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Research paper

A Simple and Efficient Method to Fabricate Graphene 2D Nanomaterial into a thin Film to Serve as a Saturable a bsorber for Fiber Laser Application

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Abstract

A passively pulsed fiber laser using saturable absorbers such as graphene has been increased dramatically in recent years. Up to now, researchers have been proposed many methods to fabricate graphene saturable absorber such as (evanescent coupling structure, electrochemical exfoliation, and mechanical exfoliation) for light pulse generation in a fiber laser. However, each of these methods has got some limitations which reduce the saturable absorber performance and restrict its range of applications. In this paper, we pr opose a simple but very efficient fabrication way of graphene saturable absorber by converting graphene Nano powder into a thin film using polyvinyl alcohol (PVA) as a host material. The fabricated film can then be easily sandwiched between two fiber pigtails and inserted inside the laser cavity to form the saturable absorber. when compared with other methods, this method is much preferable because it provides saturable absorber with combat structure, maximum interaction area, reasonable insertion loss, polarization insensitive, controllable concentration, and safe to handle. The fabricated graphene saturable absorber in this paper was characterized and found to have a uniform distribution of the graphene nanomaterial in the PVA and have a modulation depth of 6.1% which make it a very promising saturable absorber for ultra-fast fiber laser demonstration.

Keywords: *Graphene, Saturable Absorber, Thin Film*

1. Introduction

Last two decades, the interest on demonstration of a passively pulsed fiber laser is increasing dramatically due to its highly favorable advantages over the active techniques [1-5]. The key element to generate passively light pulses is saturable absorber (SA) [6, 7]. Therefore, this research increment on passively pulsed fiber laser has consequently raised the attention of the researcher on proposing simple and elective methods to fabricate the saturable absorbers. Graphene two-dimensional (2D) nanomaterial is one of the most efficient wide band SA for fiber laser application owing to its very desirable optical properties [8, 9]. Since last decade, many methods were proposed for graphene saturable absorber fabrication. One way of fabricating the graphene saturable absorber is based on evanescent coupling structure where the graphene interacts with the evanescent light field of guided modes in side-polished (or D-shaped) fiber [10], tapered fiber [11], or photonic crystal fiber (PCF) [12]. By using D-shaped fiber the graphene is coated on the polished side of the fiber, in tapered fiber the graphene is deposited around the tapered wrist, while in PCF graphene nanoparticles uniformly dispersed in the hole cladding. Using those structures, researchers are trying to transfer the graphene close to the core of the fiber along the propagation direction of the laser cavity. However, these structures have some of the inherent limitations such as high insertion loss, small interaction area, difficult to obtain finely tapered or polished fiber, and high unavoidable polarization sensitivity because of the used asymmetric structure [13-15]. Another method to fabricate the graphene saturable absorber is though electrochemical exfoliation [16, 17]. In this technique, a few-layer graphene nano-particles can be obtained using graphite foil, where the latest was set as an electrode under a suitable bias voltage. However, the graphene sheets produced using this method are usually nonuniform and got numerous structural defects which consequently reduce the performance of the graphene saturable absorber [15]. Recently, a mechanical exfoliation also proposed as a simple fabrication method of graphene saturable absorber [18]. In this method, you only need for a scotch-tape to separate the high purity graphite into few-layer graphene. Then this few-layer graphene transferred between two fiber pigtails. Even though this method is simple and cost effective, yet it is very difficult to get uniform graphene distribution, lacked real-time control over the deposition process, and graphene layer can be easily removed from the scotch- tape [19]. Here, we propose a very simple, cost effect, and an efficient method to fabricate graphene saturable absorber where graphene nanopowder is converted into a thin film. This method provides combat structure, maximum interaction area, reasonable insertion loss, polarization insensitive, and safe to handle saturable absorber [19, 20]. Furthermore, the concentration of the graphene material can be easily controlled. The saturable absorber can be fabricated with different concentration and test for pulse generation one by one to find the optimum concentration value. In this paper, we fabricated graphene thin film saturable absorber using polyvinyl alcohol (PVA) as a host material. The fabricated saturable was characterized using Field Emission Scanning Electron Microscopy (FESEM), Raman spectroscopy and twin balance technique. It found that the graphene is uniformly distributed in the PVA and have a modulation depth of 6.1% which make it a very promising saturable ab-

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sorber ultra-fast fiber laser construction. The non-saturable intensity and saturation intensity of the graphene saturable absorber were 47%, and 21 MW/cm2, respectively.

2. The fabrication process of the graphene into thin film

The fabrication method of the graphene saturable absorber is illustrated in Fig.1. Graphene nanopowder with a specific area of 100 m2/g, average flake, Purity of 99.9%, thickness of 8 nm (20-30 monolayers) and average Particle (lateral) size of ~ 550 nm (150-3000) nm was purchased from graphene supermarket and used without any change to its characteristic. To fabricate the graphene thin film, first, 25 mg of graphene nanopowder and 1% Sodium dodecyl sulfate (SDS) was dispersed in 40 ml deionized (DI) water and the resultant solution experienced bath sonification for 60 minutes. Next, in order to segregate the large graphene particles, the dispersed graphene centrifuged at 1000 rpm. Then, to prepare the host polymer, 1 g of polyvinyl alcohol (PVA) (Mw=89x103 g/mol, Sigma Aldrich) was dissolved in 120 ml of DI water. After that, 3 ml of the host polymer were mixed with a 2 ml of graphene suspension after the centrifuge process and the resultant mixture was poured onto a petri dishes and left for three days at room temperature till it totally dried. The thickness of the thin film was measured to be around 50 µm.

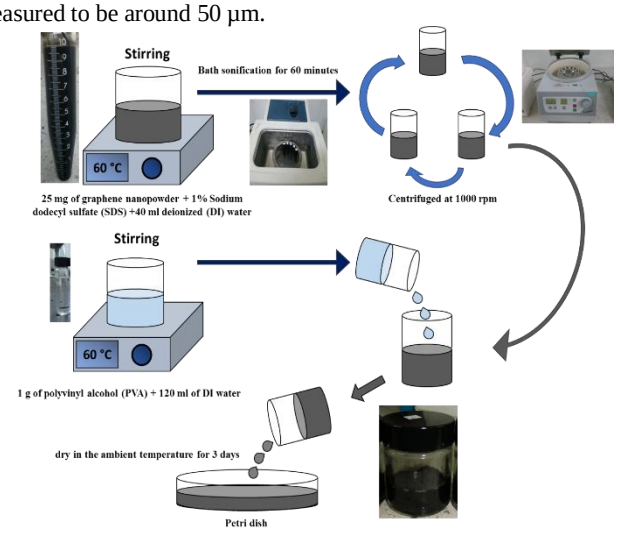


Fig.1: The fabrication process of graphene saturable absorber

3. The characterization of graphene thin film

The fabricated graphene thin film was characterized using Field Emission Scanning Electron Microscopy (FESEM), Raman spectroscopy and twin balance technique. The FESEM image in Fig.2 clearly shows that the graphene flakes are well dispersed in the PVA matrix. While Fig.3 shows the Raman spectrum of the graphene-SA when it was illuminated by 514 nm beam of an Argon-ion laser. The sample exhibits signature peaks at around D (1353 cm-1), G (1585 cm-1) and 2D (2724 cm-1) bands as indicated in the figure. D band is associated with the vibrations of carbon atoms with sp3 electronic configuration of disordered graphite, while G band contributes to an E2g mode of graphite and is related to the in-plane vibration of sp2-bonded carbon atoms. However, a negligible defect existing in the graphene film was detected by the small D peak. The number of graphene layer can be estimated by the distance between G and 2D peaks or the shape of the 2D peak [21, 22]. Therefore, the obtained G/2D peak ratio of 0.6 indicates that the graphene has a multi-layer structure. Then after, the twin balance technique was used to investigate the nonlinear absorption of the graphene-SA, where the setup of this technique is shown in Fig.4. First, a homemade mode locked fiber laser was used as a seeding source with a central wavelength, repetition rate and pulse width of 1550 nm, 1 MHz and 1.7 ps, respectively. Then, the output of the mode locked laser was amplified using Erbium doped fiber amplifier (EDFA) in order to fully saturate the graphene-SA. For the purpose of controlling the output power of the EDFA and changing it with a desirable range, a variable optical attenuator (VOA) was also used. Lastly, the output of the VOA was connected to a 3dB coupler to measure the output power with and without the graphene-SA simultaneously. Using the readings obtained from the two power meters the nonlinear absorption of the graphene-SA was plotted as shown in Fig.5. From the figure, we can see that the modulation depth, non-saturable intensity and saturation intensity of the graphene-SA are 6.1 %, 47%, and 21 MW/cm2, respectively. finally, to measure the insertion loss of the fabricated graphene saturable absorber, we have used a tunable laser source (TLS) and power meter as drawn in Fig.6. At a specific output power, the operation wavelength of the TLS was set at 1555nm and the repetition rate at 50 kHz. We have measured the output power with and without the graphene saturable absorber, and from the reading, we have estimated the insertion loss around 1 dB.

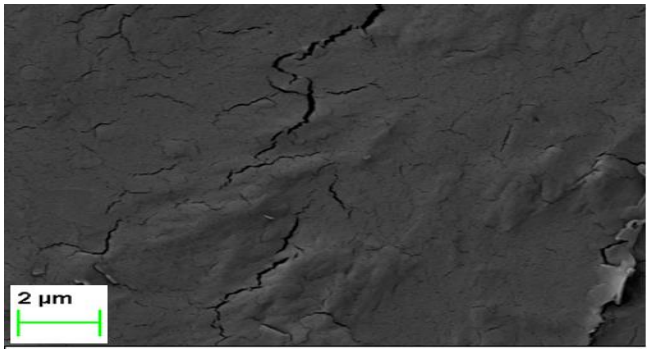


Fig.2: FESM image of the fabricated graphene-SA

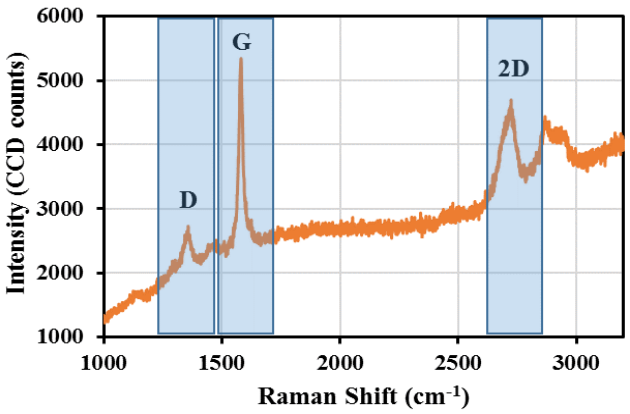


Fig.3: Raman shift of the graphene-SA

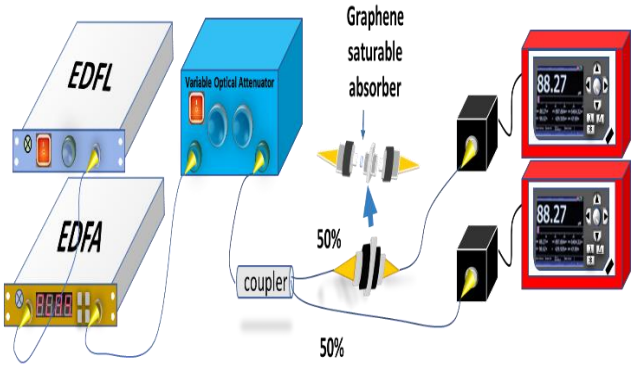


Fig.4: The setup of the dual-detector technique

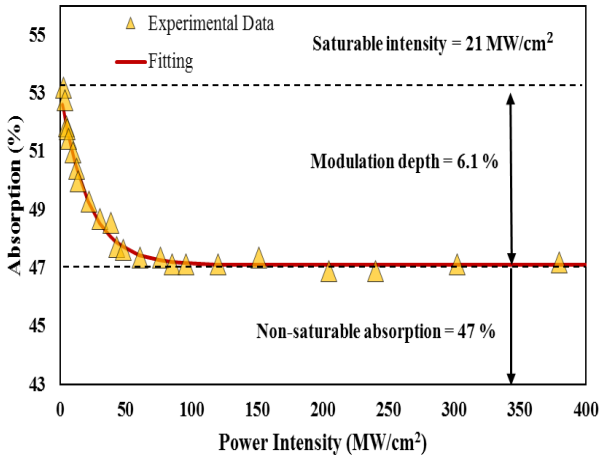


Fig.5: Nonlinear absorption of the graphene-SA

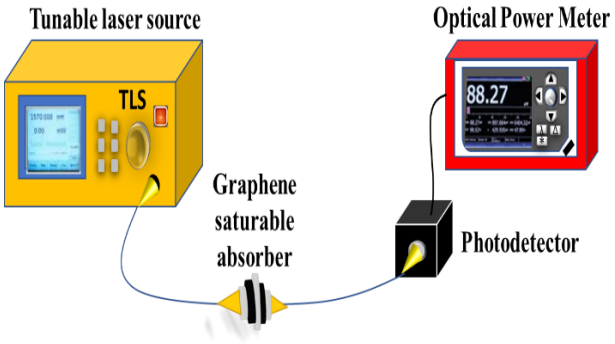


Fig.6: Setup of insertion loss measurement

4. Conclusion

In this report, we have fabricated a thin film graphene saturable absorber for pulsed fiber laser applications. Compared with other methods, the proposed fabrication method has the advantages of more combat, reasonable insertion loss, wider interaction area, polarization insensitive, controllable concentration, and safe to handle. When the fabricated graphene saturable absorber was characterized, it found that the graphene nanomaterial is uniformly distributed in the PVA and have a modulation depth, non-saturable intensity and saturation intensity of the graphene-SA are 6.1 %, 47%, and 21 MW/cm2, respectively. We believe that the proposed method can be used to fabricate an efficient graphene saturable absorber that can have a very promising application for ultra-fast light pulses generation.

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