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Discussion

Continuous wave and passively Q-switched laser performance of the mixed crystal Nd:$Lu_{x(x=0.5)}Y_{1-x}VO_4$

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ABSTRACT

Diode end-pumped continuous-wave and passively Q-switched Nd:$Lu_{x(x=0.5)}Y_{1-x}VO_4$ mixed crystal lasers were demonstrated. At the pump power of 12.6 W, the maximum output power of 6.7 W around 1066.5 nm was obtained with the output transmission of 27%. The optical conversion efficiency is 53.2%, corresponding to a slope efficiency of 55.8%. For pulsed operation, the shortest pulse width attained was 8.6 ns, with the pulse repetition frequency of 99 kHz, and the single pulse energy and the peak power were estimated to be 25.5 μJ and 2.96 kW, respectively.

1. Introduction

Neodymium-doped vanadate mixed crystals have attracted more and more interest in the fields of high peak power Q-switching and mode-locking, due to their smaller stimulated emission cross-section and larger fluorescence bandwidth compared with that of single materials [1–9]. Liu demonstrated a 2.78 W average power with a slope efficiency of 45.5% from a passively Q-switched (PQS) Nd:$Gd_{0.64}Y_{0.36}VO_4$ laser [4]. Nd:$Lu_{0.5}Gd_{0.5}VO_4$ has been demonstrated to produce a Q-switched pulse of 6.2 ns by inserting a Cr^{4+}:YAG saturable absorber [7].

Recently, we demonstrated that a novel mixed crystal of Nd:$Lu_{0.15}Y_{0.85}VO_4$ has to be an excellent candidate for Q-switching and mode-locking [11–13]. Using Cr^{4+}:YAG with the initial transmission of 75% as the saturable absorber, a maximum PQS laser output of 3 W was obtained under the pump power of 18.9 W. The Nd:$Lu_{1-x}Y_xVO_4$ crystal is an isomorph of Nd:$LuVO_4$ and Nd:YVO_4. The lattice sites formerly occupied by Y ions in Nd:YVO_4 crystal are now partly occupied by Lu ions at random. This modification of the local crystal field neighboring the Nd ions will lead to the inhomogeneous broadening of to the gain spectrum. Its fluorescence spectrum (~5 nm) is widest among the group of Nd:(Lu,Gd,Y)VO_4 mixed crystal and its absorption bandwidth is 2–3 times broader than that of Nd:YVO_4. For the Nd:$Gd_xY_{1-x}VO_4$ and Nd:$Gd_xLu_{1-x}VO_4$ crystals, the early works have proved that the mixed crystals, when the ratio between the (Gd, Y) or (Gd, Lu) ions near 0.5:0.5 [7,9,10], exhibit more excellent Q-switching ability than others. However, for the Nd:$Lu_xY_{1-x}VO_4$ crystal, the influence of ionic ratio has not been investigated.

In this paper, we changed the ratio between Lu and Y ions of the Nd:$Lu_xY_{1-x}VO_4$ crystal to 0.5:0.5, and the continuous-wave (cw) and PQS laser characteristics of the novel mixed laser crystal Nd:$Lu_{x(x=0.5)}Y_{1-x}VO_4$ were carried out successfully for the first time to the best of our knowledge. At the pump power of 12.6 W, the maximum cw laser power of 6.7 W was generated with the output transmission of 27%, resulting in an optical conversion efficiency of 53.2% and a slope efficiency of 55.8%. Using a Cr^{4+}:YAG with the initial transmission $T_0 = 75\%$ as the saturable absorber, the minimum pulse width obtained was 8.6 ns with the pulse repetition frequency of 99 kHz, and the single pulse energy and peak power was calculated to be 25.5 μJ and 2.96 kW, respectively. Comparing with the Nd:$Lu_{0.15}Y_{0.85}VO_4$ crystal, Nd:$Lu_{0.5}Y_{0.5}VO_4$ shows more excellent Q-switching ability under the same pump power in our optimized condition. The result indicates that the mixed crystal Nd:$Lu_{0.5}Y_{0.5}VO_4$ is a promising material for PQS.

2. Experimental setup

The Nd:$Lu_{x(x=0.5)}Y_{1-x}VO_4$ mixed crystal used in our experiment was fabricated by the Czochralski method and grown under a nitrogen atmosphere containing ~3% oxygen in an iridium crucible. The mixed crystal was cut along the *a*-axis with dimensions of $3\times3\times8$ mm^3 and a lower doping concentration of 0.38%, both faces were polished and

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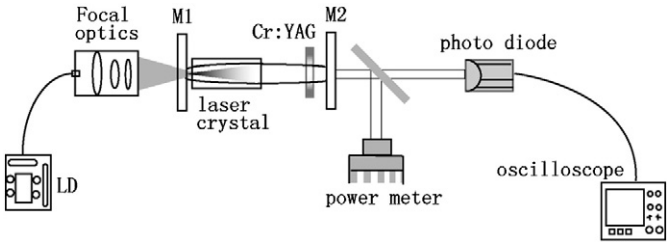

Fig. 1. Schematic diagram of the experimental apparatus.

antireflection (AR) coated at 808 nm and 1064 nm. In order to dissipate the heat deposition efficiently, the crystal was wrapped in indium foil and mounted by a copper micro channel heat-sink, and the temperature of cooling water was kept at 18 °C in the experiment.

The experimental setup shown in Fig. 1 was similar with that reported in Ref. [11], which was based on a compact plano-flat resonator. The pump source employed is a fiber-coupled LD with the central wavelength around 808 nm. The fiber core is 400 μm in diameter with a numerical aperture of 0.22. The pump beam was shaped into the laser medium with the beam diameter of about 400 μm. M_1 was a flat mirror with AR coated at 808 nm and high reflection coated (HR) at 1064 nm. The output couplers M_2 were also flat mirrors with different transmissions for 1064 nm of 10%, 27% and 40%. We demonstrated the cw laser characteristics of the Nd:$Lu_{x\,(x=0.5)}Y_{1-x}VO_4$ mixed crystal firstly, and the pulsed laser operation

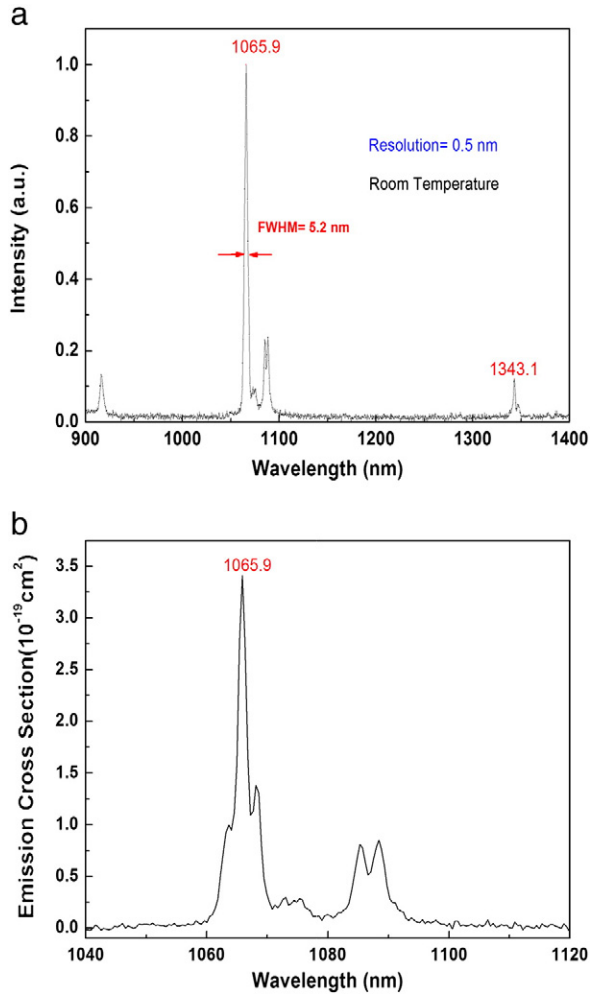

Fig. 2. (a) Fluorescence spectrum of the mixed crystal Nd:$Lu_{0.5}Y_{0.5}VO_4$. (b) The calculated stimulated emission cross-section of the mixed crystal Nd:$Lu_{0.5}Y_{0.5}VO_4$.

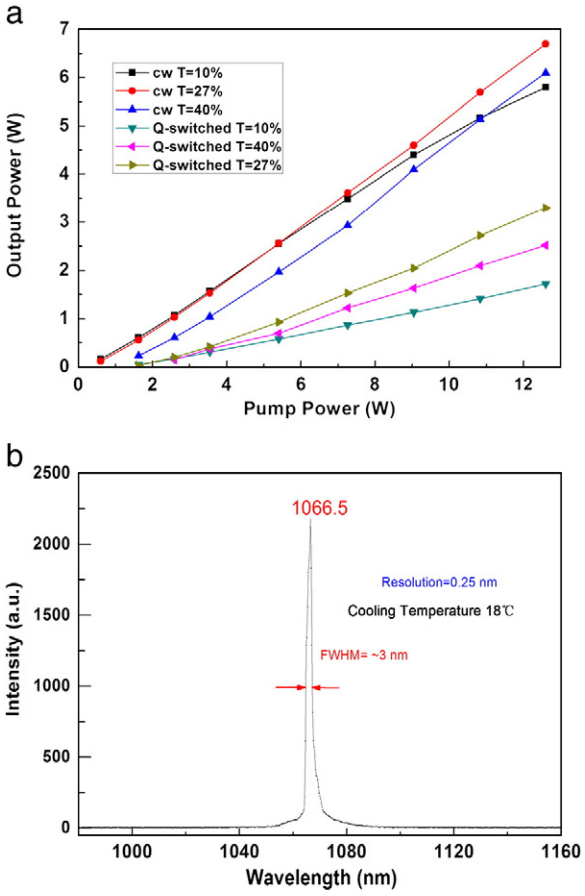

Fig. 3. (a) Cw and PQS laser characteristics of Nd:$Lu_{x(x=0.5)}Y_{1-x}VO_4$ crystal. (b) Laser spectrum of the mixed crystal Nd:$Lu_{x(x=0.5)}Y_{1-x}VO_4$.

was investigated by inserting a Cr^{4+}:YAG saturable absorber with the initial transmission of $T_0 = 75\%$ into the cavity, which was also used in Ref. [11]. A beam splitter (M_3) was positioned behind the output coupler, making it possible to measure the output power and the pulse simultaneously. The lengths of the cavities in the experiment were fixed to 35 mm all the time.

3. Experimental results and discussions

In Fig. 2(a), we illustrate the fluorescence spectrum of the Nd:$Lu_{x\,(x=0.5)}Y_{1-x}VO_4$ crystal. The central wavelength of the fluorescence

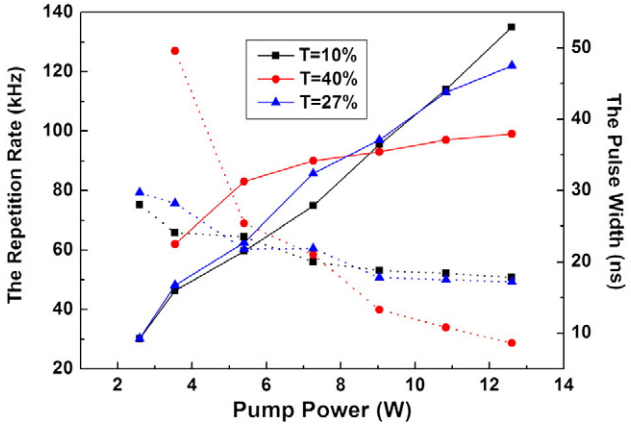

Fig. 4. The repetition rate and pulse width *versus* pump power for Nd:$Lu_{x(x=0.5)}Y_{1-x}VO_4$ crystal.