Siti Nur Fatin Zuikafly[1]
Fauzan Ahmad[1*], Mohd Haniff Ibrahim[2], Sulaiman Wadi Harun[3]
[1]Malaysia-Japan International Institute of Technology, Universiti Teknologi Malaysia, 54100 Kuala Lumpur, Malaysia
[2]Faculty of Electrical Engineering, Universiti Teknologi Malaysia, 81310 Skudai, Johor, Malaysia
[3]Photonic Research Centre, University of Malaya, 50603 Kuala Lumpur, Malaysia

fauzan.kl@utm.my)

Graphene PLA/THF Slurry based Passive Saturable Absorber in Erbium Doped Fiber Laser

Abstract
Immanent technological advantages offered by ultrafast fiber lasers are making them the go-to alternatives for comprehensive industrial and scientific applications. Graphene has been extensively utilized as passive saturable absorber (SA) in generating ultrafast laser either in Q-switched or mode-locked regime [1-4] since its first reported work by Zhang et al in 2009 [5]. Intrinsic properties of which graphene possesses such as ultrafast carrier relaxation and ultra-broadband resonate nonlinear optical response has made it to be favoured to a greater extent and prevalent in generating pulse in fiber lasers [6]. Some of the many synthesis processes of graphene such as liquid phase exfoliation (LPE), chemical vapour deposition (CVD), reduced graphene oxide (rGO), micro-mechanical cleavage [7] and electrochemical exfoliation technique [8] requires rather complicated and expensive implementation and some causes uncontrollable physical morphology that is important in the generation of pulsed laser. The recently introduced three-dimensional (3D) printer filament based on conductive Graphene-Polylactic acid (PLA) has open up a possible new approach in fabricating graphene based passive saturable absorber. The filament with a diameter of 1.75 mm is extruded through a 3D printer nozzle at 210 ˚C to reduce the diameter to 200 µm. Next, the extruded Graphene-PLA with the weight of 25 mg was mixed with 1 ml of Tetrahydrofuran (THF), then sonicated for 10 minutes in order to dissolve the PLA and produce a graphene-PLA/THF suspension. To integrate the graphene-PLA/THF slurry based saturable absorber, the suspension was placed by drop-casting method at the end of a fiber ferrule and finally graphene slurry was left behind after the THF evaporated. The characterization of the fabricated saturable absorber is investigated by using Field Emission Scanning Electron Microscope (FESEM) for its' morphology, and Raman spectroscopy for its' peak shifts. The FESEM image of the graphene-PLA/THF slurry is shown in Figure 1 where the structure of the graphene can be clearly seen. The distinct peak shift of the saturable absorber for D band, G band and 2D band are observed at 1348 cm^{-1}, 1582 cm^{-1} and 2699 cm^{-1}, respectively as shown in Figure 2. From Raman spectroscopy, the Intensity of G peak is at 389 and intensity of 2D peak is at 287, and the ratio of I(G)/I(2D) is about 1.35 which shows that it is a multi-layer graphene with the number of graphene layer (nGL) of around 25 layer [9]. The fiber ferrule with the graphene-PLA/THF slurry attached is mated with another clean ferrule connector and integrated in the fiber laser cavity. A stable passively Q-switched erbium-doped fiber laser (EDFL) operating at 1531.01 nm was observed with the threshold input pump power of 30.45 mW and the maximum input pump power of 179.5 mW. By increasing the input pump power from 30.45 to 179.5 mW, the pulse train of repetition rate increases from 42 kHz to 125 kHz, while the pulse width reduces from 6.74 μs to 2.58 µs. The generated pulsed produced maximum pulse energy and maximum peak power of 11.68 nJ and 4.16 mW, respectively at maximum input pump power. The recorded signal to noise ratio is about 44 dB shows that the proposed graphene slurry based saturable absorber able to produced pulse with good stability and low fluctuation.

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Figures

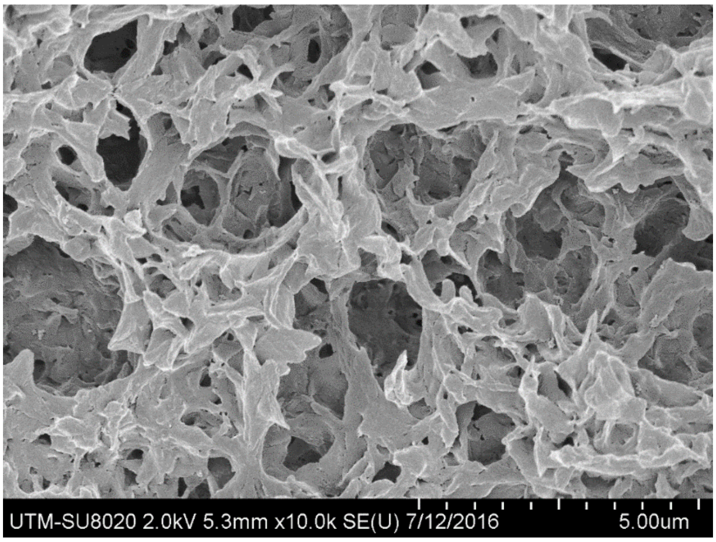

Figure 1: FESEM image of graphene-PLA/THF slurry

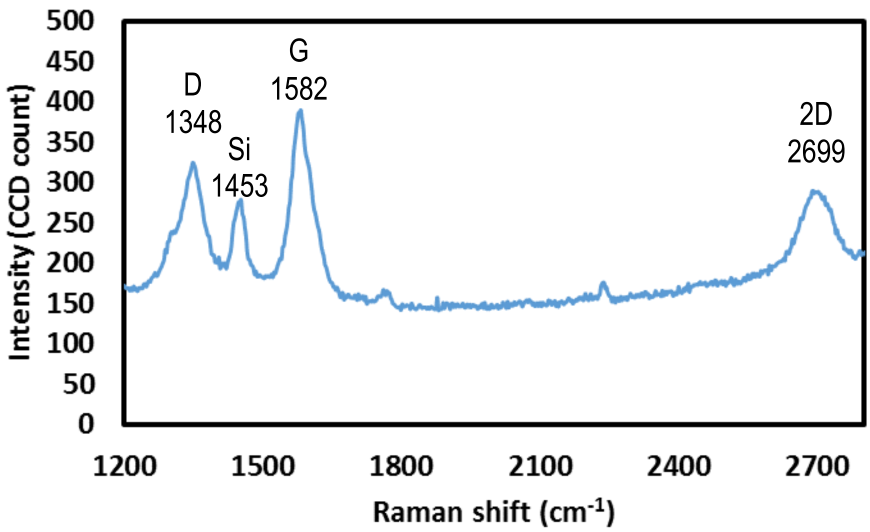

Figure 2: Raman spectroscopy of the graphene-PLA/THF slurry