Study of TMDs nanosheets based saturable absorber used for Q-switching and mode lock laser system

Chun Yin Tang[1], Long-Hui Zeng[1], Hui Long[1], Li-Li Tao[1] , Chung-Che Huang[2], Daniel W. Hewak[2], Yuen Hong Tsang[1*]
[1]*Department of Applied Physics and Materials Research Center, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong, China*
**Email: Yuen.Tsang@polyu.edu.hk*
[2]*Optoelectronics Research Centre, University of Southampton, Highfield, Southampton SO17 1BJ, UK*

Pulse width of pulsed laser determinates their applications. For the long pulse laser with μs or ns pulse width, it can be used for telecommunication, remote sensing and medical surgery. For the ultrashort pulse laser with ps or fs pulse width, it can be used for eye-surgery, precise micro- or even nano-machining on transparent material [1] and novel 3D hologram formation [2]. The saturable absorber (SA) is the crucial optical component that switch the laser operation from CW mode to pulse mode passively. Therefore it attracts great research interests from the laser photonic community.

Compared with zero bandgap graphene, 2D layered transition metal dichalcogenides, TMDs, e.g. MoS_2 and WS_2 offers a wide range of intrinsic open band gap structure and favourable electrical and providing strong interaction with light at specific wavelength range. Its bandgap changes from indirect to direct bandgap semiconductor as it is getting thinner. It has tuneable optical properties [3] and offering great potential for electronic and optical devices e.g. transistors [5], optical limiter [3-4], solar cells [6] etc.

Recently the mode locking operation has been demonstrated by using MoS_2 based saturable absorber in Yb and Er fibre laser systems to generate ultrafast pulses operating at ~1μm [7] and ~1.5μm [8-10]. However, due to the limitation of fibre structure, the laser output power is limited to several mW . In crystal based laser system, only Q-switching operation was demonstrated by using MoS_2, but without mode locking performance. The WS_2 have also been used to generate mode locking and Q-switching pulses in fibre laser system [11-13].

In this study, we used the MoS_2-SA sample fabricated by Atmospheric Pressure Chemical Vapor Deposition (APCVD) and WS_2-SA sample fabricated by Radio frequency Magnetron Sputtering deposition to generate laser pulses in the diode pumped Nd:YVO_4 crystal laser system. The Raman measurement of the MoS_2-SA and WS_2-SA sample is shown in Fig 1(a) and (b), respectively, which proved the successful control of the crystallization state of the SAs by two different deposition methods. By using the WS_2-SA, we had first demonstrated the Q-switched Nd:YVO_4 laser operation with few micro-seconds pulse width with higher output single pulse energy compared to the Q-switching pulses generated from the other fibre laser systems [12-13]. For the MoS_2-SA, we also observed the modulation phenomenon when installing the MoS_2-SA in the specially designed mode lock cavity as shown in Fig. 2.

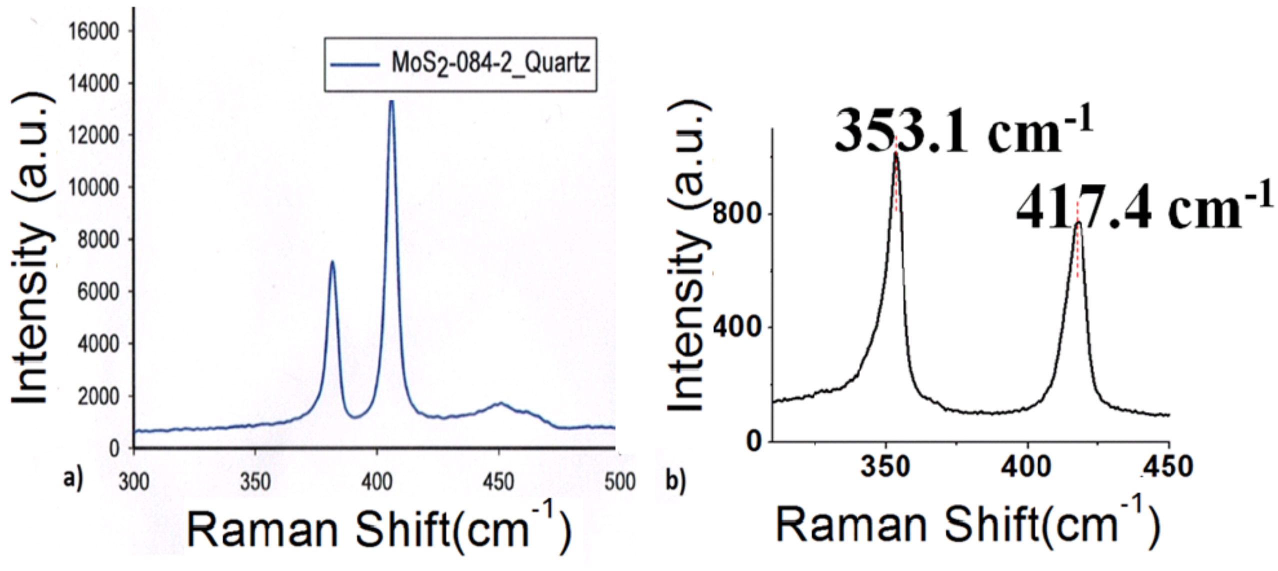

Fig. 1 Raman spectrum of (a) MoS_2-SA (b) WS_2-SA sample.

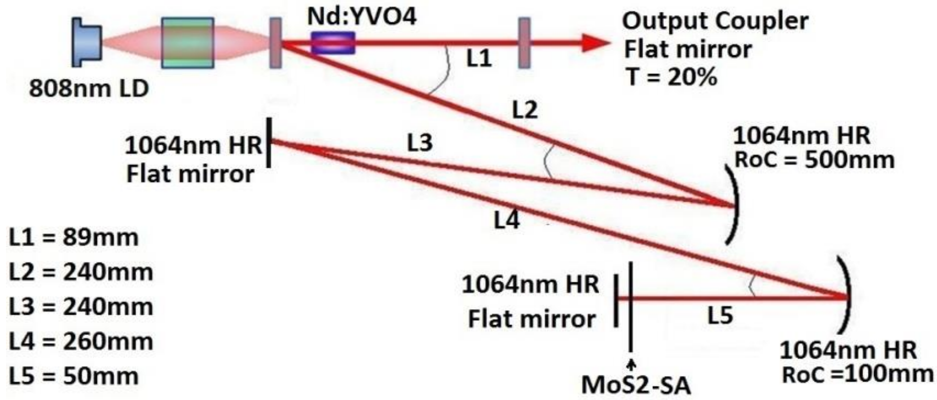

Fig 2. The schematic diagram of laser, HR-High reflection, T-Transmission ratio, RoC – Radius of Curvature of the mirror.

Acknowledgments:

This work is financially supported by the Innovation and Technology Fund: teaching company scheme UIT-120, the Research Grants Council (RGC) of Hong Kong (GRF 526511/PolyU B-Q26E).

References

1. K. Kawamura, T. Ogawa, N. Sarukura, M. Hirano, H. Hosono, " Fabrication of surface relief gratings on transparent dielectric materials by two-beam holographic method using infrared femtosecond laser pulses," Appl. Phy. B, **71**(1), 119-121(2000).
2. Y. Ochiai1, K. Kumagai, T.i Hoshi, J. Rekimoto, S. Hasegawa, Y. Hayasaki," Fairy Lights in Femtoseconds: Aerial and Volumetric Graphics Rendered by Focused Femtosecond Laser Combined with Computational Holographic Fields" Proceeding SIGGRAPH 15 ACM SIGGRAPH (2015).
3. H. Long, L. Tao, C. Y. Tang, B. Zhou, Y. D. Zhao, L. H. Zeng, S. F. Yu , S. P. Lau, Y. Chai, and Y. H. Tsang, “ Tuning nonlinear optical absorption properties of WS2 nanosheets, ” Nanoscale, (2015), In press.
4. L.L. Tao, H. Long et al., “ Preparation and characterization of few-layer MoS2 nanosheets and their good nonlinear optical responses in the PMMA matrix, ” Nanoscale 6, 9713-9719(2014).
5. B. Radisavljevic, J. Brivio et al., “Single-layer MoS2 transistors, ” Nature Nanotechnology 6, 147–150(2011).
6. M. L. Tsai, S. H. Su et al., “ Monolayer MoS2 Hetero-junction Solar Cells, ” ACS Nano, 8 (8), 8317–8322 (2014).
7. J. Du, Q. Wang et al., “Ytterbium-doped fiber laser passively mode locked by few-layer Molybdenum Disulfide (MoS2) saturable absorber functioned with evanescent field interaction, ” Scientific reports 4 (6346), 1-7(2014)
8. H. Xia, H. Li et. al., “Ultrafast erbium-doped fiber laser mode-locked by a CVD-grown molybdenum disulfide (MoS2) saturable absorber” Opt. Exp., 22(14), 17341-17348 (2014).
9. R. Khazaeizhad, S. H. Kassani et. al., “ Mode-locking of Er-doped fiber laser using a multilayer MoS2 thin film as a saturable absorber in both anomalous and normal dispersion regimes, ” Opt. Exp.22(19), 23732-23742(2014).
10. Y. Wang, D. Mao et. al. “Harmonic mode locking of bound-state solitons fiber laser based on MoS2 saturable absorber, ” Opt. Exp., 23(1), 205-10(2015).
11. K. Wu, X. Zhang, J. Wang, X. Li, and J. Chen, “WS2 as a saturable absorber for ultrafast photonic applications of mode-locked and Q-switched lasers ,” Opt. Exp. 23(9), 11453-11461 (2015).
12. S. H. Kassani, R. Khazaeinezhad, H. Jeong, T. Nazari, D.I. Yeom, and K. Oh, “All-fiber Er-doped Q-Switched laser based on Tungsten Disulfide saturable absorber, ” Op. Mat. Exp. 5(2), 373-379 (2015).
13. D. Mao, Y. Wang, C. Ma, L. Han, B. Jiang, X. Gan, S. Hua, W. Z. T. Mei ,and J.l. Zhao, “WS_2 mode-locked ultrafast fiber laser, ” Scientific Reports 5(7965), 1-7 (2015).

Presentation Method :Invited