Infrared Physics & Technology 90 (2018) 195–198

Contents lists available at ScienceDirect

Infrared Physics & Technology

journal homepage: www.elsevier.com/locate/infrared

Diode-pumped passively Q-switched Nd:$GdTaO_4$ laser based on tungsten disulfide nanosheets saturable absorber at 1066 nm

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HIGHLIGHTS

- In this paper, we investigated the passively Q-switched Nd:$GdTaO_4$ laser with based on tungsten disulfide (WS2) saturable absorber (SA).
- The diode-pumped passively Q-switched Nd:$GdTaO_4$ laser was operatinged at a central wavelength of 1066 nm.
- The stable pulse outputs were could be achieved obtained with at the single pulse width of 560 ns.

ARTICLE INFO

Article history:
Received 18 September 2017
Revised 25 February 2018
Accepted 25 February 2018
Available online 27 February 2018

Keywords:
Passively Q-switched
Nd:$GdTaO_4$
Tungsten disulfide
Saturable absorber

ABSTRACT

In this paper, we investigated the passively Q-switched Nd:$GdTaO_4$ laser based on tungsten disulfide (WS_2) saturable absorber (SA). The preparation method of WS_2 SA was to attach the WS_2-alcohol dispersion onto the quartz substrates. The diode-pumped passively Q-switched Nd:$GdTaO_4$ laser operated at a central wavelength of 1066 nm. The stable pulse output could be obtained at the single pulse width of 560 ns. In a word, WS_2 seems to be a suitable saturable absorber for solid state lasers.

1. Introduction

In recent years, passively Q-switched laser with the pulse width from nanosecond to microsecond were of great significance on many respects such as scientific research, medical application, material processing, range finding, remote sensing and nonlinear frequency conversion [1]. In order to obtain highly compact laser system, native and foreign experts researched numerous saturable absorbers such as Cr^{4+}:YAG [2], Cr^{2+}:ZnSe [3], semiconductor saturable absorption mirror (SESAM) [4], single-walled carbon nanotubes [5]. To summarize, the saturable absorbers should have the advantages of high saturated-absorption characteristic, wavelength independence, high damage threshold, simple manufacturing process, low cost and so on. In the last few years, the two-dimensional (2D) nanosheets were widely used in the preparation of saturable absorbers. There were plenty of methods to obtain 2D nanosheets including chemical vapor deposition, mechanical exfoliation and liquid-phase exfoliation [6–10]. The liquid-phase exfoliation method was a practical and cost-effective way to manufacture 2D nanosheets. WS_2 material demonstrated excellent saturable absorption property and high modulation depth at broadband wavelength, and WS_2 saturable absorber was simple to prepare.

In this paper, we designed the LD diode-pumped passively Q-switched Nd:$GdTaO_4$ laser based on WS_2 saturable absorber. With the pump power of 4.5 W, we got two sets of data: (1) when the output coupling efficiency was 15%, the output power was 356 mW, the optical conversion efficiency was 7.91%, the pulse width was 608 ns, the repetition rate was 61.2 kHz; (2) when the output coupling efficiency was 10%, the output power was 309 mW, the optical conversion efficiency was 6.87%, the pulse width was 560 ns, the repetition rate was 70 kHz. The passively Q-switched Nd:$GdTaO_4$ laser based on WS_2 saturable absorber operated at a central wavelength of 1066 nm.

2. Preparation of WS_2 saturable absorber

First of all, we added 0.02 g WS_2 powder with a purity of 99.99% into 20 ml pure alcohol. Secondly, we agitated the solution through the centrifuge for 20 min. Thirdly, we placed a quartz substrate with the size of 25 mm $\times$ 10 mm into the solution. Then, we put

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https://doi.org/10.1016/j.infrared.2018.02.011
1350-4495/

the quartz substrate in the drying oven for 10 h in order to remove the alcohol thoroughly. Finally, the WS_2 solution stably attached onto the quartz substrate.

Fig. 1 shows the transmitted spectrum of WS_2 saturable absorber. The transmissivity of WS2 saturable absorber at 400 nm, 1066 nm and 1100 nm were 83.4%, 82.6% and 82.1% respectively. The figure showed that the WS_2 material could be a stably saturable absorber in a wavelength range from 400 nm to 1100 nm. Fig. 2 shows the absorption spectrum of WS_2 saturable absorber. The absorptivity of WS2 saturable absorber at 400 nm and 1100 nm were 11.2% and 6.2%. The figure showed that the absorptivity of WS_2 material decreased when the wavelength increased.

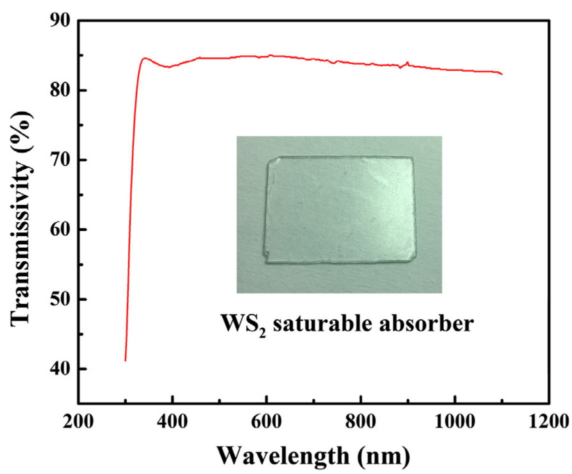

Fig. 1. Transmitted spectrum of WS_2 saturable absorber.

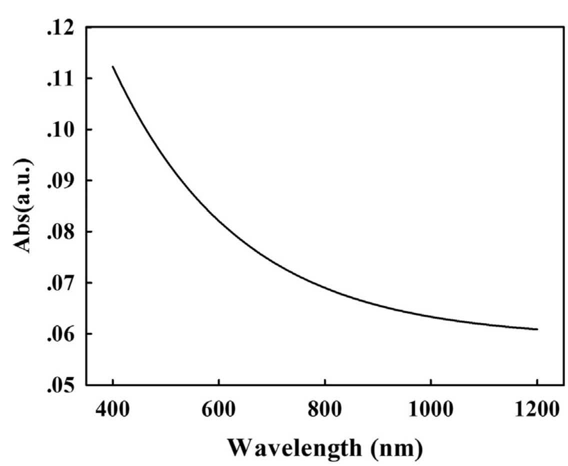

Fig. 2. Absorption spectrum of WS_2 saturable absorber.

3. Experimental methods and results analysis

3.1. Experimental setup

Fig. 3 shows the experimental setup of the LD diode-pumped $Nd:GdTaO_4$ laser based on WS_2 saturable absorber. The pumping source was the fiber-coupled diode laser with a central wavelength

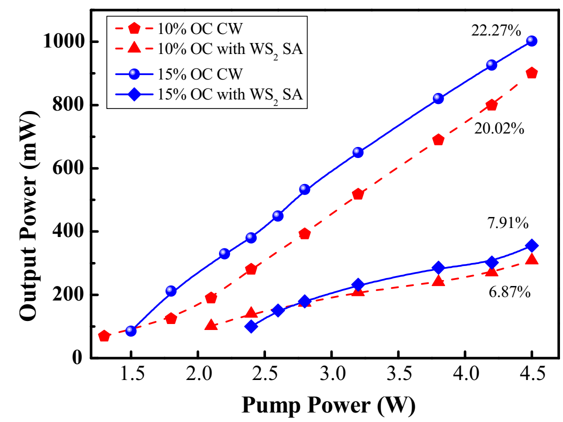

Fig. 4. Shows the optical optical conversion efficiency of the continuous wave (CW) and Q-switched operations. The line showed the optical optical conversion efficiency of the CW operation with the output coupling efficiency of 10%; and the line showed the optical optical conversion efficiency of the Q-switched operation with the output coupling efficiency of 10%. The line showed the optical optical conversion efficiency of the CW operation with the output coupling efficiency of 15%; and the line showed the optical optical conversion efficiency of the Q-switched operation with the output coupling efficiency of 15%.

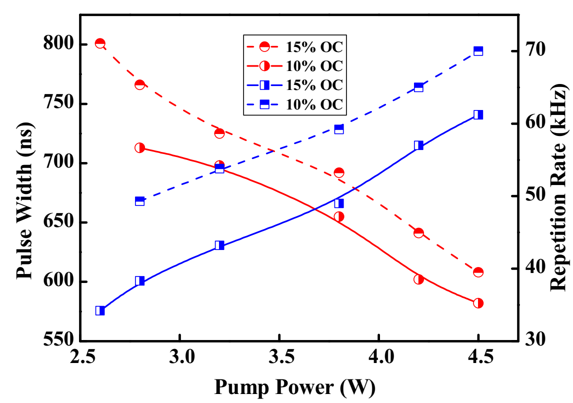

Fig. 5. Shows the relationship between different laser condition (the pulse width and repetition rate) and the pump power. The line showed the relationship between the pump power and the pulse width with the output coupling efficiency of 10%; and the line showed the relationship between the pump power and the pulse width with the output coupling efficiency of 15%. The line showed the relationship between the pump power and the repetition rate with the output coupling efficiency of 10%; and the line showed the relationship between the pump power and the repetition rate with the output coupling efficiency of 15%.

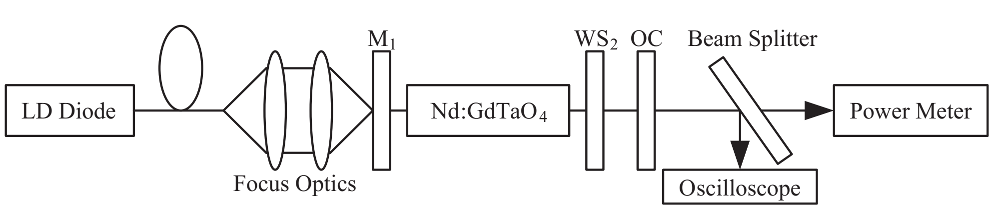

Fig. 3. Experimental setup of the LD diode-pumped $Nd:GdTaO_4$ laser based on WS_2 saturable absorber.