An LD-pumped dual-wavelength actively Q-switched $Nd:Sc_{0.2}Y_{0.8}SiO_5$ laser*

YANG Xiu-qin (杨秀芹)[1,2]**, **MA Zhi-guo** (马志国)[1], **ZHENG Li-he** (郑丽和)[3], **SHANG Lian-ju** (尚连聚)[1], and **SU Fu-fang** (苏富芳)[1]

1. *Shandong Provincial Key Laboratory of Laser Polarization and Information Technology, Department of Physics, Qufu Normal University, Qufu 273165, China*
2. *State Key Laboratory of Crystal Materials, Institute of Crystal Materials, Shandong University, Jinan 250100, China*
3. *Shanghai Institute of Ceramics, Chinese Academy of Sciences, Shanghai 200050, China*

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We demonstrate a laser-diode (LD) pumped actively Q-switched laser with $Nd:Sc_{0.2}Y_{0.8}SiO_5$ (Nd:SYSO) crystal for the first time. A stable actively Q-switched laser is obtained at dual wavelengths of 1 075.2 nm and 1 078.2 nm. The maximum average output power of 720 mW is obtained at the repetition rate of 15 kHz under the pump power of 8.7 W. The minimum pulse width of 58 ns is obtained at the repetition rate of 5 kHz under the pump power of 8.7 W, corresponding to the peak power of 1.9 kW and the pulse energy of 112 μJ.

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In recent years, many studies have been done on the oxyorthosilicate crystals doped with rare earth as laser gain medium, such as $Nd^{3+}:Lu_2SiO_5$[1], $Nd^{3+}:LuYSiO_5$[2], $Nd^{3+}:Y_2SiO_5$[3], $Yb^{3+}:LuYSiO_5$, $Yb^{3+}:GdYSiO_5$[4], $Yb^{3+}:Y_2SiO_5$,$Yb^{3+}:Lu_2SiO_5$[5], $Tm^{3+}:Lu_2SiO_5$[6] and $Ho^{3+}:Lu_2SiO_5$[7]. The fluorescence spectrum of rare earth ions doped in the mixed crystal can be significant broader than those in single crystals. Therefore, it is possible to realize the multi-wavelength and ultra-fast laser operation. $Nd:Sc_{0.2}Y_{0.8}SiO_5$ (Nd:SYSO) was grown by Shanghai Institute of Ceramics with Czochralski method, and it is a mixed mono-clinical bi-axial positive crystal. Preliminary, the performance of passively Q-switched and mode-locked laser of Nd:SYSO have been reported, and it was fund that the laser can oscillate in the multi-wavelength regime[8,9].

In this paper, we investigate the performance of active Q-switched Nd:SYSO laser for the first time. It is found that the Q-switched laser oscillates at dual wavelengths of about 1 075.2 nm and 1 078.2 nm. The maximum average output power of 720 mW is obtained under the pump power of 8.7 W at repetition rate of 15 kHz. The maximum peak power and the maximum pulse energy are calculated to be 1.9 kW and 112 μJ, respectively at the repetition rate of 5 kHz under the pump power of 8.7 W, which corresponds to the minimum pulse width of 58 ns.

The experimental setup for the laser-diode (LD) pumped actively Q-switched Nd:SYSO laser is shown in Fig.1. A commercial fiber coupled LD emitting at 811 nm is used as the pump source, and its radiation is coupled into the laser crystal by a coupling system with a numerical aperture (N.A.) of 0.22. The laser cavity consists an input mirror M1, an Nd:SYSO crystal, a 30 mm-long acousto-optic (AO) Q-switch, which is driven at center frequency of 27 MHz by radio frequency (RF) power of 50 W, and an end mirror M2. M1 is a plano-concave mirror with a curvature radius of 500 mm. The plane face is anti-reflection at 811 nm (R<0.2%), and the concave face is coated for high transmission at 811 nm (R<3%) and high reflection at 1 000–1 100 nm (R>99.8%). The output mirror M2 is coated with partial transmission (T_{oc}=5%) at 1 075 nm. The overall laser cavity length is 75 mm. The laser crystal of Nd:SYSO with dimension of 3 mm×3 mm×3 mm is doped by Nd^{3+} with atom percent of 0.8%. Both sides of the Nd:SYSO crystal are uncoated. The laser crystal is wrapped with indium and mounted in a copper block cooled by water at 18 °C. The laser pulse signal was recorded by a digital oscilloscope and a photo-detector (New focus, model 1611). The average output power was measured by a laser power meter (Fieldmax-Ⅱ, coherent). The laser spectra were measured by an optical analyzer (AQ6370D).

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** E-mail: xiuqinyang@126.com

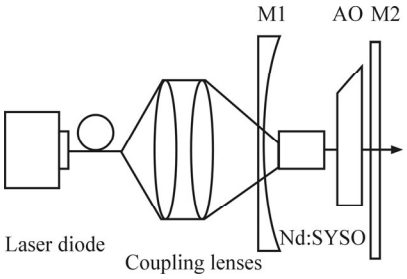

Fig.1 Schematic diagram of experimental setup for AO Q-switched Nd:SYSO laser

First, the operating characteristics of the continuous wave (CW) Nd:SYSO laser using a simple plano-concave cavity with length of 75 mm is examined. The threshold pump power of the CW laser operation is measured to be 0.7 W. The highest CW output power is 1.21 W, and the slope efficiency and the optical conversion efficiency are 16.9% and 12.5%, respectively. Because the Nd:SYSO crystal is un-coated, the absorption efficiency at the pump wavelength of crystal is low (≈48%). The energy conversion efficiency from pump source to output power can be optimized by coating both side of the crystal.

Fig.2 shows the spectrum of AO Q-switched Nd:SYSO laser obtained under the absorbed pump power of 8.7 W. It can be seen that the output laser operates at dual wavelengths of 1 075.2 nm and 1 078.2 nm. The variation of the average output power of AO Q-switched Nd:SYSO laser with absorbed pump power is shown in Fig.3. The pulse repetition rates of AO Q-switch are 5 kHz, 10 kHz and 15 kHz, respectively. The CW operation is also shown in Fig.3 for comparison. Under the absorbed pump power of 8.7 W, the maximum AO Q-switched average output power is 720 mW at a pulse repetition rate of 15 kHz. The corresponding maximum conversion efficiency from CW to Q-switching operation is 61.2%. When the pulse repetition rates are 5 kHz and 10 kHz, the maximum Q-switched average output powers are 556 mW and 626 mW, respectively, and the corresponding conversion efficiencies from CW to Q-switching operation are 53.1% and 46.8%, respectively. The simultaneous dual-wavelength pulsed Nd:SYSO laser at 1 075.2 nm and 1 078.2 nm has potential applications for the generation of terahertz (THz) radiations[10-12].

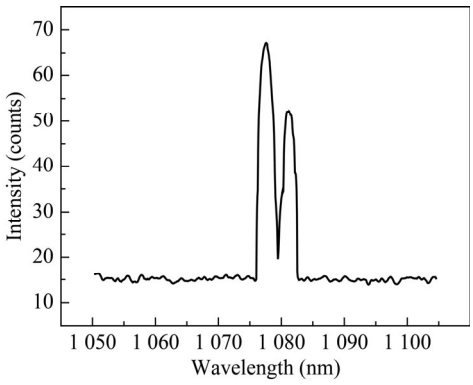

Fig.2 The spectrum of AO Q-switched Nd:SYSO laser

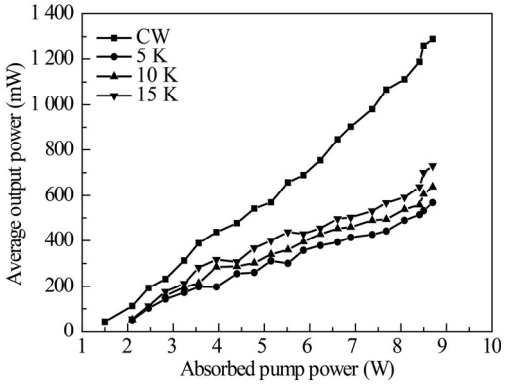

Fig.3 The variation of average output power with absorbed pump power for AO Q-switched Nd:SYSO laser

Fig.4 shows the pulse width versus the pump power at different repetition rates. It can be seen from Fig.4 that the pulse width decreases with the increase of the pump power at the same repetition rate. By using the formulas of $E=P_{av}/F$ and $P_{peak}=E/t_p$, where E is the pulse energy, P_{av} is the average Q-switched output power, F is the repetition rate, P_{peak} is the peak power, and t_p is the pulse width, the pulse energy and the peak power can be obtained. The variations of the pulse energy and the peak power with the pump power are shown in Figs.5 and 6, respectively. Under the same pump power, with the in-

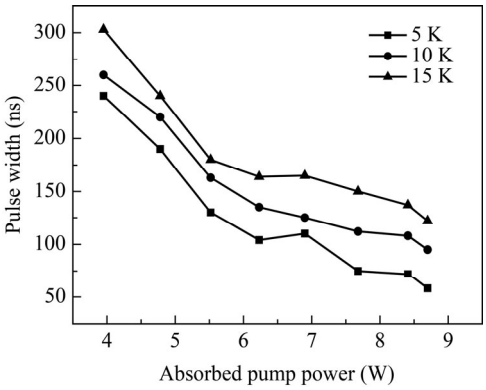

Fig.4 The pulse width versus the absorbed pump power for AO Q-switched Nd:SYSO laser

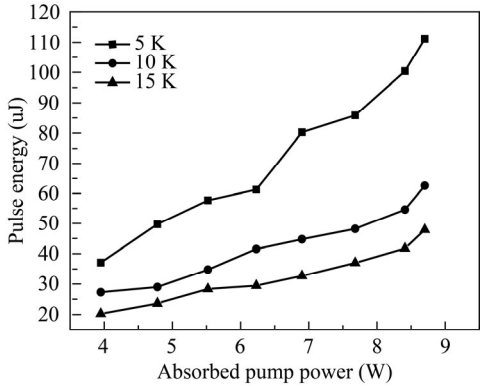

Fig.5 The pulse energy versus the absorbed pump power for AO Q-switched Nd:SYSO laser

crease of repetition rate, the average output power is increased, and the pulse width is broadened, while the pulse energy and peak power are reduced. It can be seen that the shortest pulse width of 58 ns is obtained at the repetition rate of 5 kHz under the pump power of 8.7 W. Correspondingly, the maximum pulse energy is 112 μJ, and the maximum peak power is 1.9 kW. Fig.7 shows the minimum pulse width of 58 ns.

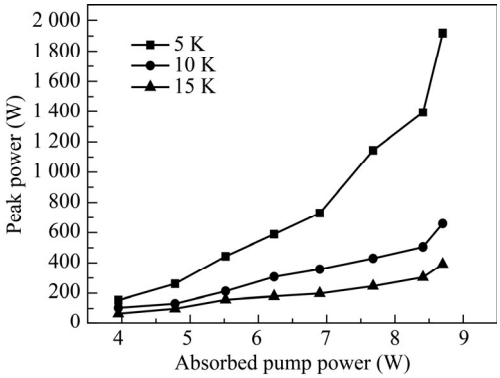

Fig.6 The peak power versus the absorbed pump power for AO Q-switched Nd:SYSO laser

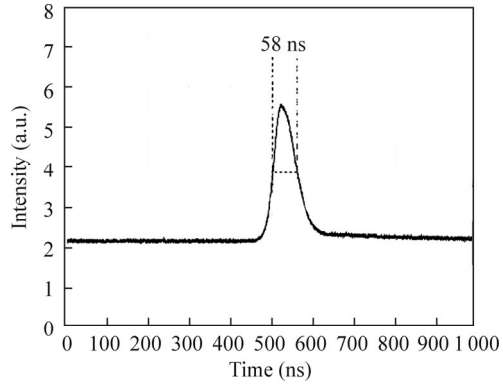

Fig.7 The typical pulse shape with pulse width of 58 ns

The LD pumped active Q-switched dual-wavelength laser at about 1 075.2 nm and 1 078.2 nm using Nd:SYSO crystal is demonstrated. A maximum average output power of 720 mW is obtained under the pump power of 8.7 W at repetition rate of 15 kHz. The conversion efficiency of the output power from CW to Q-switching operation is amounted to be 61.2%. At the repetition rate of 5 kHz under the pump power of 8.7 W, the maximum peak power and the maximum pulse energy are calculated to be 1.9 kW and 112 μJ, respectively, and correspondingly the minimum pulse width is 58 ns.

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