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Q-switched erbium doped fiber laser using antimony telluride-polyvinyl alcohol (Sb_2Te_3-PVA) as saturable absorber

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Abstract. Q-switched erbium doped fiber laser was demonstrated using antimony telluride (Sb_2Te_3) as saturable absorber (SA). The SA was fabricated by adding Sb_3Te_2 powder into PVA suspension and left dry in room temperature for two days. Then, the SA was sandwiched in between two FC/PC fiber ferrules, which can provide easy integration and flexibility into the laser cavity. Stable and self-started Q-switched laser operates at 1531 nm center wavelength. The laser repetition rate increased from 54.5 kHz to 88.4 kHz and pulse duration decreased from 6.84 µs to 4.58 µs as the pump power increased. A signal to noise ratio value of 55 dB was achieved at pump power 130 mW. At the maximum pump power, the average output power and pulse energy are 0.26 mW and 2.78 nJ.

1 Introduction

Topological insulator materials has captured many research interest due to the outstanding mechanical, electronic and optical properties that are highly promising in a variety of potential applications, for example electronics [1], fiber laser [2-3], solar cell [4] and automotive [4]. Antimony telluride (Sb_2Te_3) is one of the significant topological insulator due to narrow bandgap which is approximately 0.2 eV [5], a valuable characteristic, especially in fiber laser application for pulse generation. Besides, Sb_2Te_3 has an outstanding electronics properties [6] and thermoelectric properties for [7] that are highly beneficial for electrical applications.

Fiber laser is one of essential tool that can fulfill a wide range application from scientific, medical and industrial application. In fiber laser, there are two ways to generate fiber laser, either by active or passive technique. In active techniques, a modulator is used to modulate the loss in the cavity. This technique can promise more stable pulse, higher repetition rate, and shorter pulse width but are costly to execute [8]. For passive technique, saturable absorber (SA) are incorporated to modulate the loss in the fiber laser cavity. This simple and low cost techniques also can generate a stable pulse depending the on pump power to tune the pulse repetition rate [9].

On the basis of limited study on Sb_2Te_3 saturable absorber (SA) fabrication. There are several fabrication techniques to fabricate SA including mechanical exfoliation, drop cast and thin film or polymer composite, but only mechanical exfoliation of Sb_2Te_3 has been reported [10]. In mechanical exfoliation technique, most of the techniques are using bulk Sb_2Te_3 instead of powder form. The main drawbacks of this technique is its' difficulty to control the desired Sb_2Te_3 layer and thickness that need to be transferred on the FC/PC fiber ferrule [11]. To embed into PVA polymer, using powder is a suitable ways in order to ensure the Sb_2Te_3 strongly bind with the polymer. Using this method, concentration and thickness of the SA can be controlled. There are several kinds of polymer material, for example polymethylmethacrylate (PMMA), polyvinyl alcohol (PVA), polyethylene oxide (PEO) and polyimide that can be used as polymer host [12].

In this paper, we successfully demonstrated generation of Q-switched EDFL using Sb_2Te_3 based SA. The Sb_2Te_3 SA embedded in PVA thin film was sandwiched in between FC/PC fiber ferrule to generate stable pulsed.

2 Experiment Details

2.1. Fabrication of Sb_2Te_3-PVA Saturable Absorber (SA)

SA was prepared by dissolving 25 mg Sb_2Te_3 powder [Sigma Aldrich, -325 Mesh, 99.6% trace metal basis] into the PVA suspension and stirred for an hour, followed by sonication for 15 minutes until the powder completely dissolves. Then, the mixture was poured into the petri dish and left dry in ambient temperature. After 2 days, thin film was slowly peeled from the petri dish and cut into 2 mm^2 then attached onto the FC/PC fiber

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ferrule. Fig 1 shows the Sb_2Te_3–PVA SA attached on the FC/PC fiber ferrule.

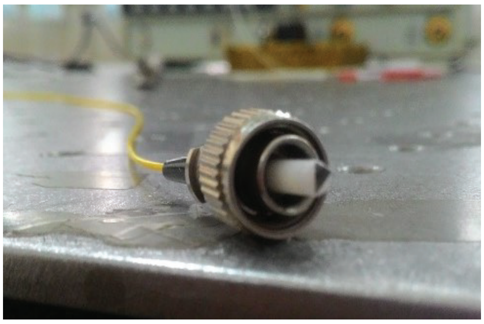

Fig. 1. Sb_3Te_2 – PVA saturable absorber.

2.2 Experimental setup

Fig 2 shows the configuration of the Q-switched erbium doped fiber laser (EDFL) based on Sb_2Te_3–PVA SA, which consists of a 980 nm laser diode (LD), 980/1550 nm wavelength division multiplexing (WDM), 2.4 m Erbium-doped fiber (EDF), isolator and 90/10 output coupler.

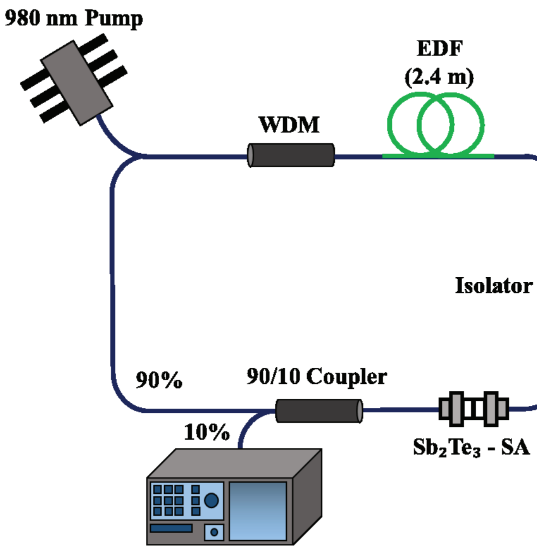

Fig. 2. Configuration setup of the Q-switched EDFL.

The SA was cut into a small pieces (2 mm^2) and sandwiched in between two FC/PC fiber ferrule. The EDF has a core and cladding diameters of 4 µm and 125 µm, with a numerical aperture of 0.16 and erbium ion absorption 23 dB/m at 980 nm. The laser is pumped by a 980 nm LD via the WDM. An isolator is incorporated in the cavity to ensure unidirectional propagation of the laser. The light is extracted from the cavity by 90/10 coupler, 90% of the lights are propagates in the cavity and 10 % are used for output. An optical spectrum analyzer (YOKOGAWA: AQ6370B), oscilloscope (QW Instek, GDS-3352) and radio frequency spectrum analyzer (Anritsu, MS2638A) coupled with 1.2 GHz InGaAs photodetector (Thorlabs, DET01CFC) were used to measure optical spectrum, pulse train and signal to noise ratio of the pulse. An optical power meter is used to measure the output power. The total cavity length of the laser cavity is measured to be approximately 13 m.

3 Results and Discussion

A self-starting Q-switched pulse were achieved at pump power 39.2 mW. Q-switched performance was observed when the pump power is tuned from 39.2 mW until 65.5 mW. Beyond 65.5 mW, the pulse generated started to become unstable and diminished.

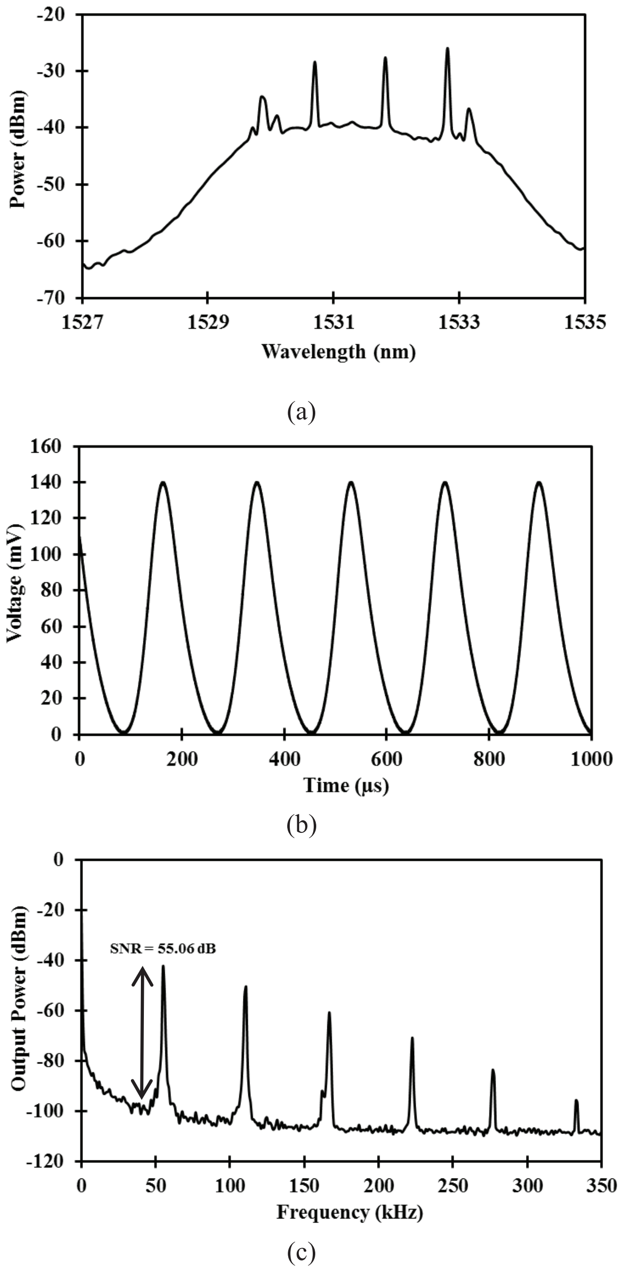

Fig. 3. (a) Output spectra (b) Pulse train and (c) RF spectrum at 39.2 mW pump power.

Fig 3 (a) displays the optical spectrum at pump power of 39.2 mW. The laser operates at center

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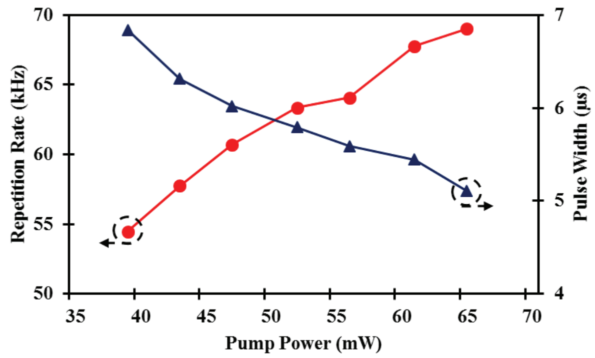
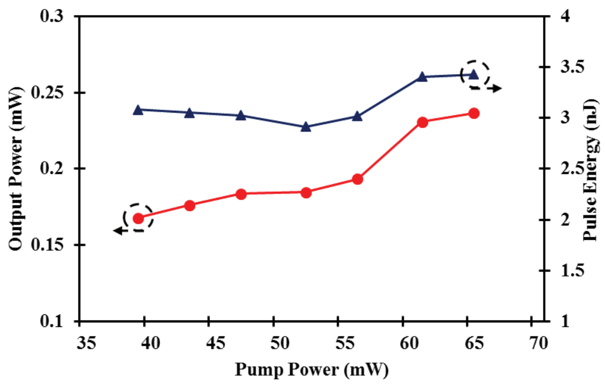
wavelength 1531 nm with a 3 dB spectral bandwidth of 4.68 nm. To verify the Q-switching pulses, the SA was removed from the fiber ferrule and no pulses was observed when the pump power was tuned over a wide range. Fig 3(b) shows the typical oscilloscope traces of the Q-switched pulse trains at pump power of 39.2 mW. The pulses shows a uniform and no distinct amplitude with peak to peak duration of 186 µs. In Fig 3(c) shows the output RF spectrum at 39.2 mW matching with the 54.48 kHz repetition rate. The signal to noise ratio (SNR) of the fundamental peak to the pedestal extension is estimated 55.06 dB.

Fig 4 (a) represent the pulse repetition rate and pulse duration as the function of pump power. It is observed that repetition rate is increased from 54.5 mW to 69.0 mW as the pump power increased 39.2 mW until 65.5 mW. The pulse width are reduced from 6.84 µs to 5.11 µs when the pump power increased. Fig 4 (b) shows the average output power and calculated pulse energy at 39.2 mW to 65.5 mW. The average output is raised from 0.17 mW to 0.24 mW as increased the pump power. The pulse energy are increased from 3.08 nJ until 3.43 nJ at 39.2 mW to 65.5 mW.



(a)



(b)

Fig. 4. (a) Repetition rate and pulse width, and (b) Output power and pulse energy at pump power 39.2 mW to 65.5 mW.

3 Conclusion

In summary, Q-switched EDFL using Sb_2Te_3 are demonstrated in this paper. The Sb_2Te_3 was prepared by mixing with PVA suspension and SA was peeled after dried in ambient for 2 days. Then, the SA is cut into small piece and sandwiched between the fiber ferrule to generates pulse laser. The Q-switched operates at the center wavelength of 1531 nm and a stable pulse is achieved at the pump power 39.2 mW to 65.5 mW. At the maximum pump power, the output power of 0.24 mW and pulse energy of 3.43 nJ are produced.

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