Journal of Science and Technology, Vol. 9 No. 3 (2017) p. 96-100

Saturable Absorption Measurement of Platinum as Saturable Absorber by using Twin Detector Method Based on Mode-Locked Fiber Laser

Atiqah Nabieha Azmi, *Noor Azura Awang, Zahariah Zakaria, Fatin Shaqira Abdul Hadi and Yushazlina Roshaini Yuzaile

Department of Physics and Chemistry, Faculty of Applied Sciences and Technology, Universiti Tun Hussein Onn Malaysia, Pagoh Educational Hub, Johor,Malaysia.

Received 30 September 2017; accepted 30 November 2017; available online 28 December 2017

Abstract: This paper illustrates the absorption measurement of Pt as saturable absorber (SA) by using mode-locked fiber laser system. The SA is fabricated by depositing 10 nm of Pt on the fiber ferrules using sputtering method. The absorption measurement of Pt is characterised by employing a balanced twin detector method based on mode-locked fiber laser with central wavelength of 1532.25 nm, repetition rate of 2.833 MHz and pulse duration of 34.3 ns. The Pt-SA produce modulation depth of 21.9% and saturation intensity of 21.6 MW cm^{-2}.

Keyword: Absorption; platinum; saturable absorber; mode-locked.

1. Introduction

Q-switched and mode locked fiber laser based on saturable absorber has been useful in light source and widely use in telecommunication, medicine, fiber optic sensing, remote sensing, range finding and industrial processing [1]. Q-switched and mode locked fiber laser are used to produce optical pulses by suddenly switching cavity losses [2]. There are two different techniques to switching the losses that can be identified which are active and passive Q-switched and mode locked fiber laser. Active Q-switched and mode locked fiber laser mean the losses control involves modulator such as acousto-optic or electro-optic modulator while passive Q-switched and mode locked fiber laser rely on with saturable absorber which itself transforms by light field.

Of late, research into 1- and 2-D materials for use in fiber devices has led to study of Topological Insulators (TIs) and Transition Metal Dichalcogenides (TMDs) due to its unique electronic, optical and physical properties such as black phosphorus (BP) [3,4], MoS_2 [5], $MoSe_2$ [6], Bi_2Se_3 [7], zinc oxide [8,9], phosphorene [10], silver [11] and gold (Au) [12,13,14,15] as saturable absorbers. This led to explore platinum as saturable absorber due to discovering properties of saturable absorbers.

In this paper, we report the absorption saturation of Pt which acts as an SA where the modulation depth and saturation intensity are determined to be 21.9% and 29.6 MW cm^{-2}, respectively.

2. Pt saturable absorber preparation and characterization

2.1 Pt saturable absorber preparation

The process of deposition of Pt takes place on the surface of the fiber ferrule. The process of deposition has been done using the sputtering method. The equipment used for this method is the DC Sputter QT300TD by Quorum Technologies. Before coating, the fiber ferrule must be free from dirt, dust and finger print. The fiberscope is used to check the cleanliness of the ferrule. The next process is coating Pt on the fiber ferrule surface. The process of coating had been done by using the sputter coater as in Fig. 1. The sputtering process basically involves the bombardment of energetic particles from a target to substrate which is performed in the vacuum chamber. In this case, the fiber ferrule became a target to a coat in the sputter coater while Pt became the substrate to coat. For allowing the coating process, there were some distances between the anode (fiber ferrule) and the cathode (Pt). The thickness of Pt coated on the fiber ferrule surface was set at 10 nm. Then,

*Corresponding author: norazura@uthm.edu.my

penerbit.uthm.edu.my/ojs/index.php/jst

the 10 nm Pt fiber coated as shown in Fig. 2 was characterize using the Scanning Electron Microscope (SEM) and Enegy-dispersive X-ray spectroscopy (EDX) for characterisation purposes.

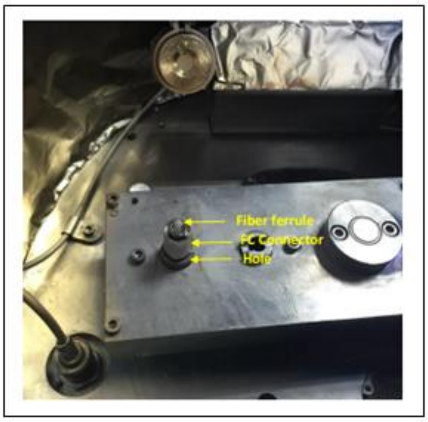

Fig. 1 The image of the FC connector inside the sputtering machine (rewritten as fiber ferrule, FC connector and hole), DC Sputter QT300T D by Quorum Technologies.

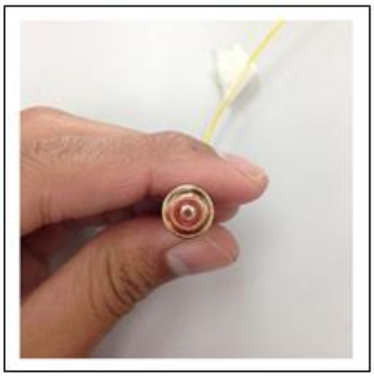

Fig. 2 The coated 10 nm of Pt on fiber ferrule by using DC Sputter QT300T D by Quorum Technologies.

2.2 Scanning Electron Microscope (SEM) characterization

Fig. 3 shows the images of platinum, Pt coated ferrule under the Scanning Electron Microscope (SEM). The images were under the magnification of 700 × and 1290 × respectively. It can be seen that the surface of platinum was not really smooth, as there were many small holes or pores detected on the surface. The images were zoomed on the core surface of the ferrule.

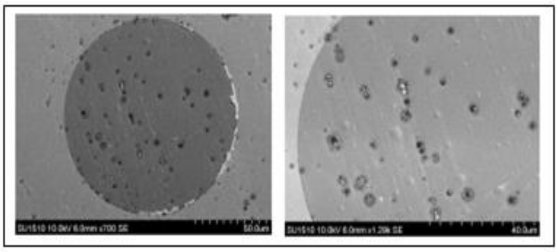

Fig. 3 SEM measurement for deposited Pt.

2.3 Energy dispersive X-ray spectroscopy (EDX) characterization

Fig. 4 shows the EDX analysis on the platinum coated ferrule. The analysis on the percentage of element is tabulated in Table 1. The EDX has traced three elements such as oxygen, silicon and platinum. Silicon element is represented by the porous parts on the ferrule surface because the ferrule itself is made of borosilicate glass. Based on weight percentage, platinum element indicates the highest percentage among the other two elements with percentage of 59.36%. The least is oxygen element which is 17.31%. However, based on atomic percentage, the platinum indicates the least value of 19.73% whereas oxygen indicates the highest value of 48.80%. Atom percentage is based on the number of atoms in the sample while weight percentage is based on the mass of element detected.

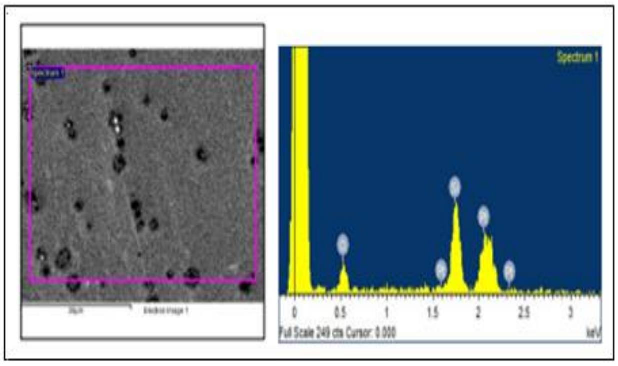

Fig. 4 EDX spectrums for deposited Pt.

Table 1 Percentages of the elements on the Pt coated ferrule.

Element	Weight (%)	Atomic (%)
Oxygen, O	17.31	48.80
Silicon, Si	23.33	37.47
Platinum, Pt	59.36	19.73

3. Experimental Setup

The experimental setup is designed to measure the modulation depth of the Pt-SA as in Fig. 5 is known as a twin detector measurement technology. The experiments began with the mode locked fiber laser linked to a 50/50 coupler. The output port of 50/50 coupler was connected to Optical Spectrum Analyser (OSA) and 980/1550 nm wavelength division multiplexer (WDM), respectively. The 1 m long of Erbium doped fibre (EDF) was used to act as gain medium which has a 125 µm cladding diameters meanwhile 50 µm core diameters. For numerical aperture, its value is 0.545 and cross-sectional area of 5.027×10^{-11} cm^2. The output light from EDF is divided into two equal laser beams by using a 3 dB coupler. One laser beam pass through the Pt-SA and connected to optical power meter (OPM), while the other one is directly connected to an identical OPM. Both OPMs are used for measuring absorption of Pt as SA. The SA composition is of approximately 17.31% of oxygen, 23.33% of silicon and 59.36% of platinum. The pumped power from 980 nm laser diode was decreasing from 320 mA to 50 mA, to obtain the measurement. The mode-locked pulse laser had a repetition rate of 2.833MHz.

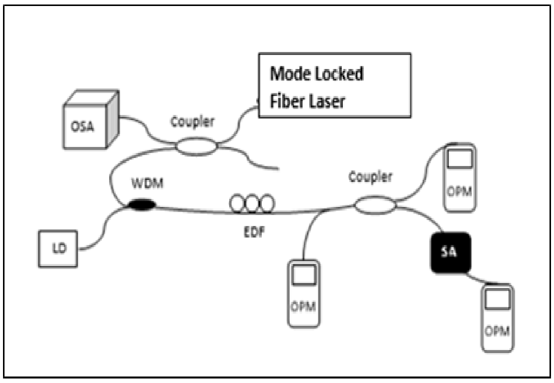

Fig. 5 Schematic diagram of the absorption measurement of Pt as SA.

4. Results and discussion

In this experiment, a 980nm laser diode acts as source for generating passively Q-switched. The highest value of Q-switched obtained is at 600 mA with the central wavelength of 1532.250 nm. The value of peak power is -39.07 dBm. The Q-switched spectrum at 600 mA is illustrated in Fig. 6. From the spectrum, the achieved optical signal-to-noise ratio (OSNR) and bandwidth are 33.43 dB and 34.3 nm, respectively. In order to generate Q-switched pulses, it need a short cavity length and a high gain value [4].

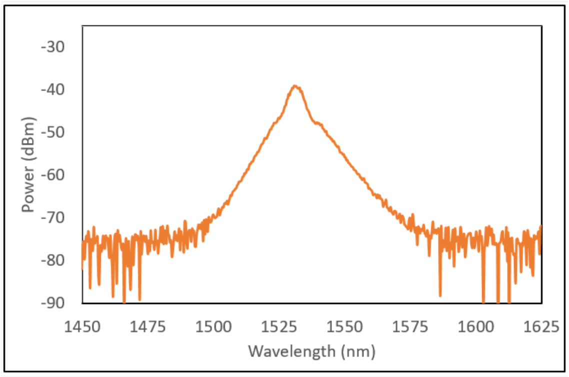

Fig. 6 Q-switched spectrum at 600 mA.

The pulse for this experiment has a repetition rate of 22.833 MHz which corresponds to pulse width of 34.3 ns. The pulse width depends on the cavity length and the modulation depth SA [5]. The repetition rate has been displayed as pulse train by using an oscilloscope. The repetition rate of the Q-switched pulse for 600 mA is shown in Fig. 7.

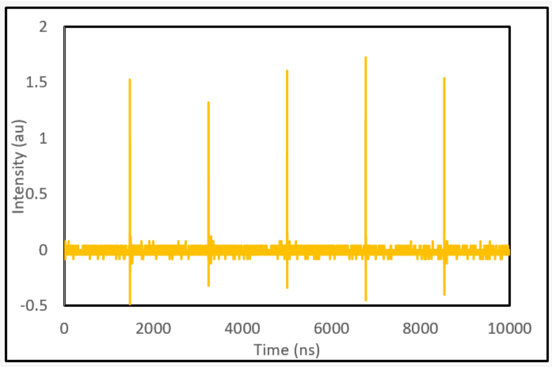

Fig. 7 Repetition rate of the Q-switched pulses for 600 mA.

For modulation depth, the input power was varying from 320 mA down to 50 mA. Therefore, it led to the output power. Thus, the value of modulation depth and saturation energy obtained can be obtained. Both values are 21.9% of modulation depth 21.6 MW cm^{-2} of saturation intensity, respectively. As a comparison, it is reported, by using Bi_2Se_3, the value of modulation depth was 11.1% [4]. The result of modulation depth is plotted in Fig. 8 based on input power and output power.

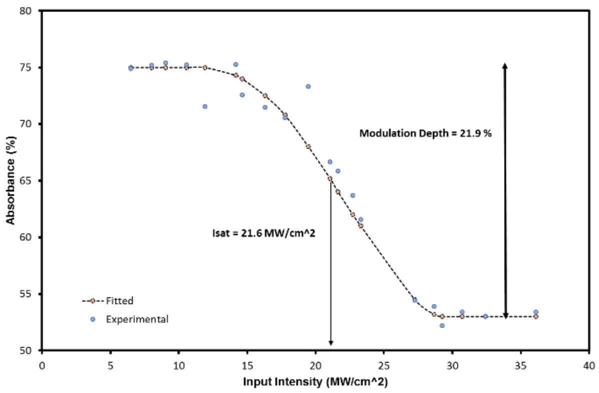

Fig. 8 The transmission spectrum of Pt with a modulation depth of 21.9%.

5. Conclusion

The twin detector method for measuring saturable absorption platinum (Pt) as saturable absorber has been experimentally demonstrated. The Pt SA was coated with thickness of 10 nm. The passive Q-switching operation produced modulation depth of 21.9% and saturation intensity of 21.6 MW cm^{-2}. The repetition rate value was 2.833 MHz and the pulse width obtained was 34.3 ns. The value of pulse energy and peak power are obtained about 0.399 J and -39.07 dBm, respectively. These results may contribute to continuous research work on generation of pulse fiber laser and its application.

Acknowledgements

This paper was partly sponsored by the Centre for Graduate Studies UTHM.

References

[1] J. Mohanraj, V. Velmurugan, and S. Sivabalan (2016). "Transition metal dichalcogenides based saturable absorbers for pulsed laser technology" in Optical Materials, Vol. 60 pp. 601-617

[2] W. Q. Yang, B. Zhang, J. Hou, R. Xiao, R. Song, and Z. J. Liu (2013). "Gain-switched and mode-locked Tm/Ho-codoped 2 µm fiber laser for mid-IR supercontinuum generation in a Tm-doped fiber amplifier" in Laser Physics Letters, Vol. 10. No. 4

[3] E. I. Ismail, N. A. Kadir, A. A. Latif, H. Ahmad, S.W Harun (2016). "Black phosphorus crystal as a saturable absorber for both Q-switched and mode locked erbium-doped fiber laser" in RSC Advances, Vol. 76 pp. 72692-72697

[4] M. H. M. Ahmed, A. H. H. Al-Masoodi, A. A. Latiff, H. Arof and S. W. Harun (2017). "Mechanically exfoliated 2D nanomaterials as saturable absorber for Q-switched erbium doped fiber laser" in Indian J Physics

[5] Shuxian Wang, Haohai Yu, Huaijin Zhang, Aizhu Wang, Mingwen Zhao, Yanxue Chen, Liangmo Mei and Jiyang Wang (2014). "Broadband Few-Layer MoS_2 Saturable Absorbers" in Advance Master

[6] H. Ahmad, M.A Ismail, S.Sathiyan, S.A. Reduan, N.E. Ruslan, C.S.J. Lee, M.Z. Zulkifli, K. Thambiratnam, M.F Ismail, S.W Harun (2017). "S-band Q-switched fiber laser using $MoSe_2$ saturable absorber" in Optics Communications, Vol. 382 pp 93-98

[7] H. Ahmad, M. R. K. Soltanian, Leila Narimani, I. S. Amiri, A. Khodaei, and S. W. Harun (2015). "Tunable S-Band Q-Switched Fiber Laser Using Bi_2Se_3 as the Saturable Absorber" in IEEE Photonics Journal, Vol. 7 No. 3

[8] R. A Shahruddin, S.A. Azzuhri, M.A. Ismail, F.A.A Rashid, M.Z. Samion, M.Z.A Razak, H.Ahmad (2017) "Tunable Q-switched ytterbium-doped fiber laser by using zinc oxide as saturable absorber" in Opto-Electronics Review, Vol. 23. pp 10-14

[9] N. A. Aziz, A. A. Latiff, M. Q. Lokman, E. Hanafi, S. W. Harun. "Zinc Oxide-Based Q-Switched Erbium-Doped Fiber Laser" in China Physics. Letters, Vol. 34. No 4.

[10] J. Du, M. Zhang, Z. Guo, J. Chen, X. Zhu, G. Hu1, P. Peng, Z. Zheng, and H. Zhang (2017) "Phosphorene quantum dot

saturable absorbers for ultrafast fiber lasers" in Scientific Reports. Vol. 7

[11] H. Ahmad1, N. E. Ruslan, M. A. Ismail, Z. A. Ali, S. A. Reduan, C. S. J. Lee and S. W. Harun (2016). "Silver nanoparticle-film based saturable absorber for passively Q-switched erbium-doped fiber laser (EDFL) in ring cavity configuration" in Laser Physics Letters, Vol. 26 pp 095103

[12] Huanian Zhang, Bowen Li and Jie Liu (2017). "Gold nanobipyramids as a saturable absorber for passively Q-switched Yb-doped fiber laser operation at 1.06 μ m" in Laser Phyics Letter, Vol. 14. pp 025104

[13] Chao Feng, Mingyi Liu, Yanbin Li, Xuejian Gao, Zhe Kang, Guanshi Qin, Zhitai Jia, Xutang Tao, Teng Song, Yangyang Dun, Fen Bai, Ping Li, Qingpu Wang and Jiaxiong Fang (2017). "Gold nanorods saturable absorber for Q-switched Nd:GAGG lasers at 1 μm" in Appied Physics B. Vol. 123. No. 81

[14] Songang Bai, Qiang Li, Han Zhang, Xingxing Chen, Si Luo, Hanmo Gong, Yuanqing Yang, Ding Zhao, and Min Qiu (2015). "Large third-order nonlinear refractive index coefficient based on gold nanoparticle aggregate films" in Applied Physics Letters, Vol. 107. pp 141111

[15] Feng Zhang, Hua-Nian Zhang, Dan-Hua Liu,Jie Liu, Feng-Kai Ma, Da-Peng Jiang,Si-Yuan Pang, Liang-Bi Su, Jun Xu (2017). "Tunable Nd,La:SrF2 laser and passively Q-switched operation based on gold nanobipyramids saturable absorber" in China Physics B, Vol. 26, No. 2 pp. 024205