ARTICLE IN PRESS

Optics Communications xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Optics Communications

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

Passively Q-switched laser based on gold nanobipyramids as saturable absorbers in the 1.3 μm region

Zhaozheng Chu[a,b], Huanian Zhang[a,b], Yongjing Wu[a,b], Cheng Zhang[a,b], Jie Liu[a,b,*], Jimin Yang[a,**]

[a] Shandong provincial key laboratory of optics and photonic device, School of Physics and Electronics, Shandong Normal University, Jinan 250014, China
[b] Institute of Data Science and Technology, Shandong Normal University, Jinan 250014, China

ARTICLE INFO

Keywords:
Nanomaterials
Laser materials
1.3 μm
Solid-state lasers
Q-switched

ABSTRACT

We demonstrate a passively Q-switched solid-state laser operating at the central wavelength of 1342 nm based on gold nanobipyramids (Au-NBPs) as saturable absorber (SA) for the first time. Au-NBPs are fabricated through a seed-mediated growth method, and placed in a simple linear cavity. Under an absorbed diode-pumped power of 5.339 W, an average power of 175 mW was generated with a minimum pulse width of 342 ns and a repetition rate of 141.8 kHz, corresponding to a pulse energy of 1.23 μJ.

1. Introduction

Pulsed lasers operating in 1.3 μm have wide applications in many fields, such as remote sensing, information storage, and atmospheric pollution monitoring for their radiation coincides with the low-dispersive and low-loss spectrum of silica fiber [1–7]. Nd^{3+} is the first three valence rare earth ion used in laser systems. At present, there are dozens of practical Nd^{3+} laser medium. It is the most common way to obtain the 1.3 μm laser by using the doped Nd^{3+} laser crystal [6–10]. Traditional ways for achieving pulsed lasers are passively Q-switched and mode-locked solid-state lasers based on different materials as saturable absorbers (SAs). Development of new saturable absorber materials has directly promoted the advancement of pulsed laser techniques. At present, semiconductor saturable absorber mirrors (SESAMs) [7,11,12] are considered to be the most mature SAs. Many other materials such as carbon materials (carbon nanotubes [13,14], grapheme [15,16], grapheme oxide [17,18]), topological insulators [19,20], and two-dimensional materials (MoS_2 [21,22], WS_2 [22,23], $MoSe_2$ [22] and black phosphorus [24,25]) have also been investigated.

Nano-materials have been demonstrated as SAs for mode-locking or Q-switching lasers by different research groups in recent years [26–32]. Nano-material SAs have a variable surface plasmon-resonance (SPR) peak by controlling the aspect of the materials which makes it irreplaceable than other SAs. Kang et al. have demonstrated Yb-, Er-, and Tm-doped pulsed fiber lasers based on gold nanorods by controlling the SPR peak at 1030,1550, and 1950 nm [26–29]. Fan et al. have reported a passively Q-switched erbium-doped fiber laser based on gold nanosphere at 1 μm wavelength [30]. Recently, Zhang et al. have demonstrated that gold nanobipyramids (Au-NBPs) can be used as SAs for ultrafast pulsed-laser application in the 1.1 μm region and 1.4 μm region for the first time [31,32]. Those results illustrated that nanomaterials have great potential in the application of obtaining pulsed lasers as a new kind of SAs.

In this paper, we demonstrate a Q-switched solid-state Nd: $GdVO_4$ laser using Au-NBPs as saturable absorbers by controlling the longitudinal SPR peak of Au-NBPs within 1.3 μm region. The maximum output power of 175 mW was obtained at the pump power of 5.339 W, with the pulse width of 342 ns at the repetition frequency of 141.8 kHz. To our knowledge, this is the first time to realize a passively Q-switched solid-state laser of 1.3 μm region using Au-NBPs as saturable absorber.

2. Fabrication and characterization of the Au-NBPs

The Au-NBPs used in our experiment were prepared with 50 μL of 1% chloroauric acid($HAucl_4$) and 74 μL of 1% trisodium citrate added into 9.875 mL pure water and was vigorously stirred for 1 min. After the solution was on a longstanding status after 150 μL of 0.01 M ice, $NaBH_4$ was added and vigorously stirred for 1 min. The growth solution was prepared with 28.5 mL of 0.01 M cetyltributylammonium bromide, 1.2 mL of 0.01 M $HAucl_4$, 60 μL of 0.01 M $AgNO_3$, and 400 μL of 0.1 M ascorbic acid, which were dissolved in a flask. After a 30 μL seed solution was injected into the growth solution, the mixed

* Corresponding author at: Shandong provincial key laboratory of optics and photonic device, School of Physics and Electronics, Shandong Normal University, Jinan 250014, China.
** Corresponding author.
E-mail addresses: jieliu@sdnu.edu.cn (J. Liu), jmyang@sdnu.edu.cn (J. Yang).

http://dx.doi.org/10.1016/j.optcom.2017.02.025
Received 26 October 2016; Received in revised form 7 February 2017; Accepted 10 February 2017
0030-4018/

Please cite this article as: Chu, Z., Optics Communications (2017), http://dx.doi.org/10.1016/j.optcom.2017.02.025

Fig. 1. Photograph of Au-NBPs solution and TEM image of the gold nanobipyramids.

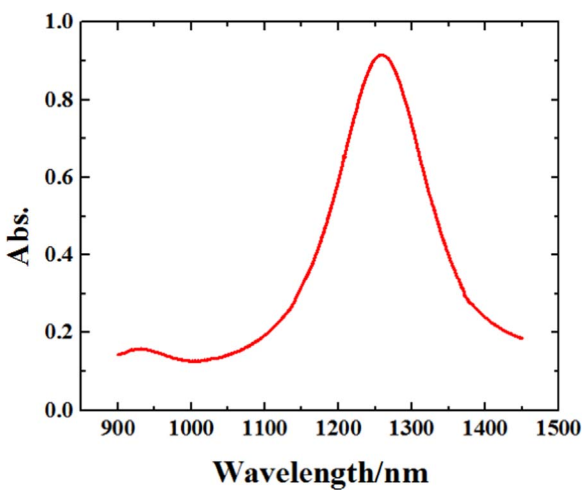

Fig. 2. The absorption spectrum of the gold nanobipyramids.

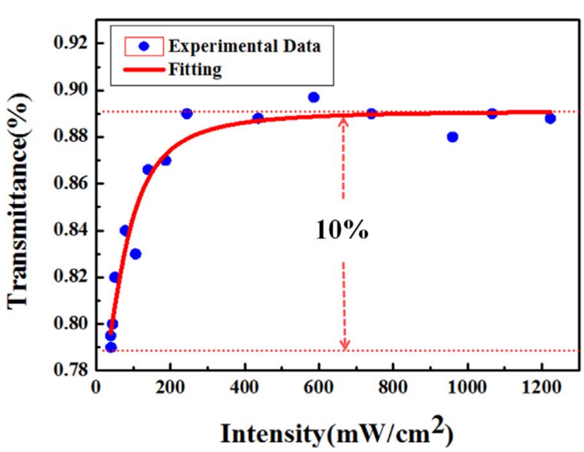

Fig. 3. The nonlinear transmission curve of Au-NBPs film.

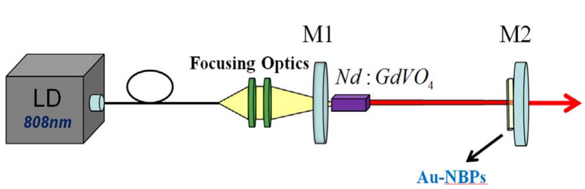

Fig. 4. Schematic configuration of the Passively Q-switched Nd:GdVO4 laser.

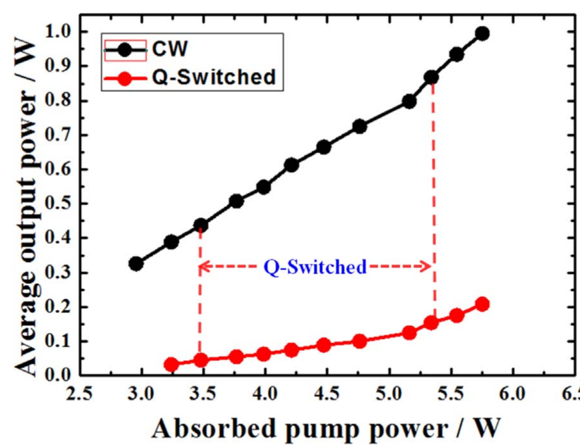

Fig. 5. Average output power as a function of absorbed pump power for CW and Q-switching.

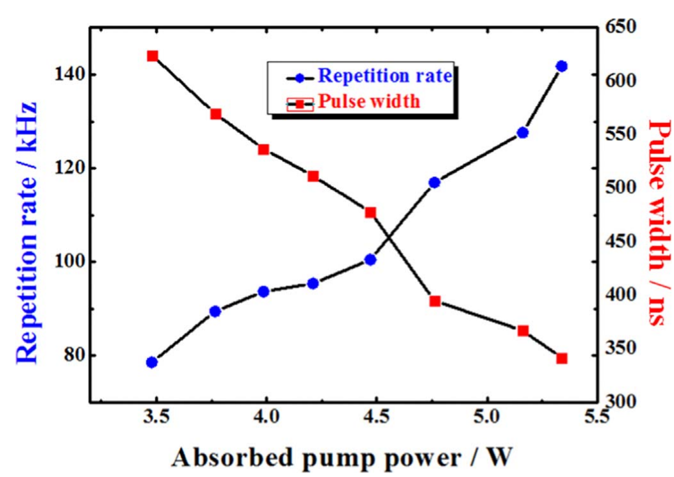

Fig. 6. The pulse width and the repetition rate versus the absorbed pump power.

solution was centrifuged at a rate of 6000 rpm for 10 min and placed into the oven with a temperature of 65 °C for 10 h. The Au- NBPs dispersion was on a long-term stable state. The final Au-NBPs SA film was formed by casting the dispersion onto a flat substrate and then followed by slow drying at room temperature.

The transmission electron microscopy (TEM) image of the Au-NBPs SA film was shown in Fig. 1 at a scale bar of 2 μm and 200 nm. Fig. 2 Showed the corresponding absorption spectrum of the gold nanobipyr-