International Journal of
Science and Engineering Investigations
vol. 2, issue 14, March 2013
ISSN: 2251-8843

Using of Graphane in the Optical Fiber Amplifier

Mahmoud Peiravi[1], Mohammad Peiravi[2], Majid Heidari[3]
[1] Payam Nour Univ., Parand Branch, Tehran, Iran
[2,3] Islamic Azad Univ., Fars Science and Research Branch, Shiraz, Iran
([1]mahmoud_peiravy@yahoo.com, [2]eng.mohammad.peiravi@gmail.com, [3]majidak_ak@yahoo.com)

Abstract- In this paper deal to investigation the semi-conductor effect of graphane in Optical Fiber Amplifier. This semi-conductor that focused in the last years, because of having the ability of electron mobility more than another semi-conductor, can be more effective in the structure of Optical Fiber Amplifier. In this paper investigated the index of amplifier graphane in optical fiber amplifier.

Keywords- *Optical Fiber Amplifier; Graphane; Index of Amplifier.*

I. INTRODUCTION

Optical Fiber Amplifier, have high application in Optical communication. Amplify the considered phase (wavelength), Attenuation or deleting unsuitable phases, amplify send signal and prevention of decay of signal considered such as application and advantages of these amplifiers, which any of them investigated in different papers [1].

What is important is that designing the Amplifier that can have amplifies efficiency from the view of Attenuation and amplifies. On the base of made investigations, optical Fiber Amplifiers divided to five main groups: 1- Amplifiers on the base of Pomp [2], 2- Amplifiers on the base of modulator Mach-Zehnder [3], 3- Amplifiers on the base of Optical Switch [4], 4- Amplifiers on the base of Quantum Dots [5], and 5- Amplifiers on the base of Semi-Conductor that used of some of them for Amplify light [6]. In this method, the used semi-Conductor in fiber, help to amplify the light of signal in fiber, by releasing energy during a clear process.

The process that investigated in this paper is application of Graphane in optical communication industry. Such that focused very much in the recent years. The role and effect of Graphane investigated in light fiber lasers. Wang and his cooperators investigated the Thulium laser passive Q-switches by using of Graphane on the base of attractor [7]. Ahmed and et. Al. study passive Q-switch in Erbium laser that used Garphene in it[8]. Ahmed and his cooperators investigated passive Q-switch in Zirconia-Erbium co-Doped and its application in pulse laser of light fibers [9]. In the structure of Zirconia they used of Graphane. Zhang and his cooperators showed that by using of Graphane on the base of saturation absorber, the laser factor in lock state of fibers thulium-doped is in 1.94 micro meters [10]. Yang and et. Al. Both experimental and numerical studies have graphene-based transistor amplifiers. They show that strengthening the capabilities of amplifiers made with unipolar semiconductors has increased. They have stated that unlike other semiconductors, transistors made of graphene can be configured and types are n-type, p-type and hybrid-type [11]. Oya and his cooperators Also have to consider the use of graphene in optical switches. In the next generation Photonics networks, are used of Pico-Second switches in the routers nodes. So they have to replace all the light switches can be two interacting Mach - Zehnder by adsorbing graphene film has been created, it can be used. Their numerical analysis show that the switching characteristics of the switching speed is increased due to the graphene [12]. Sun and colleagues noted that ultrafast lasers are increasingly being used in industrial applications. For this reason, the use of graphene and carbon nanotubes in these lasers is highly regarded [13]. In the Most of Article study and are discussed the effect of graphene in optical fiber amplifiers and lasers. The lasers are also used to enhance the optical fiber amplifier.

The investigated issues in this paper is using of Graphane as a semi-conductor by mobile ability in the structure of amplifier of optical communication. These amplifiers are used along the way and for amplify the light carrier.So Graphane considered in the form of Nano-ribbon in the optical fiber. In this paper, at the first, introduced Graphane, and then by introducing amplifiers on the base of semi-conductors and receiving its relations, received the effect of Graphane in this class.

II. GRAPHANE

Graphane discovered in 2004, that focused by many theory and experiment researchers [14]. In graphane, atoms are look like a strap, and Hydrogen’s atoms placed regularly and Decussate in two sides of them. In reality, Graphene and Graphane are two isotopes of carbon, that in Graphene the atoms of carbon placed in each other in sextuplet form, but in Graphane to any atom of carbon, attached a Hydrogen’s atom in Zig-zag form.

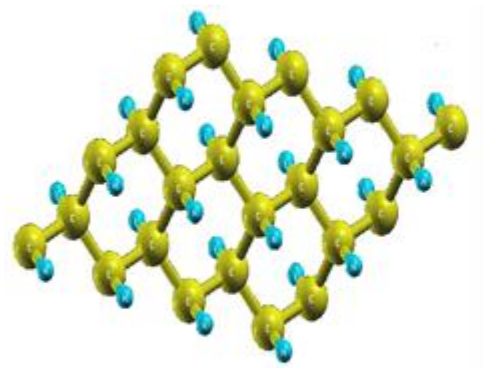

Figure 1: Designed Graphane Structure by Software Wien2K.

The main feature of this material is its high speed of loads to another semi-conductor. Making transistors of this material changed the speed of processors significantly. The solid Garphane is a Un-magnetic semi-conductor, that its gap energy is zero [15]. For this reason, for having semi-conductor features considered in the form of Nano-Ribbon.

III. USING OF GRAPHANE IN OPTICAL FIBER AMPLIFIERS

As mentioned before, one of methods of amplify in optical communication, is using of semi-conductors. In this amplifiers, the light promoted by passing of active area. What happen in this amplifier (Active area efficiency) is investigated in two views: 1- using of semi-conductors as a bristling surface (Mirror-like) for reflection of light and also amplify the light (Similar to what is done in laser produced). 2- using of semi-conductor as a releasing source and using of it for amplify light, that the second kind used in this paper. The kind of amplify light in light amplifier by using of semi-conductor(SOA) is that, in semi-conductor electron active by receiving energy from light's photon of signal, and transformed from valance band to conductivity band. Then this electron by losing energy, back to valance band repeatedly, that this released energy result in amplify light carrier of signal. In this kind of amplifiers of electrons, replaced to each other. In some semiconductors, the conduction-band capacity and bandwidth, middle band is also the name of another band, because this band came to the integration of several different materials with different band gap semiconductor for. In this electronic amplifier that receives the least provocation, the bandwidth capacity of the conduction band is transmitted. Some of these electrons to the conduction band rather than pass to the middle band. However, the amount of energy released from the normal mode (when there is no intermediate band) is higher.

Now, it is important that used from which kind of semi-conductor in optical fiber, that transformed highest electron from valance layer to transforming level with lowest mobility that made by light carrier of signal, and in return releases the highest energy?

Semi-conductor with the ability of high electron mobility can replaced high electrons between two bands of valance and conductivity, that graphane considered and of them because of its high speed of carrier of load. In optic amplifiers by using of semi-conductor, the gain of amplifier received from the following equation [16]:

$$g_m(\nu,n)=\beta\times\left(\frac{2m_e m_{hh}}{\hbar(m_e+m_{hh})}\right)^{\frac{3}{2}}\times I \qquad (1)$$

That [16]:

$$\beta=\frac{C^2}{4\sqrt{2}\pi^{3/2}n_1^2\tau\nu^2} \qquad (2)$$

$$I=\int_0^{\infty}\left[\begin{array}{l}\sqrt{\nu'-\frac{E_g(n)}{h}}\,(f_c(\nu')-f_v(\nu'))\\ \times\left(\frac{2T_0}{1+(2\pi T_0)^2(\nu'-\nu)^2}\right)\end{array}\right]d\nu' \qquad (3)$$

In the above equation, C is the speed of light in fiber, ν is light frequency, n_1 is the index of fracture of active area, τ is life length of carrier radiation, $\hbar$ is Plank state ($\hbar=\frac{h}{2\pi}$), m_e is effective mass of electron, m_{hh} is effective mass of hole, n is electron density and f_c and f_v are distribution of Fermi-Dirac Level. The amount of integral of equation (3) received from the following equation [16]:

$$I=\left(\nu-\frac{E_g}{h}\right)^{\frac{1}{2}}\times\left(f_c(\nu)-f_v(\nu)\right) \qquad (4)$$

And also we can received the amount $E_g(n)$ from the following equation:

$$E_g(n)=E_{g0}-qk_g n^{1/3} \qquad (5)$$

That in which k_g is index of gap band and E_{g0} is the energy of the first gap band [16]. In another way, for distribution of Fermi-Dirac Level there are following equation [16]:

$$f_c(\nu)=\left\{\exp\left(\frac{E_a-E_{fc}}{KT}\right)+1\right\}^{-1} \qquad (6)$$

$$f_v(\nu)=\left\{\exp\left(\frac{E_b-E_{fv}}{KT}\right)+1\right\}^{-1} \qquad (7)$$

That [16]:

$$E_a=\left(h\nu-E_g(n)\right)\frac{m_{hh}}{m_e+m_{hh}} \qquad (8)$$

$$E_b=-\left(h\nu-E_g(n)\right)\frac{m_e}{m_e+m_{hh}} \qquad (9)$$

Graphane in usual state considered as a conductor, that for this reason $E_g(n)=0$. That concluded from the (1-2 , 4) the following equations:

$$g_m(\nu,n)=\frac{C^2}{4\sqrt{2}\pi^{3/2} n_1^2 \tau\nu^2}\times\left(\frac{2m_e m_{hh}}{\hbar(m_e+m_{hh})}\right)^{\frac{3}{2}}\times\sqrt{\nu}\times\left(f_c(\nu)-f_v(\nu)\right) \qquad (10)$$

That from Ref. [17], received the following equation for effective electron mass and hole:

$$m_{hh}=1.25\times m_e \quad for \quad 0.7\times10^{12}<n<4.1\times10^{12} \qquad (11)$$

That by using of the amount in table (1), and also considering $0.7\times10^{12}<n<4.1\times10^{12}$, the amplify index for sate graphane that performed in conductor form is such as the following:

Table 1. Used amount for Graphane

m_e	9/11×10^{-31} Kg
$\hbar$	1/05×10^{-34} J.s
h	6/62×10^{-34} J.s
ν	10^{14} Hz
τ	100×10^{-12} s
K	1/38×10^{-23} J/K
T	300 K

$$g_m(n)=0 \qquad (12)$$

That the reason of it is lack of Fermi-Dirac Level in Graphane with metal features. Consider the graphane in the form of nano-Ribbon, so has semi-conductor features. In this state $E_g=3.4\,eV$ [18]. from the relation between Fermi-Dirac Level and energy of these level received:

$$E_c-E_v=E_g \qquad (13)$$

$$f(E_c)=1-f(E_v) \qquad (14)$$

According to the relation (8-9,11) received the following equation:

$$\begin{aligned}E_a&=\left(h\nu-E_g(n)\right)\frac{m_{hh}}{m_e+m_{hh}}\\&=\left(h\nu-E_g(n)\right)\frac{1.25m_e}{m_e+1.25m_e}\\&=\left(h\nu-E_g(n)\right)\frac{1.25}{2.25}\\&\approx0.6\left(h\nu-E_g(n)\right)\end{aligned} \qquad (15)$$

$$\begin{aligned}E_b&=-\left(h\nu-E_g(n)\right)\frac{m_e}{m_e+m_{hh}}\\&=-\left(h\nu-E_g(n)\right)\frac{m_e}{m_e+1.25m_e}\\&=-\left(h\nu-E_g(n)\right)\frac{1}{2.25}\\&\approx-0.45\left(h\nu-E_g(n)\right)\end{aligned} \qquad (16)$$

From dividing the equations (15-16) received the following equation:

$$\frac{E_a}{E_b}=-1.5\Rightarrow E_a=-1.5E_b \qquad (17)$$

Now, from (14) and diving (6-7) received the following equation:

$$\frac{f_c(\nu)}{f_v(\nu)}=\frac{\left\{\exp\left(\frac{-1.5E_b-E_g(n)+E_{fv}}{KT}\right)+1\right\}^{-1}}{\left\{\exp\left(\frac{E_b-E_{fv}}{KT}\right)+1\right\}^{-1}}=\frac{\exp\left(\frac{E_b-E_{fv}}{KT}\right)+1}{\exp\left(\frac{-1.5E_b-E_g(n)+E_{fv}}{KT}\right)+1} \qquad (18)$$

That in this equation T is temperature, K is the state of Boltzmann and h is Plank Stable. Now by attention to the table (1) and also amount of E_g, received the following amount:

$$E_b=-0.0000186\ eV \quad E_a=0.0000279\ eV \quad \frac{f_c(\nu)}{f_v(\nu)}=1.000009 \qquad (19)$$

And on the base of equation (7) received the following equation:

$$f_v(\nu)=0.99999 \qquad (20)$$

That in totally:

$$\frac{f_c(\nu)}{f_v(\nu)}=1.000009\ \Rightarrow f_c(\nu)=0.0000018 \qquad (21)$$

And from the equation (10), the amplify index is:

$$g_m(n)=\frac{9\times10^{18}}{n^2} \quad for\ \nu=10^{14}\ Hz\ \ \&\ 0.7<n<4.1 \qquad (22)$$

That in Figure 2, the amount of this index showed by attention to the n changes. As showed, by increasing refraction index, reduce the amount of amplify index ($1 < n < 7$). It seems that increasing the fracture index has relation to the thick of Nano-Ribbon. For this reason by increasing refraction index of Nano-Ribbon of Graphane, the thickness of Nano-Ribbon, increased and result in reduction of amplify index in amplifier.

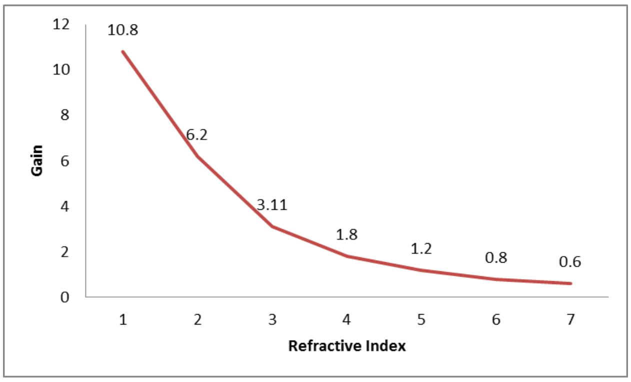

Figure 2: The relationship between index of amplify of graphane and n.

IV. Conclusion

In this paper investigated the relation between amplify index in optical fiber amplifier by using of semi-conductor of Graphane. By using of relations for semi-conductors, it is cleared that the index of amplify for amplifier of light fibers by using of Graphane, reduced by increasing the refraction index.

References

[1] M. Wasfi, "Optical Fiber Amplifiers: Review" Int. J. of Communication Network and Information Security(IJCNIS), Vol. 1, No. 1, pp. 42-47, 2009.

[2] A.W. Naji et al., "Review of Erbium-Doped Fiber Amplifier" International Journal of the Physical Sciences, Vol. 6, No. 20, pp. 4674-4689, 2011.

[3] M. Fiorentino, J. SHARPING, P. Kumar and A. Porzio, "Amplitude Squeezing in a Mach-Zehnder Fiber Interferometer: Numerical Analysis of Experiments with Microstructure Fiber" Optics Express, Vol. 10, No. 2, pp. 128-138, 2002.

[4] I. Oshima, K. Nishiyama, K. Kurotori and H. Hayakawa, "Compact Optical Fiber Amplifier" Furukawa Review, No. 23, pp. 71-75, 2003.

[5] T. Akiyama, M. Sugawara and Y. Arakawa, "Quantum-Dot Semiconductor Optical Amplifiers" Proceedings of the IEEE, Vol. 95, No. 5, pp. 1757-1766, 2007.

[6] B. Utreja, "A Review Paper on Comparsion of Optical Amplifiers in Optical Communication System" Canadian Journal on Electrical and Electronics Engineering, Vol. 2, No. 11, pp. 505-513, 2011.

[7] F. Wang, F. Torrisi, Z. Jiang, D. Popa, T. Hasan, Z. Sun, W.B. Cho, and A.C. Ferrari, "Graphene Passively Q-Switched Two-Micron Fiber Lasers" Quantum Electronics and Laser Science Conference, California, 2012.

[8] H. Ahmad, K. Thambiratnam, M.C. Paul, A.Z. Zulkifli, Z.A. Ghani, and S.W. Harun, "Fabrication and Application of Zirconia-Erbium Doped Fibers" Optical Materials Express J., Vol. 2, No. 12, pp. 1690-1701, 2012.

[9] H. Ahmad, M.Z. Zulkifli, F.D. Muhammad, M.H. Jemangin, K. Dimyati, B.P. Pal, and S.W. Harun, "Passively Q-Switched 11-channel Stable Brillouin Erbium-Doped Fiber Laser with Graphene as the Saturable Absorber" IEEE Photonics J., Vol. 4, No. 5, pp. 2050-2056, 2012.

[10] M. Zhang, E.J.R. Kelleher, F. Torrisi, Z. Sun, T. Hasan, D. Popa, F. Wang, A.C. Ferrari, S.V. Popov, and J.R. Taylor, "Tm-Doped Fiber Laser Mode-Locked by Graphene-Polymer Composite" Optical Materials Express J., Vol. 20, No. 22, pp. 25077-25084, 2012.

[11] X. Yang, G. Liu, A.A. Balandin, and K. Mohanram, "Triple-Mode single-Transistor Graphene Amplifier and Its Applications" American Chemical Society J., Vol. 4, No. 10, pp. 5532-5538, 2010.

[12] M. Oya, H. Kishikawa, N. Goto, and S.I. Yanagiya, "All-Optical Switch Consisting of Two-Stage Interferometers Controlled by Using Saturable Absorption of Monolayer Graphene" Optical Society of America J., Vol. 20, No. 24, pp. 27322-27330, 2012.

[13] Z. Sun, T. Hasan, and A.C. Ferrari, "Ultrafast Lasers Mode-Locked by NanoTubes and Graphene" Physica E: Low-dimensional Systems and Nanostructures J., Vol. 44, No. 6, pp. 1082-1091, 2012.

[14] K.S. Novoselov, A.K. Geim, S.V. Morozov, D. Jiang, Y. Zhang, S.V. Dubonos, L.V. Grigorieva and A.A. Firsov, "Electric Field Effect in Atomically Thin Carbon Films" Science Mag., Vol. 306, No. 5696, pp. 666-669, 2004.

[15] V.N. Kotov, V.M. Pereira and B. Uchoa, "Polarization charge distribution in gapped grapheme: Perturbation theory and exact diagonalization analysis" Phys. Rev.B, Vol. 87, No. 7, 2008.

[16] M.J. Connelly, "Wideband Semiconductor Optical Amplifier Steady-State Numerical Model" IEEE Journal of Quantum Electronics, Vol. 37, No. 3, pp. 439-447, 2001.

[17] K. Zou, X. Hong and J. Zhu, "Effective mass of electrons and holes in bilayer graphene: Electron-hole asymmetry and electron-electron interaction" Phys. Rev.B, Vol. 84, No. 8, 2011.

[18] Y. Wang, Y. Ding, S. Shi and W. Tang, "Electronic Structures of Graphene Sheets with Foreign Atom Substitutions" Applied Physics Letters, Vol. 98, No. 16, pp. 163104-163104-3, 2011.