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Abstract. Upon exfoliation from the bulk form, two-dimensional materials have shown ubiquitous properties which are suitable for Q-switched pulsed laser generation. In this research, a successful solution process of graphene-MoS_2 nanocomposite saturable absorber through liquid phase exfoliation has been carried out. The method offers a low-cost route for simple and scalable production while providing a promising material quality with on-demand properties and integration flexibility. Stable Q-switched laser operation was realized with graphene-MoS2 hybrid saturable absorber. The pulse duration was measured to be 6 µs with repetition rate of 63.92 kHz corresponding to a peak power and pulse energy of 5.05 mW and 30.87 nJ, respectively.

1. Introduction

Optical fiber system with broadband and tunable saturable absorber (SA) is important for creating a compact Q-switched fiber laser. The discovery of two-dimensional (2D) graphene offers plenty of opportunities for the next generation of SAs to be used in passive Q-switching [1]. The gapless nature of graphene has led to the wavelength-independent absorption which makes it suitable for broadband spectrum. Inspired by the disclosure of graphene phenomenon, a significant number of other 2D materials such as transition metal dichalcogenides (TMDs), phosphorene, topological insulators, and MXenes have been actively pursued [2].

Not only that, many endeavours have concentrated their works in the avenues of synthesis and viable routes for scalable production and exploration of properties that will enable novel device applications. Liquid-phase exfoliation (LPE) is one of the eminent methods of choice among researchers for 2D materials fabrication. This is due to its simplicity, cost-effectiveness, and high scalability for production of large quantities of mono- and few layer 2D materials in a commercially viable way [3]. Therefore, this research work proposed a simple solution process through liquid-phase exfoliation of graphene-MoS_2 nanocomposite for passive Q-switched pulse laser with chitin as a biocompatible host polymer.

2. Methodology

2.1. Graphene-MoS2 SA fabrication

Graphene solution was prepared with conductive graphene-PLA based 3D printer filament as the starting material. The graphene-PLA filament will be extruded through a 3D printer nozzle and weighed to 25 mg before dissolved in 1 ml of THF solution. The graphene-THF suspension is then undergo ultrasonication for 10 minutes. For MoS_2 solution, 5 mg MoS_2 powder and 5 ml THF solution are mixed together until MoS_2 powder dissolved homogeneously in THF solution with stirring time of about 2 hours, at ambient temperature and 1200 rpm. Meanwhile, a host polymer is needed to become a binder in the fabrication of SA film. A recent bio-host polymer namely chitin which is prepared from the oyster mushroom is introduced in this research. The synthesis work for chitin biopolymer can be found in report by Wan Nawawi et al. [4]. Solution-processed of graphene-MoS_2 hybrid is done by mixing the prepared graphene and MoS_2 solution with chitin in one-to-one ratio and placed in ultrasonic bath for sonication process about 60 minutes to ensure a well-homogenized dispersion form with good viscosity matrices. Ample time of sonication process allowed exfoliation of bulk crystals into nanosheets as the van der Waals interaction weaken due to production of microjets and shockwaves from collapsing cavitation bubble. The obtained dispersion mixtures are then poured into 35 mm × 15 mm circular shape petri dish and let dry in ambient temperature for about 36 hours before they ready to be peeled off as a free-standing film SA.

2.2. Experimental setup

The graphene-PLA filament will be extruded through a 3D printer nozzle and weighed to 25 mg before dissolved in 1 ml of THF solution. The fabricated SA was integrated into fiber laser cavity by sandwiching it between two ferrules as shown in Figure 1.

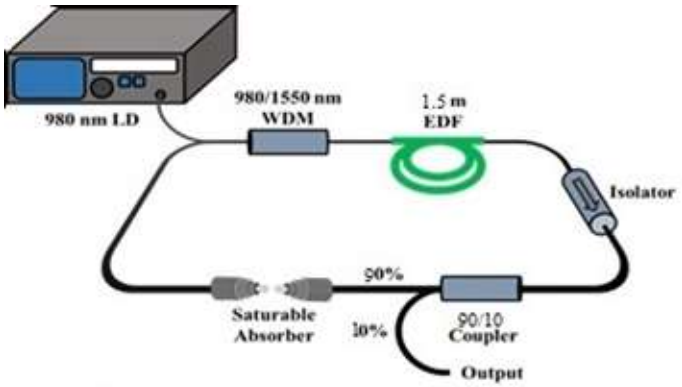

Figure 1. Laser cavity setup of Q-switched EDFL based on graphene-MoS_2 chitin SA.

The output was tapped out by a 90/10 optical coupler, where 90 % of the light is kept oscillating in the cavity, and the remaining 10 % is used for output measurement to simultaneously observe the pulse train, signal to noise ratio and optical spectrum through a 3 dB coupler. The output are obtained through Optical spectrum analyzer (OSA) (Yokogawa AQ6370B), optical power meter (OPM) (Thorlab PM100D), mixed domain oscilloscope (Tektronix MDO3024) which were connected through a 460 kHz bandwidth photodetector (PD) (Thorlab DET01CFC).

3. Results and Discussions

The performance of SAs in generating pulsed laser were graphed for graphene-MoS_2 chitin nanocomposite at one-to-one ratio. Figure 2 shows optical spectrum with Q-switched pulse lasing operated at around 1558 nm at maximum pump power of 104.93 mW when fabricated SA is integrated into the laser cavity.

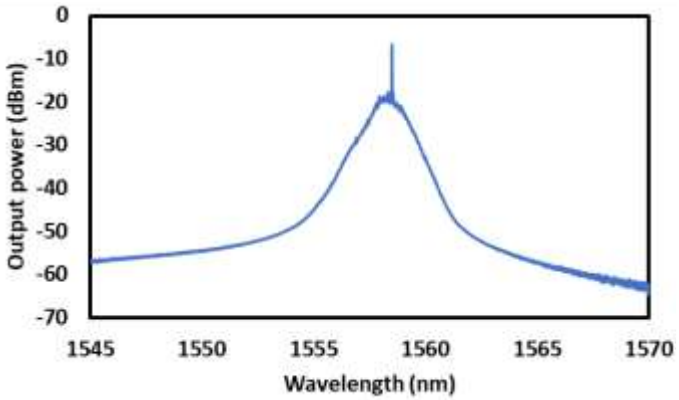

Figure 2. Optical spectrum at maximum pump power of 104.93 mW.

The pulse train repetition rate and the associated pulse width of graphene-MoS_2 is shown in Figure 3 as recorded at maximum input pump power. The graphene-MoS_2-chitin based SA film was able to generate Q-switching pulse pump power of 66.32 mW, tunable up to 104.93 mW. The graph also indicates a highly stable Q-switching operation with little to no amplitude modulation can be obtained from graphene-MoS_2 SA.

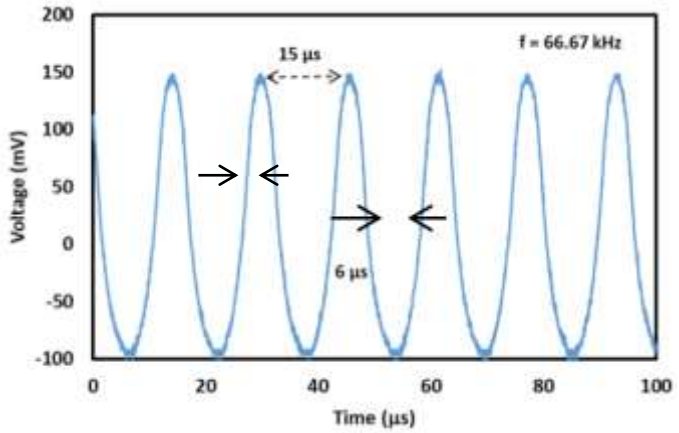

Figure 3. Pulse train repetition rate and pulse width at maximum input pump power.

The relationship between repetition rate and pulse width against the input pump power is depicted in Figure 4.

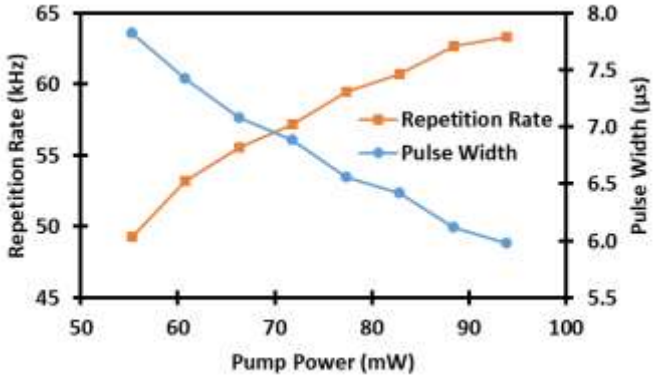

Figure 4. Repetition rate and pulse width against pump power.

As the pump power increased, the repetition rate increased up to 63.29 kHz while the pulse width was reduced to 6 µs. The trend shows a typical Q-switched operation. This resulted in instantaneous peak power and pulse energy of 5.05 mW and 30.87 nJ as shown in Figure 5.

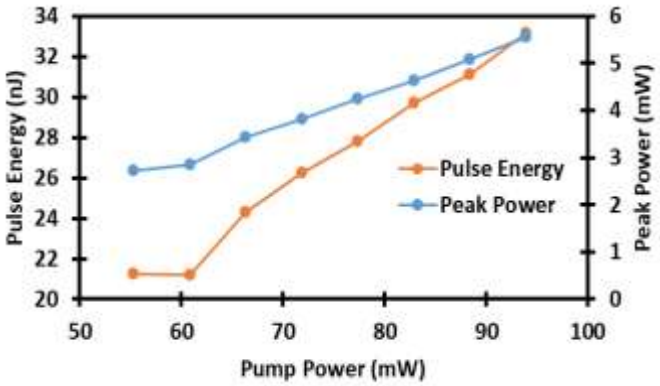

Figure 5. Instantaneous pulse energy and peak power with respect to input pump power.

The pulse energy and peak power is calculated from obtained repetition rates frequency and pulse width. Typically, both of these parameters share the same trend of inclination towards the maximum input pump power. On the other hand, the SA film demonstrated Q-switching pulsed lasing with high stability of over 60 dB. Figure 6 shows the radio frequency spectrum analyser (RFSA) to confirm the stability parameter in pulse laser generation.

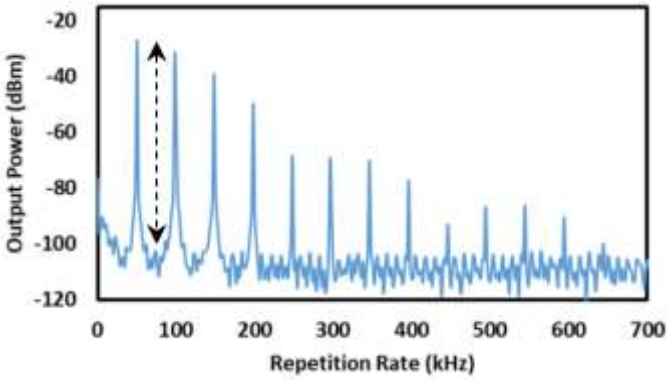

Figure 6. RFSA measurement of the Q-switched EDFL.

4. Conclusion

The SA films of proposed material were successfully fabricated via solution process through liquid phase exfoliation in a desirable condition i.e., scalable production, low-cost consumption, room temperature condition, and minimal apparatus. Apart from that, a passively Q-switched EDFL is successfully demonstrated by using graphene-MoS_2 chitin SA with high repetition rate, low pulse width and good stability and repeatability.

References

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