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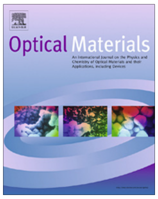

808-nm diode-pumped dual-wavelength passively Q-switched $Nd:LuLiF_4$ laser with Bi-doped GaAs

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ABSTRACT

Diode-pumped CW and passively Q-switched $Nd:LuLiF_4$ lasers with stable, synchronous dual-wavelength operations near 1047 and 1053 nm were demonstrated for the first time. The maximal CW output power of 821 mW was obtained at an incident pump power of 6.52 W. Employing high quality Bi-doped GaAs as saturable absorber, stable dual-wavelength Q-switched operation was realized. Under 6.52 W incident pump power, the minimal pulse duration of 1.5 ns, the largest single pulse energy of 11.32 μJ, and the highest peak power of 7.25 kW were achieved.

1. Introduction

Passive Q-switching laser is considered as a simpler and more effective way of producing shorter pulses. It is accomplished by inserting the saturable absorbers into the cavity, like Cr^{4+}:YSO [1] and Cr^{4+}:YAG [2]. Compared with other saturable absorbers, GaAs possesses the merits of good thermal conductivity, stable photochemical property, saturable absorption, non-degradability and high damage threshold [3–6]. At 1.06 μm wavelength, the energy of a photon is far below the GaAs band gap of 1.42 eV. The absorption at this wavelength is due to the deep donor EL2 defects [7]. However, the concentration of EL2 deep-level defects is very low, and it is a challenge to control the amount of EL2 defects in GaAs.

The effective way of improving the properties of a material is alloying, which is highly desirable for bandgap engineering applications. Employing isovalent impurities to replace a small amount of anion species in GaAs could lead to dramatic changes in its electrical and optical properties, such as $GaBi_xAs_{1-x}$, GaP_xAs_{1-x}, GaN_xAs_{1-x} and $GaSb_xAs_{1-x}$. Among these, the ternary alloy $GaBi_xAs_{1-x}$ was investigated for various potential device applications [8,9]. Theoretical calculations on the effects of Bismuth doping in GaAs saturable absorber have been reported previously [10,11]. The Bismuth-doped GaAs as saturable absorber in Nd:GGG lasers were investigated by Cong et al. [12,13].

Similar to the $YLiF_4$ crystal, the $LuLiF_4$ crystal has a tetragonal crystalline structure. The Nd^{3+}-doped $LuLiF_4$ crystal and the Nd^{3+}-doped $YLiF_4$ crystal are similar in structure and share similar types of absorption and fluorescence spectra. Unlike $YLiF_4$ crystal, the thermal conductivities of $LuLiF_4$ crystal are almost isotropic rendering less thermal stress during crystal growing processes [14]. 792 nm diode-pumped efficient continuous-wave (CW) and passively Q-switched dual-wavelength $Nd:LuLiF_4$ (Nd:LLF) laser at 1314 and 1321 nm was reported by Li [15], in which V:YAG was employed as saturable absorber. Bi-doped GaAs as saturable absorber was seldom investigated, especially in realizing Q-switched dual-wavelength laser operation. As far as we know passively Q-switched dual-wavelength Nd:LLF laser performance with Bi-doped GaAs near 1047 and 1053 nm has not been reported.

In this letter, the stable CW and Q-switched dual-wavelength laser performance of Nd:LLF with Bi-doped GaAs saturable absorber was investigated for the first time. The CW and passively Q-switched Nd:LLF laser oscillated simultaneously at 1047 and 1053 nm. The maximum output power of 821 mW and average output power of 215 mW were obtained with a pulse duration of 1.8 ns and a pulse repetition rate of 19 kHz at an incident pump power of 6.52 W with an output transmission of 15%, correspondingly the single pulse energy was 11.32 μJ.

2. Experimental setup

The experimental setup of the Nd:LLF laser performance is shown in Fig. 1. The pump source was a commercial

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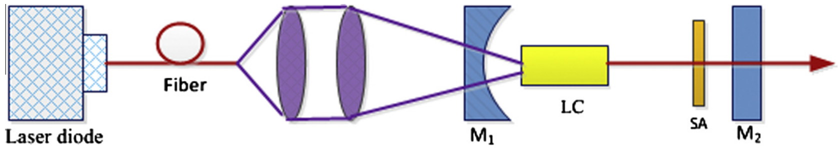

Fig. 1. Schematic setup of dual-wavelength Q-switched Nd:LLF laser. (LC, Nd:LLF; SA, Bi-GaAs).

fiber-coupled laser diode (FAP system, Coherent Inc., USA) with a central wavelength of 808 nm. The pump beam was collimated and focused into the gain medium with 400 μm core diameter. The Nd:LLF crystal was cut along *a*-axis with the dimension of $3 \times 3 \times 6$ mm^3 and the Nd^{3+}-doping concentration of 1.0 at.%. The pump facet of the gain medium was polished and antireflection (AR)-coated at 808 nm and 1030–1060 nm, while the other facet was AR-coated at 1030–1060 nm. To efficiently dissipate the heat deposition and avoid thermal fracture, the laser crystal was wrapped with indium foil and mounted on water-cooled copper heat-sink whose temperature was maintained at 289 K during laser operation.

Using ion bombardment, GaAs was doped with Bismuth at 500 keV with a dose of 1×10^{14} ions/cm^2. The Bi-doped GaAs was subsequently annealed in a rapid thermal system in nitrogen ambient. The annealing duration and the annealing temperature were set to be 60 s and 973 K, respectively. Anneal conducted in this way is observed to be appropriate to eliminate lattice damage and activate implants while minimizing impurity diffusion [16,17]. The initial transmission of Bi-doped GaAs is ~77.8% at 1.0 μm.

A simple two-mirror-cavity configuration was employed in this experiment. A short cavity length is excellent for passive Q-switching operation, thus the short pulse duration could be achieved. For the limitation of the thickness of crystal holder, the cavity length was experimentally 30 mm. A concave mirror M_1 with radius of curvature of 100 mm was AR-coated at the pump wavelength of 808 nm on the entrance surface, the other facet was high-transmission (HT)-coated at 808 nm ($T > 85\%$) and high-reflection (HR)-coated at the range from 1030 to 1060 nm ($R > 99\%$). A flat mirror M_2 with a transmission of 10% (or 15%) at 1030–1060 nm was served as the output coupler (OC). The pulse temporal behavior was recorded by a digital oscilloscope (1 GHz bandwidth and 20 G samples/s sampling rate, DPO7104C Tektronix Inc., USA) and a fast pin photodiode detector with a rise time of 0.4 ns. A laser power meter (MAX 500AD, Coherent, USA) was used to measure CW output power and average output power.

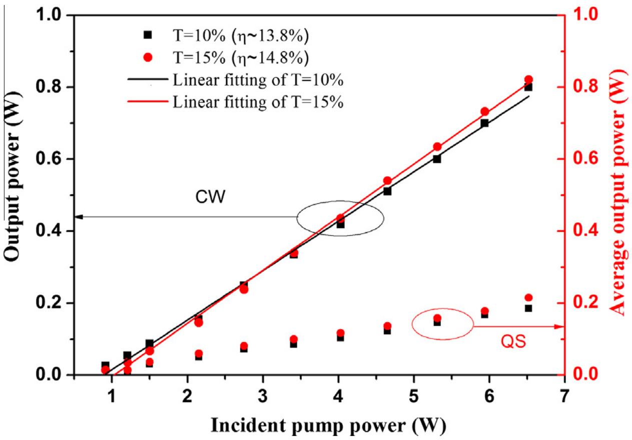

Fig. 2. The output power versus incident pump power.

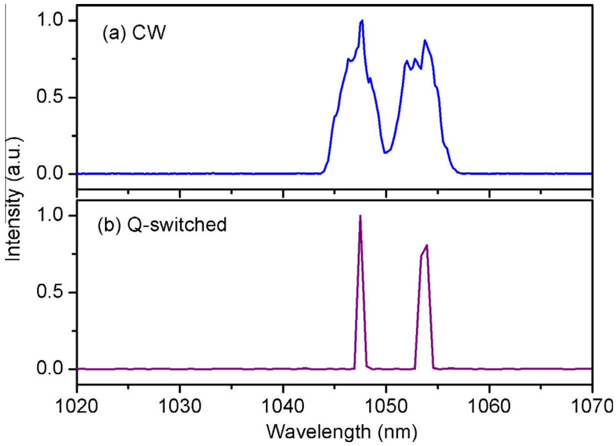

Fig. 3. Spectra of Nd:LLF laser at an incident pump power of 6.52 W.

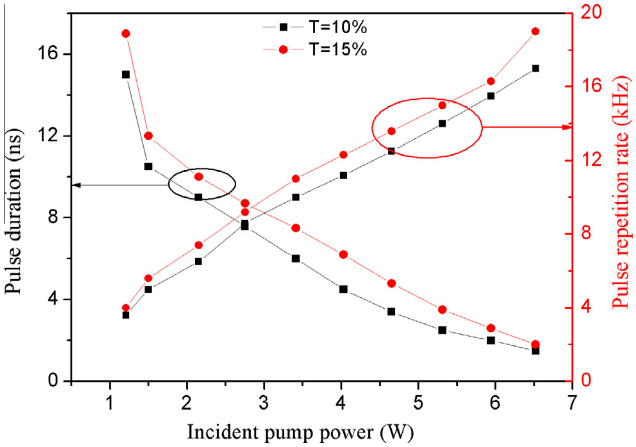

Fig. 4. Pulse duration and pulse repetition rate versus incident pump power.

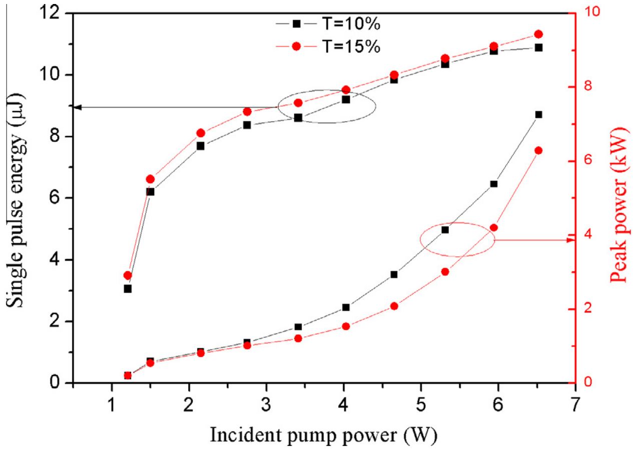

Fig. 5. Single pulse energy and peak power versus incident pump power.