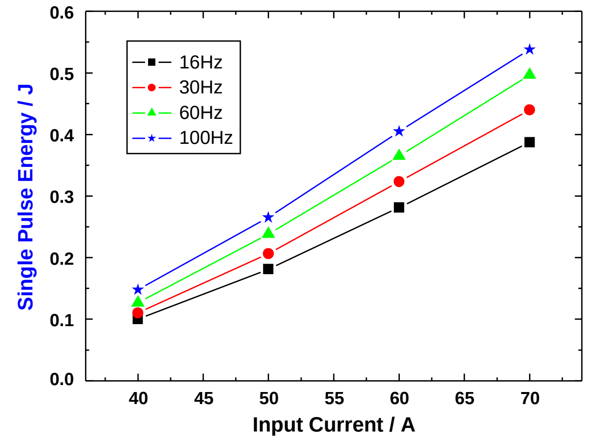


Fig. 4. The single pulse output energy of the laser under different repetition rates in free running operation.

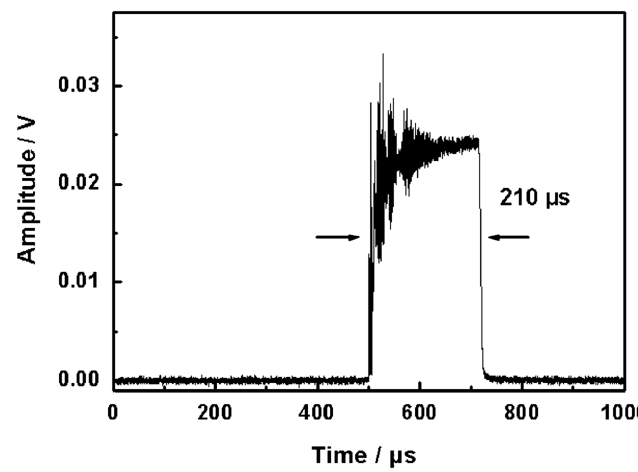


Fig. 5. IR temporal profile in free running operation.

Fig. 4 shows a comparison of the free running single pulse output energy under different repetition rates with a fixed cavity length of 400 mm and the same cooling water temperature of 30°C. The output coupling optimized is 50%. The single pulse output energy increases linearly with the electrical input. The maximum output energy of one single pulse is about 538 mJ under the repetition rate of 100 Hz with a pulse width of 200±20 μs as shown in Fig. 5. The maximum peak power is about $0.53/(2 \times 10^{-4}) = 2650$ W. The corresponding average output power is 53.8 W at the average pump power of 150 W. As can been seen from Fig. 5 the relaxation oscillation occurs during the duration of the laser oscillation.