The Stability of WSe_2 Q-Switched Fiber Laser

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Abstract— In this paper, we present an environmentally stable all-polarization-maintaining Erbium-doped Q-switched fiber laser based on WSe_2-PVA as a saturable absorber. WSe_2-PVA film is synthesized by liquid phase exfoliation. We let the fiber laser continue to work twelve hours, and we keep a record of the output power, optical spectrum, and frequency spectrum every thirty minutes. The results shows the stability of the WSe_2 in a stable ring cavity. Our work demonstrates the feasibility for this 2D material to be applied in the field of fiber laser.

1. INTRODUCTION

The emergence of graphene as a promising material for optical applications has triggered great interest in other 2D materials. Transition metal dichalcogenides (TMDs) have received the most attention [1]. TMDs have a generalized formula as XY_2, where X is transitional metal atom such as Mo, W and Y is S, Se. Many fiber research works combined with TMDs have been reported since 2014 [2]. Q-switching is a common method in laser field to generate high energy, low frequency and long time-duration pulses. It is an important method which had been utilized to obtain pulses soon after the birth of ruby laser [3]. In this work, we demonstrated an all-PM Q-switched fiber laser operating at 1550 nm, which worked for twelve hours continuously. The all-PM ring cavity provided a more stable environment for this material. The stability of the WSe_2 based Q-switched fiber laser was investigated.

2. EXPERIMENT AND RESULTS

We fabricated the WSe_2 nanosheets by liquid phase exfoliation (LPE) method. Briefly, 5 mg/ml WSe_2 water dispersions were prepared with sodium cholate as surfactant. Meanwhile, 50 mg/ml PVA solution was also prepared. 2 ml WSe_2 dispersions were mixed with 10 ml PVA solution for 24 hours by a magnetic stirrer. Then the mixture was processed by ultrasonic water bath device for another 4 hours. Finally, we transferred the mixture to the surface of a clean dish and dried under 50°C condition for 3 days [2].

The setup of fiber laser is shown in Fig. 1. The pump source is a 980 nm diode laser with tunable output power. A 980/1550 nm wavelength division multiplexer couples the pump light into the ring cavity. The gain medium is a section of Erbium-doped fiber. A 90/10 coupler extracts 10% optical power as output. An isolator assures the unidirectional running of fiber laser. An optical spectrum analyzer (OSA, YOKOGAWA AQ6370C) is used to measure power spectrum. An oscilloscope (Agilent Technologies, DSO9254A) is used to detect waveform in time domain. Electric

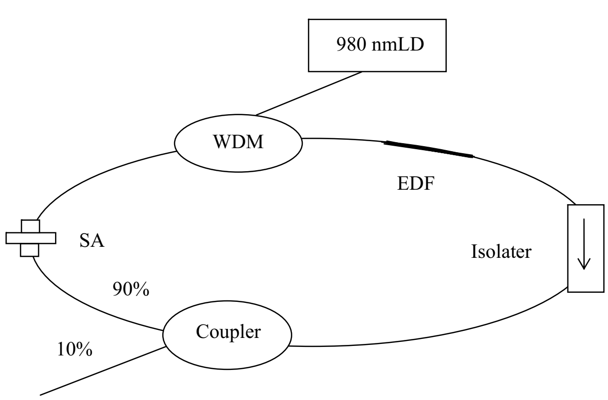

Figure 1: The setup of the fiber laser.

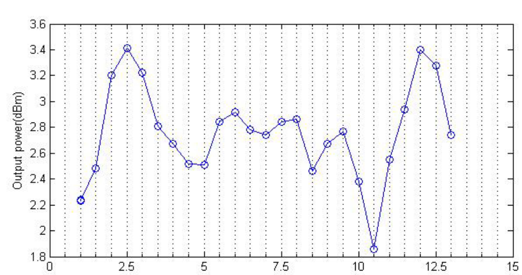

Figure 2: The change of the output power with time.

spectrum analyzer (ESA, ROHDE & SCHWARZ) is used to measure power spectrum. WSe_2-PVA saturable absorber is incorporated in a pair of FC/PC connectors. All the equipment in the ring is polarization maintaining, which is important to measure the stability of the material.

Figure 2 shows the variation of the output power with time. From the figure, the working state of the fiber laser included three sections: the first section showed that the fiber laser took some time to obtain a stable state; the second state showed the fiber laser has a low fluctuation in the output power, meaning the stable Q-switched state was obtained for eight hours; the last section showed that the WSe_2-PVA film began to be damaged and the output power dropped. Fig. 3 shows the waveform of the time.

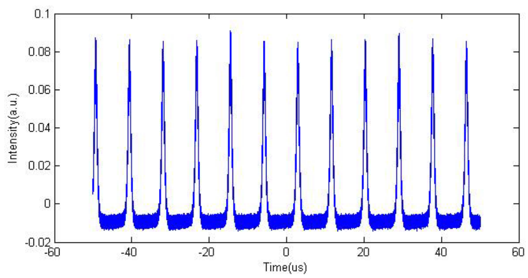

Figure 3: The pulse train of the oscilloscope.

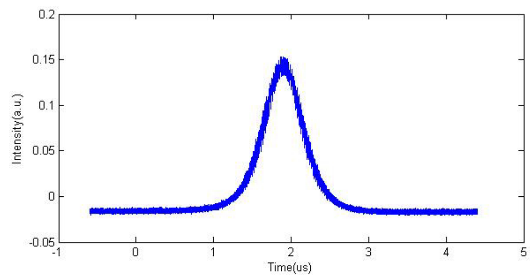

Figure 4: The waveform of the Q-switch mode-locked.

3. DISCUSSION

When the pump power was tuned to a high level, Q-switched mode-locking operation can also be observed. Fig. 4 shows the waveform in time domain. The envelope of the pulse is a Q-switched pulse and the mode-locked pulses are overlapped on this Q-switched pulse. Fig. 5 shows the optical spectrum and Fig. 6 shows the electrical frequency spectrum. In Fig. 6, frequency components with a spacing of 50 MHz represent the mode-locking operation and their unstable envelopes indicated the Q-switched property.

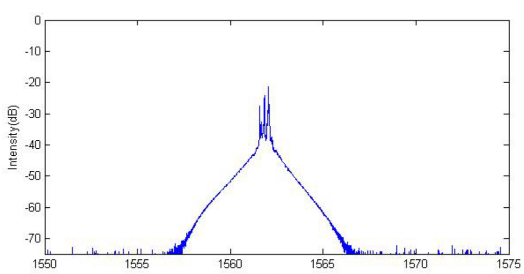

Figure 5: The optical spectrum of the Q-switch mode-locked.

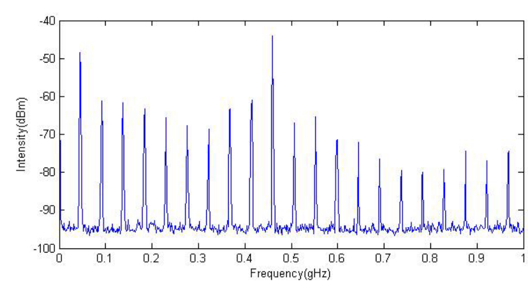

Figure 6: The frequency spectrum of the Q-switch mode-locked.

4. CONCLUSION

We demonstrated a Q-switched all-PM erbium-doped fiber laser based on WSe_2-PVA saturable absorber. All-PM cavity prevented the perturbation from the environment and the stability of the laser was investigated for 12 hours. It is found that WSe_2-PVA saturable absorber can sustain an 8-hour stable operation after a warming process. Q-switched mode-locking was also observed in the cavity when the pump power was high.

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