A passively Q-switched diode pumped Yb:YAG microchip laser

Haisheng Wu (吴海生), Ping Yan (闫 平), Mali Gong (巩马理), and Qiang Liu (柳 强)

Digital Photonics Laboratory, Department of Precision Instruments, Tsinghua University, Beijing 100084

Received July 22, 2003

A passively Q-switched diode pumped Yb:YAG microchip laser with Cr^{4+}:YAG saturable absorber mirror is reported. The TEM_{00} laser pulses are obtained with 1.7-μJ pulse energy, 15-ns pulse width, 0.11-kW peak power, and a repetition rate of 2.2 kHz at 1049 nm. The doped concentration and dimension of Yb:YAG microchip crystal are 10 at.-% and $\phi5 \times 0.6$ mm^2, respectively.

OCIS codes: 140.3540, 140.3480, 140.3580.

Passively Q-switched diode-pumped solid state lasers are of interest for their applications in the field of micromachining, remote sensing, target ranging and microsurgery. Passively Q-switched lasers employing Cr^{4+}:YAG as the saturable absorber have become more common because of the favorable spectroscopic properties and the mechanical sturdiness of the YAG host. Recently, Yb:YAG has been used as a replacement to Nd:YAG for DPSSL due to its benefits in thermal management and its high doping without concentration quenching. Moreover, the small emission cross section of Yb:YAG makes a high saturation fluence, so the laser system can store higher energy for Q-switched. It is approved that passively Q-switched Yb:YAG laser using Cr^{4+}:YAG is more favorable than based on Nd:YAG in theory[1]. Several theoretical models of passively Q-switched laser are developed[1−4]. But the experiments of diode-pumped passively Q-switched Yb:YAG laser are presented rarely especially with Cr^{4+}:YAG. The diode-pumped passively Q-switched Yb:YAG lasers with semiconductor saturable absorber mirrors[5] have been reported. Using Cr^{4+}:YAG pulse energy of 0.5 mJ and extraction efficiency of 30% at high repetition rate are only presented in CW diode-end-pumped passively Q-switched Yb:YAG laser[6]. In China, using Ti:sapphire laser as pump resource, the self Q-switched Cr^{4+}:Yb^{3+}:YAG laser[7] and passively Q-switched Yb:YAG with Cr^{4+}:YAG[8] are demonstrated. In this paper, we report a passively Q-switched diode pumped Yb:YAG microchip laser with Cr^{4+}:YAG saturable absorber. Here, using a diode with 1-W output power, 10 at.-% dopant concentration Yb:YAG crystal and Cr^{4+}:YAG mirror, we obtain the pulse energy about 1.7 μJ at 1049 nm.

The laser experimental setup is showed in Fig. 1. The Yb:YAG microchip is $\Phi = 5$ mm in diameter and $L = 0.6$ mm in thickness, and is doped with 10 at.-% of Yb^{3+}. The crystal is coated AR/HR at 940/1030 nm on the pump side and HR/AR at 940/1030 nm on the other side. The pump resource is InGaAs diode array with 1-W output power. The SDL-820 laser driver, which may control the external TEC cooler (the resolution is ±0.1°C), can keep the diode array temperature at 20°C in order to make the diode work at the pump transition peak of 941 nm. The pump light is coupled by two lenses (f = 9.8 mm) and focused to a pump spot of 104 μm radius (RMS) in crystal[9]. The transmission efficiency is about 76%. The pump configuration is end-pumped with a flat-flat cavity. The pump side of Yb:YAG crystal is as a back mirror. The output mirror is Cr^{4+}:YAG crystal, its initial transmission T_0 = 93.3% and the reflectivity of output surface is 97% at 1030 nm. The cavity length is about 2 cm. The Yb:YAG crystal is mounted on a brass back plate which is cooled by TEC coolers.

A model 1554 photo detector (12 GHz, New Focus Inc.) and an Agilent Oscilloscope (1.8 GHz, 8 GSa/s) are used to receive and display the pulse, respectively. The output average power is measured using EPM2000 power meter (Molectron Detector Inc.).

When the diode is operated at 2.15 A, 1.7-μJ pulse energy is obtained with pulse width (FWHM) of 15 ns. The peak power is 0.11 kW and the repetition rate is 2 kHz. The typical pulse is showed in Fig. 2. Pulse to pulse

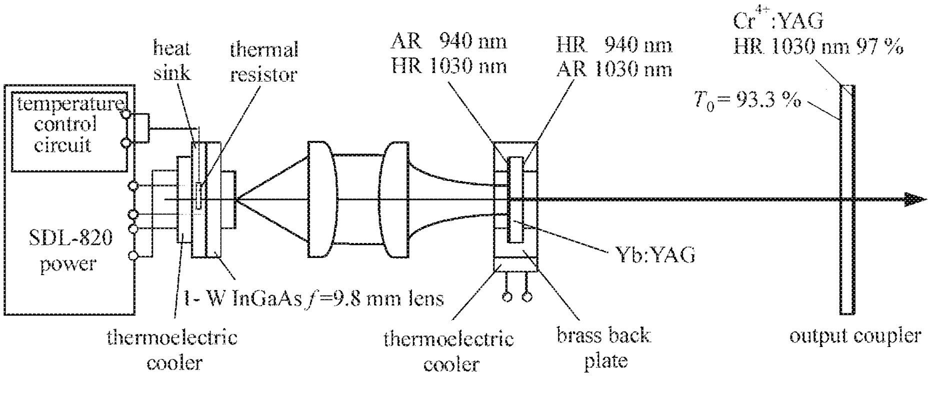

Fig. 1. The setup of the passively Q-switched diode pumped Yb:YAG microchip laser with Cr^{4+}:YAG as the saturable absorber.

energy fluctuation and pulse width fluctuation are 4.9% and 1.67%, respectively. Figure 3 shows the average output power as a function of the incident pump power (on crystal). We do not obtain the 1030 nm laser output as expected, but achieve 1049 nm laser output. One reason is that the absorption at the wavelength of 1030 nm is higher than the gain at the same wavelength. On the other hand, the minimum pump power density that is necessary to keep the material transparent at 1049 nm (7.7 kW/cm^2) is lower than the one at 1030 nm (17.2 kW/cm^2), and therefore the oscillation at 1049 nm is easier to set up at pump power density which is not high enough. The wavelength at CW operation has been given in Ref. [9].

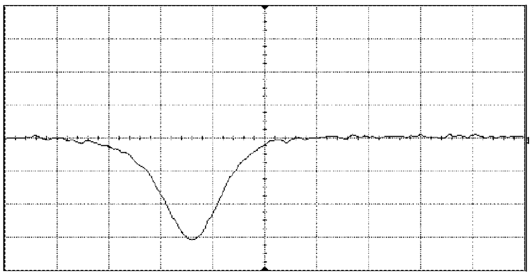

Fig. 2. Oscilloscope trace of a 15.1-ns pulse (10 ns/div).

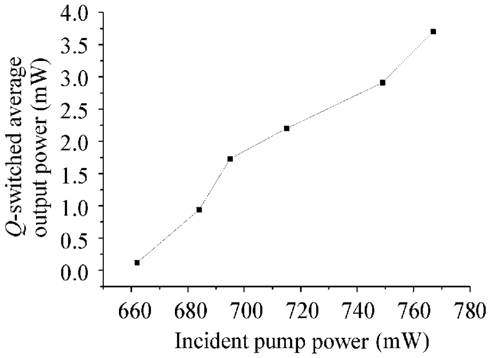

Fig. 3. Average output power as a function of the incident pump power.

The coating damage has occurred in the experiment of CW Yb:YAG operation[9]. It is possible to further increase the pulse energy and peak power if the coating quality can be improved. The higher efficient cooling can also increase the laser output for the quasi-three level Yb:YAG laser.

In conclusion, we have demonstrated a passively Q-switched diode pumped Yb:YAG microchip laser using Cr^{4+}:YAG. 1.7-μJ pulse energy, 15-ns pulse width, 0.11-kW peak power and a repetition rate of 2.2 kHz at 1049 nm are achieved. Pulse to pulse energy fluctuation and pulse width fluctuation are 4.9% and 1.67%, respectively.

H. Wu's e-mail address is wuhs99@mails.tsinghua.edu.cn.

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