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Neodymium Oxide (Nd_2O_3) as Passive Q-switcher for Pulsed Fiber Laser Generation in C-band Region

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Abstract:

This work demonstrate Neodymium Oxide (Nd_2O_3) film as a passive saturable absorber (SA) for pulse generation within C-band region. The saturable absorber was fabricated from Nd_2O_3 powder, and polyvinyl alcohol (PVA) was used to form a film. The all-fiber ring cavity configuration was used in the experiment. The Q-switching operated with the pump power from 60 mW to 120 mW. The repetition rate increases from 52 kHz to 77 kHz, while the pulse width shown decrement of 7.4 µs to 5.3 µs. The signal-to-noise ratio obtained of the fundamental frequency is 64 dB. The maximum output power and pulse energy are 3.6 mW and 4.6 nJ respectively. The maximum peak power obtained is 0.87 mW.

Keywords: fiber laser, Q-switching, saturable absorber, transitional metal oxide

1. Introduction

The usage of short-pulses produced by a passively Q-switched fiber laser presents a remarkable purpose such as optical communication, remote sensing, material cutting, and oral surgery [1]–[4]. Furthermore, Q-switching is easier to stimulate as contrasted to mode-locking, which would involve precise balancing between the nonlinearity and dispersion in the laser cavity [5]. As such, Q-switching is generally the preferred method of obtaining pulses in a laser cavity. Recently, the generation of excellent beam quality in alignment-free and compact assembly leads to scholars' interest to uncover more knowledge regarding Q-switched fiber lasers [4]–[6]. By using the passive technique, the structure of the laser cavity will be compact, flexible, and cost-effective [2]–[4]. Saturable absorber (SA) needs to be employed in the laser cavity to produce a passive pulsed fiber laser. Hence, back in the days, graphene was frequently used as the saturable absorber. However, due to high demand of graphene used as the saturable absorber, the price of graphene increased as of lately. Although semiconductor saturable absorber mirrors (SESAMs) have been commercialized and been used for so long, it has its disadvantages side which was it has narrowband operation and designed for explicit wavelength. Moreover, they are rather big for fiber lasers and have much more complex fabrication. Hence, it was decided to use two-dimensional (2D) materials as the saturable absorber and in this research, organic material was used as the saturable absorber as it can be easily obtained, and the discovery of organic material as saturable absorber are quite new and not extensively studied yet. In past years, several types of saturable absorber was discovered which includes zero dimensional (0D) nanomaterials which is quantum dots [7], one-dimensional (1D) which is carbon nanotubes (CNTs), 2D materials such as graphene [8], black phosphorus, transition metal dichalcogenides (TMDs) [9], topological insulators (TIs), and quite recently antimonene, MXenes [10] and organic materials such as spent ground coffee [11]. More recently, other materials such as transition metal oxides (TMOs), metals and metal oxides have also been reported as SA to generate lasers in various regions because they have high-chemical stability. These materials include Holmium oxide (Ho_2O_3), Nickel oxide (NiO), Zinc oxide (ZnO) and Lutetium oxide (Lu_2O_3) [6]. In this paper, a Q-switched fiber laser operating in C-band region is demonstrated by using Neodymium Oxide (Nd_2O_3) film as SA in all-fiber ring cavity configuration.

2. Methodology

Fig. 1 shows the all-fiber laser ring cavity with integration of Nd_2O_3 film as a passive SA and 2.4 m long erbium-doped fiber (EDF) as a gain medium. The EDF used has absorption coefficient of 27 dB/m at 980 nm and core with diameter of 9 µm with numerical aperature (NA) of 0.16. A 980 nm wavelength from single-mode laser diode pump source was pumped to EDF via 980/1550 wavelength division multiplexer (WDM). An isolator is used to ensure one-way direction of laser operation in the ring cavity. To observe the laser performances, the 10% portion of the laser intensity was tapped out from the laser cavity via 90:10 output coupler. The total length of the cavity is approximately 7 m. The laser performance was recorded by a highspeed photodetector (1.2 GHz InGaAs), optical power meter (OMM-6810B), 100 MHz digital storage oscilloscope (DSO-X 2012 A), optical spectrum analyzer (MS974QA Anritsu) and a 3 GHz RF spectrum analyzer (PSA-3000).

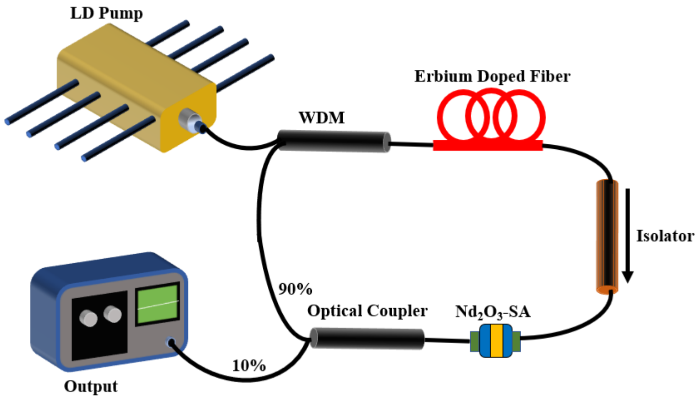

Fig. 1. Laser cavity in ring configuration.

3. Results and discussion

Fig. 2 illustrated the RF spectrum with presence of Nd_2O_3 SA where the signal-to-noise ratio (SNR) obtained was 64 dB at the fundamental frequency of 77 kHz when the 980 nm pump is fixed at 120 mW. The obtained pulse train is stable with a pulse width observed from the oscilloscope is 5.3 µs.

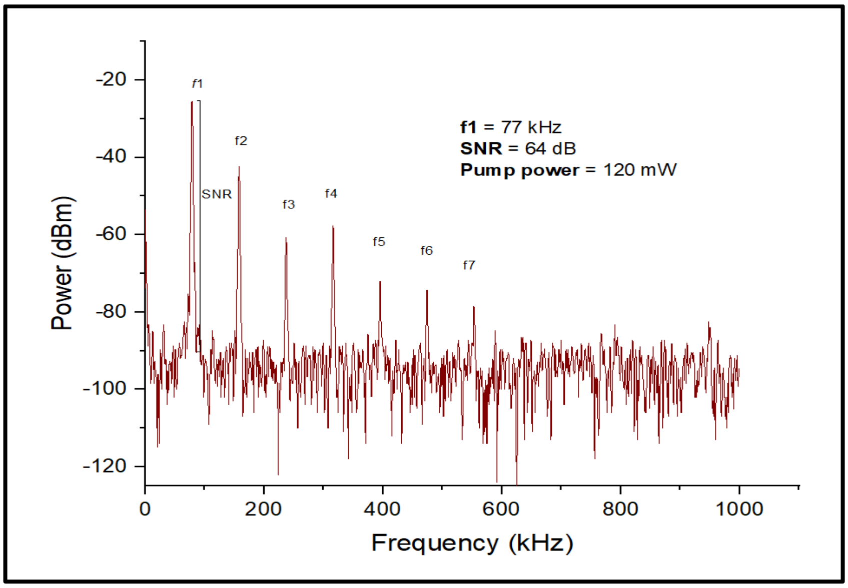

Fig. 2. The RF spectrum of Nd_2O_3 at pump power 120 mW.

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Fig. 3 demonstrates the emission optical spectrum when it was inserted with saturable absorber and without saturable absorber by using optical spectrum analyzer (OSA). The difference in intensity between both graphs is about 2 dBm. It can be observed from the graph that the emission optical spectrum which has SA in it slightly dropped from the graph of emission optical spectrum without SA. This can be proved that there was linear optical absorption occurred within the SA [12], [13] . So, the absorption phenomena of Nd_2O_3 is presence within a C-band region due to the quantum defect has affected the bandgap size of the obtained SA film.

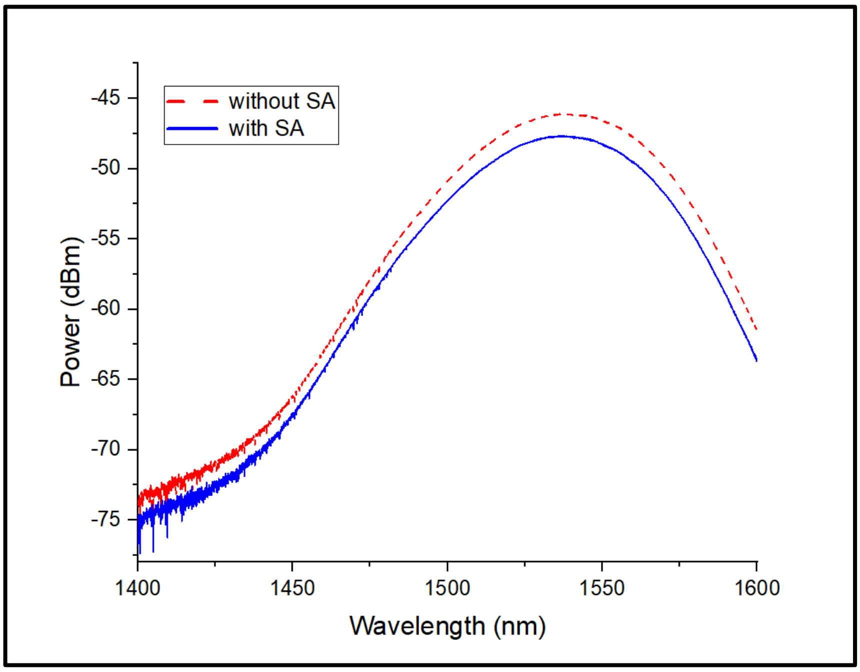
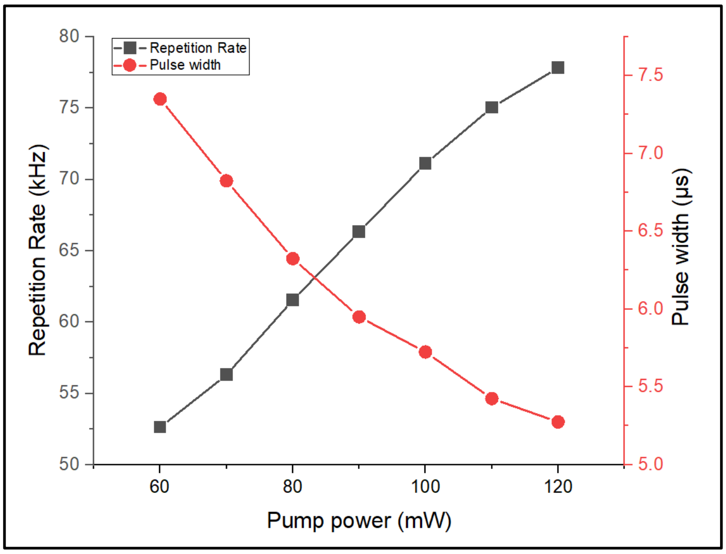
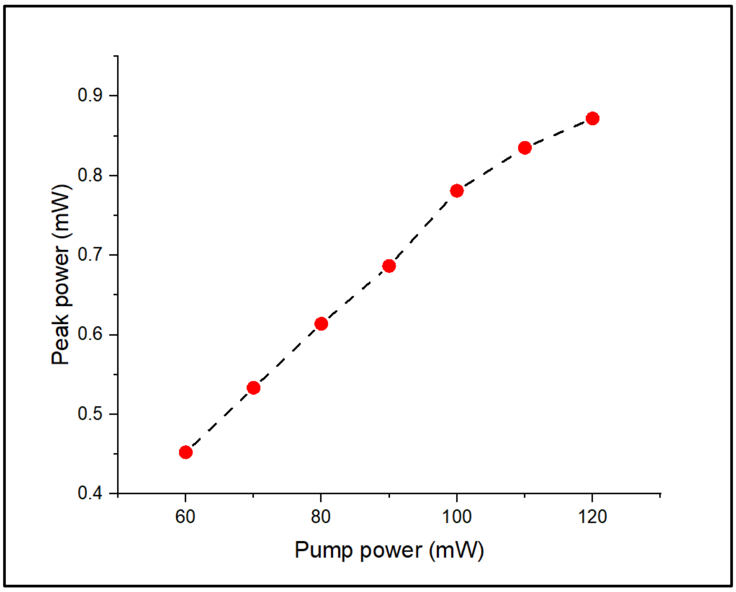


Fig. 3. The emission optical spectrum with and without saturable absorber

For the time-domain and output power performance of the Nd_2O_3 film, **Fig.4** shows the repetition rate, pulse width, and peak power. **Fig. 4(a)** demonstrates the pulse repetition rate and pulse width against pump power. As the pump power increases from 60 mW to 120 mW, the repetition rate also increase from 52 kHz to 77 kHz. Other than that, the pulse width also decreases from 7.4 µs to 5.3 µs. The average output power and pulse energy was also measured in this experiment. The output power increases from 1.8 mW to 3.6 mW while the pulse energy also increases from 3.3 nJ to 4.6 nJ. **Fig. 4(b)** shows the obtained Q-switched laser has peak power from 0.45 mW to 0.87 mW. At maximum pump power, the maximum output power and maximum pulse energy is 3.6 mW and 4.6 nJ, respectively. The prepared Nd_2O_3 film has lower threshold pump power of 60 mW compared to previous researcher which is 91.17 mW [14] and low loss within the cavity.



(a)



(b)

Fig. 4. *Q-switched EDFL performances. (a) Repetition rate and pulse width. (b) Peak power.*

4. Conclusion

An all-fiber ring cavity configuration based Q-switched EDFL is proposed and demonstrated based on Nd_2O_3 film as SA. The 2.4 m Erbium-doped fiber is used as the gain medium to generate laser at C-band region. The EDFL generates Q-switching pulse at a low threshold pump power of 60 mW. The maximum output power, maximum pulse energy and maximum repetition rate obtained are 3.6 mW, 4.6 nJ and 77 kHz, respectively. The minimum pulse width obtained is 5.3 μs at the maximum pump power of 120 mW.

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