Experimental study of nonlinear characterization of hybrid SWCNTs/Ag-NPs fluids, using nonlinear diffraction technique

Eman A. Aboob and Fadhil A. Umran

Institute of Laser for Postgraduate Studies, University of Baghdad, Baghdad, Iraq

E-mail: Light11_moon@yhoo.com

Abstract

Based on nonlinear self- diffraction technique, the nonlinear optical properties of thin slice of matter can be obtained. Here, nonlinear characterization of nano-fluids consist of hybrid Single Wall Carbon Nanotubes and Silver Nanoparticles (SWCNTs/Ag-NPs) dispersed in acetone at volume fraction of 6×10^{-6}, 9×10^{-6}, 18×10^{-6} have been investigated experimentally. Therefore, CW DPSS laser at 473 nm focused into a quartz cuvette contains the previous nano-fluid was utilized. The number of diffraction ring patterns (N) has been counted using Charge - Coupled- Device (CCD) camera and Pc with a certain software, in order to find the maximum change of refractive index (Δn) of fluids. Our result show that the fraction volume of 18×10^{-6} is more nonlinearity than others.

دراسة تجريبية للصفات اللاخطية لموائع هجين من الكاربون الانبوبي احادي الجدران مع جسيمات الفضة النانوية باستخدام تقنية الحيود اللاخطي

ايمان عدنان عبعوب و فاضل عباس عمران

معهد الليزر للدراسات العليا ،جامعة بغداد، بغداد، العراق

الخلاصة

اعتمادا على تقنية الحيود الذاتي اللاخطي، يمكن الحصول على الخواص الضوئية اللاخطية لشريحة رقيقة من مادة. هنا تم التحري تجريبيا للصفات اللاخطية لموائع نانوية متكونة من هجين من الكاربون الانبوبي احادي الجدران مع جسيمات الفضة النانوية المنتشرة في الاستون وبأجزاء حجمية 6×10^{-6}، 9×10^{-6}، 18×10^{-6}. لذلك استخدم ليزر ذو موجة مستمرة وبطول موجي 473 نانومتر وتم حصره الى حاوية كوارتز تحتوي على الموائع السابقة. تم عد حلقات نمط الحيود بواسطة جهاز اقتران الشحنات (CCD) كاميرا وحاسبة شخصية ذات برنامج معين لغرض ايجاد التغيير الاقصى لمعامل انكسار الموائع. اظهرت نتائجنا بأن الجزء الحجمي (18×10^{-6}) هو اكثر لا خطية من الاجزاء الحجمية الاخرى.

Introduction

Nonlinear optical effects have attracted much interest for their huge capability in employments such as, self-phase modulation, multiple-photon absorption and frequency conversion [1-3]. Therefore, nonlinear concentric ring can be revealed as far field nonlinear diffraction patterns when a Gaussian laser beam illuminates a thin slice of matte [4-6]

The first evidence of this process was demonstrated using CS_2 with Vanadium Phthalocyanine dye as a nonlinear material [7]. Moreover, this phenomenon was observed in another many nonlinear materials such as organic materials [8, 9], nano-fluid consist of metal nanoparticles[9, 10], dye [11], graphene[12] and CNTs [13, 14]. The pattern of self- diffraction effect will be useful for many

applications such as optical limiting [15, 16], optical switching [17, 18], beam flattening ,weak absorption measurement, spatial dark solution transmission and so on [19, 20].

Experimental work

This experimental was carried out using TEM_{00} Gaussian beam of CW diode pumped solid state laser at 473 nm (model MBL-FN-473nm-200mW-15050466) focused by a lens of focal length 0f 7 cm to a waist radius (w_0) of 154.559 μm through 5 mm quartz cuvette. The cuvette contains hybrid SWCNTs/Ag-NPs fluids at volume fraction of $6x10^{-6}$, $9x10^{-6}$, and $18x10^{-6}$ respectively. Power-meter (model UNO-200982, gentec-EO, Canada), attenuator, CCD camera (model Beamage - CCD12, gentec-EO, Canada) and PC have been used in this experiment as it can be shown in the Fig.1.
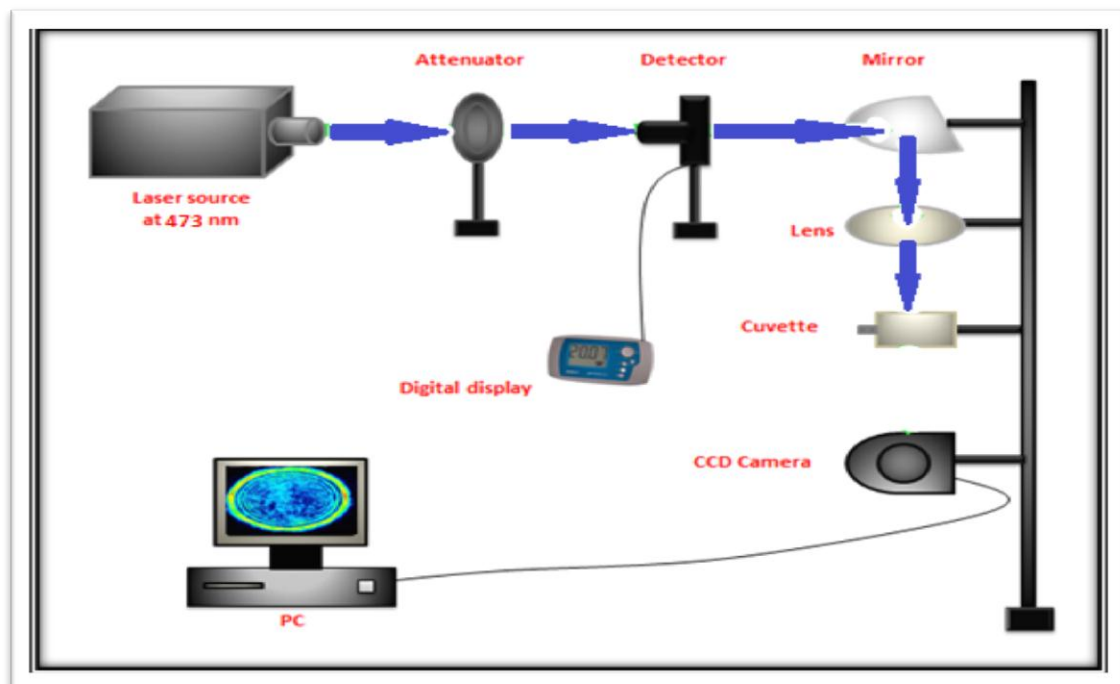

Fig. 1: Schematic diagram of the experimental set- up.

Result and discusses

The absorption spectra of hybrid materials (SWCNTs /Ag – NPs) acetone suspension at volume fraction 9×10^{-6} was measured by UV-VIS Spectrophotometer as it is shown in fig. 2. It has been shown in Fig. 2 that the peak wavelength was∼ 468 nm which indicates that the utilizing laser source (473 nm) is suitable for this process. Almost all particulate in contact with a liquid acqurie an electronic charge on their surface. Zeta potential is an important and useful indicator of this charge which can be used to predict and control the stability of suspention.Therefor, zeta potential examination was measurd for the suspension at volum fraction 9 x 10^{-6}, which was almost (-63.12). Zeta potential of this nano-fluid suspention possesss a good stability [21] as shown in Fig. 3.
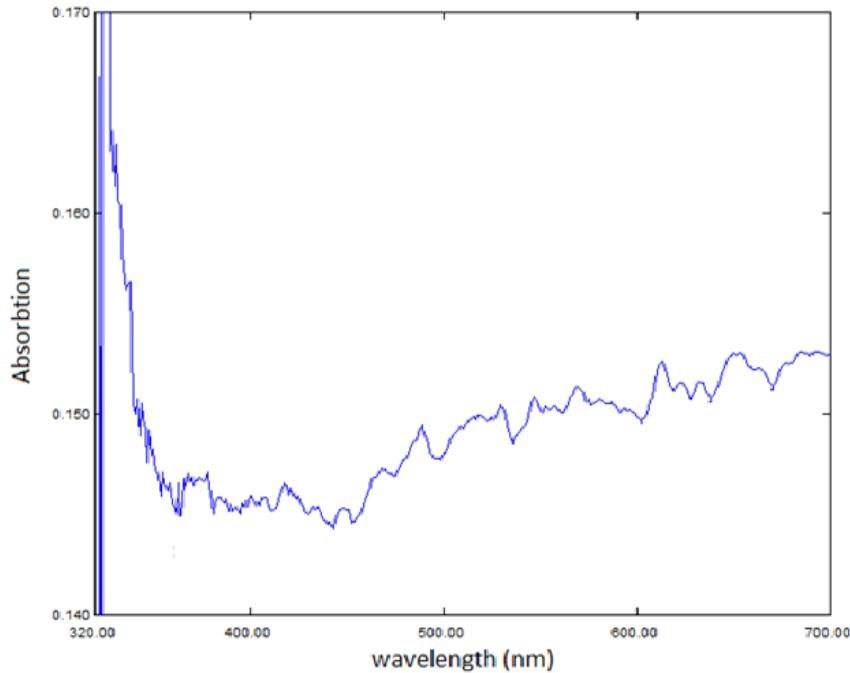
Fig. 2: The UV-VIS absorption spectrum 0f SWCNTs/Ag-NPs acetone suspension at volume fraction 9×10^{-6}.
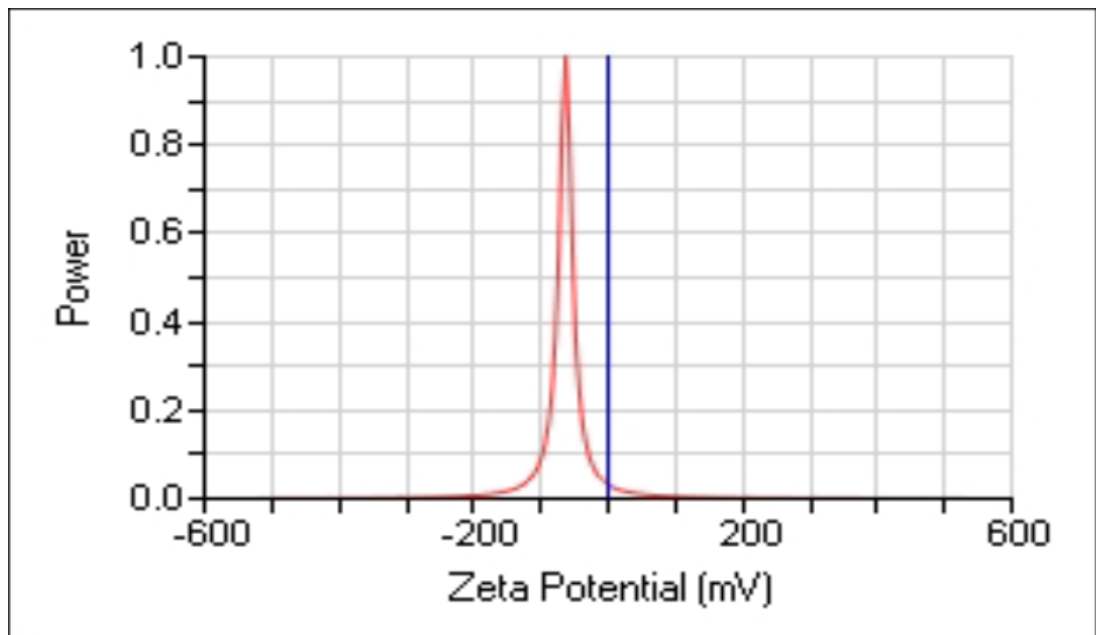

Fig. 3: Zeta potential at volume fraction of 6 $x10^{-6}$.

Table 1 shows the reported result of the present experiment. It has been noticed that the nonlinear refractive index of the suspension increases by increasing the volume fraction values of nanoparticles inside the solution. It can be attributed these increment due to the physical concept, that the hybrid metal nanoparticles (SWCNT/ Ag-NPs) spread in fluid lead absorption the light energy due to Surface Plasmonic Resonance (SPR) of the free electrons excitation on the metal surface. The absorbed energy firstly transports to particles and then to the encircling liquid causing it's

temperature to be increased in the suspension. Thereby, the refractive index of the nano- suspension will be changed. Using 473 nm CW laser beam it is near to the resonance absorption peak of the hybrid material, this phenomenon leads to formation of

thermal stimulate nonlinear refractive index inner the suspension. On the other hand the absorption light energy based on SPR is more powerful when the volume fraction values of the particles is high.

Table 1: The nonlinear refractive index and their coinciding volume fraction.

Laser intensity W/cm^2	Volume fraction x10^{-6}	Number of rings	Nonlinear refractive index ,n$_2$×10^{-6}(cm^2/W)
366.61	6	14	3.61
366.61	9	15	3.78
366.61	18	17	4.38

Various values of incident intensity have been used to get various numbers of nonlinear pattern rings which lead to get various values of the maximum

change nonlinear refractive index of the previous hybrid nano-fluids, as shown in Fig. 4 and 5, respectively.
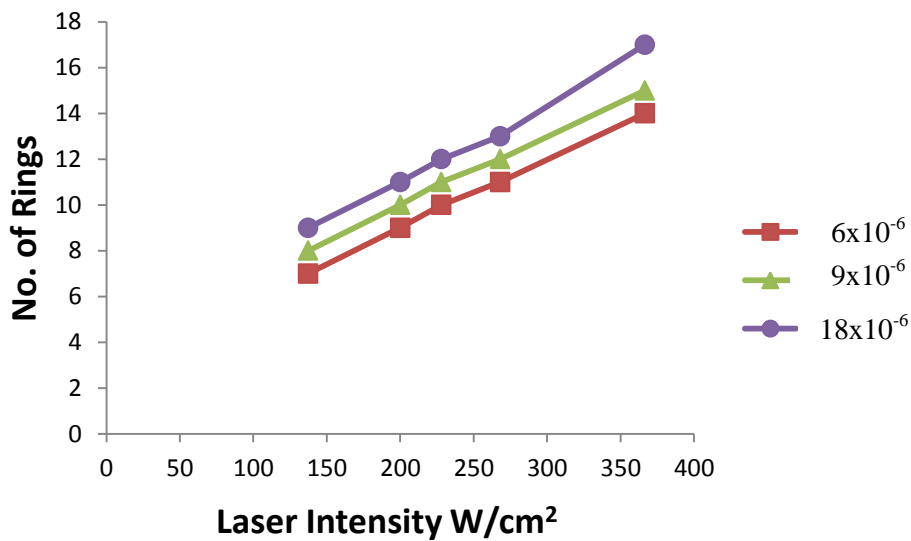

Fig. 4: Number of diffraction rings produce by SWCNTs/Ag- NPs acetone suspension at various laser intensities.
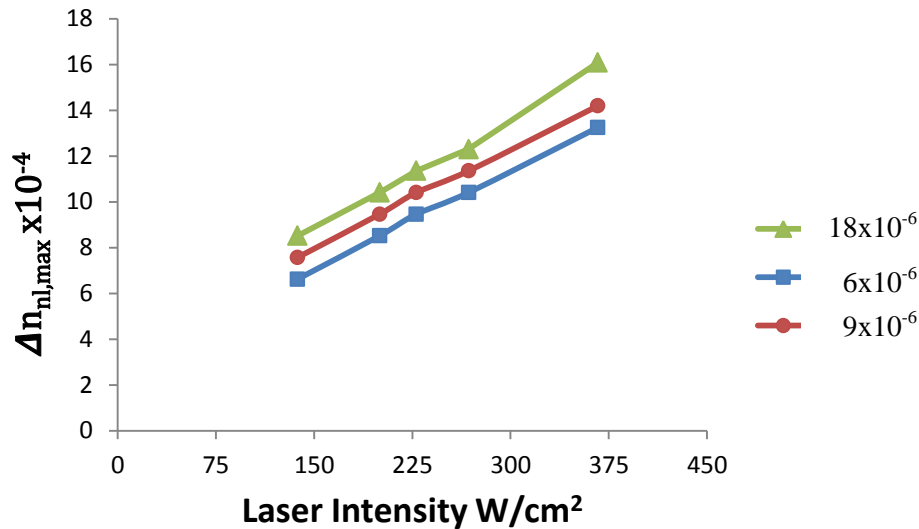
Fig. 5: Maximum change of nonlinear refractive index formed using SWCNT and silver nanoparticles acetone suspension at different volume fraction of 6×10^{-6}, 9×10^{-6} and $18 x10^{6}$ irradiated by varies laser intensities.

The following equation has been used to calculate the maximum change of the nonlinear refractive index ($n_{nl,max}$) [22].

$$\Delta n_{nl, max} = \frac{\lambda_{beam}}{L_{material}} \, N_{rings}$$

where λ is the laser wavelength, L and N are the cuvette thickness and number of diffraction rings respectively. For each volume fraction value the nonlinear refractive index were calculated by the following equation [23].

$$\Delta n_{nl} = n_2 I$$

I is the laser intensity.

Fig. 6 shows the relationship between the incident laser intensity and nonlinear refractive index of the hybrid nano-fluid at various volume fractions.
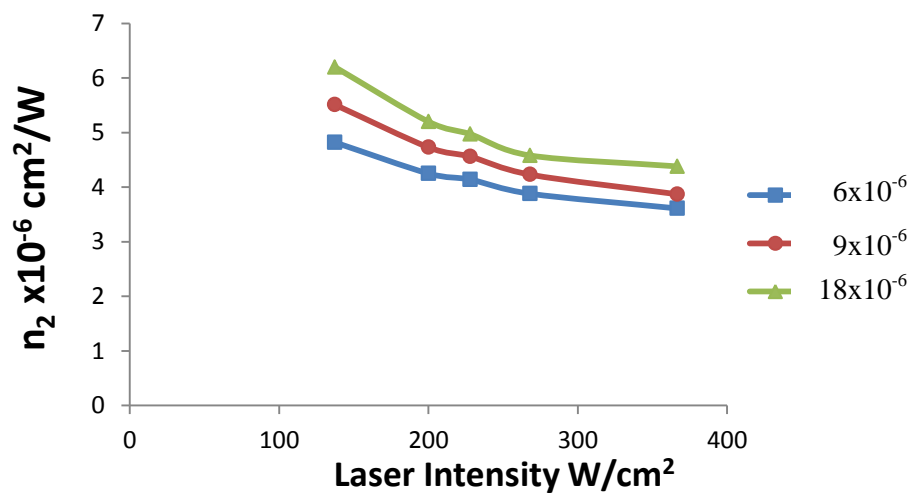

Fig. 6: The nonlinear refractive index formed using SWCNT and silver nanoparticles acetone suspension at different volume fraction of 6×10^{-6}, 9×10^{-6} and $18 x10^{-6}$ irradiated by varies laser intensities.

Fig. 7 shows that the number of nonlinear diffraction pattern rings which have been revealed by CCD camera increases by increasing of laser power density.
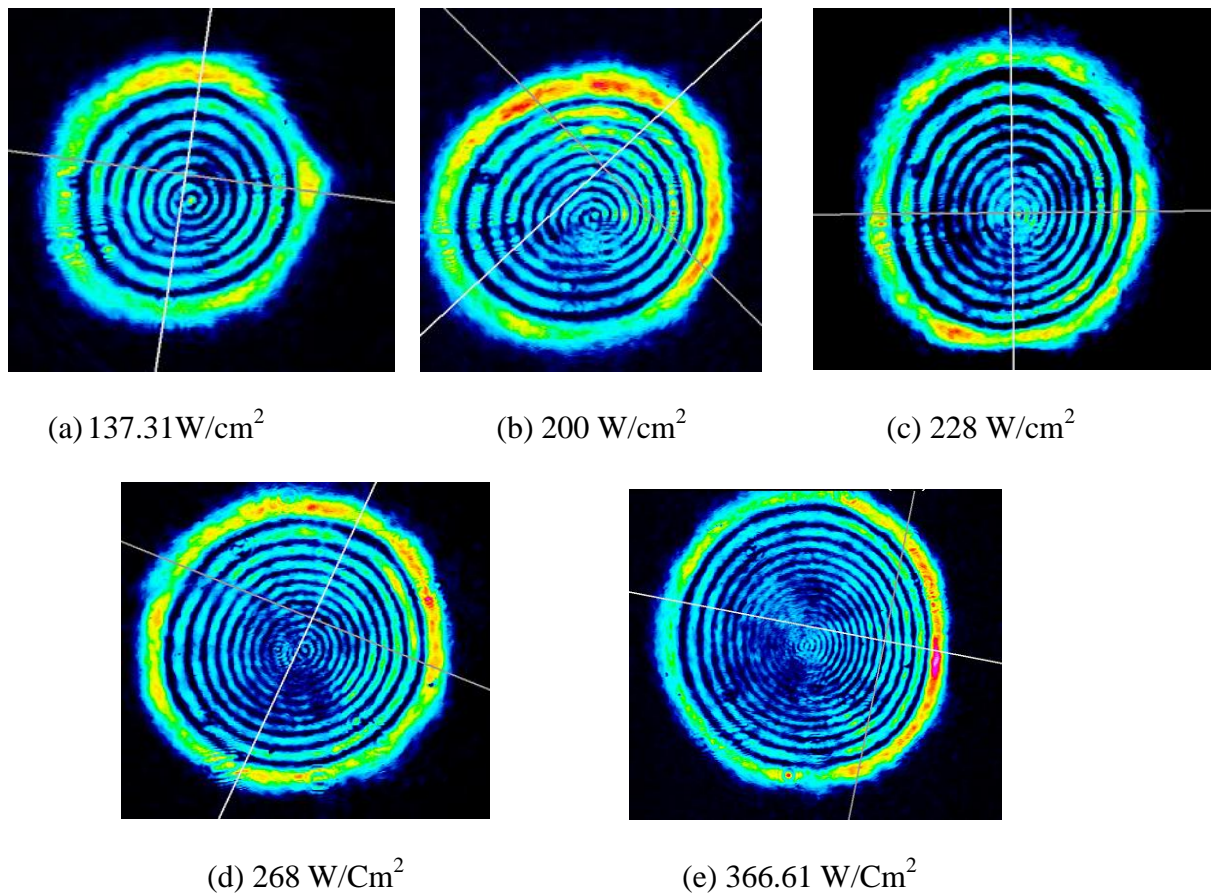

(a) 137.31W/cm^2　　　　　(b) 200 W/cm^2　　　　　(c) 228 W/cm^2

(d) 268 W/Cm^2　　　　　(e) 366.61 W/Cm^2

Fig.7: Shows that the nonlinear patterns rings using volume fraction value 6×10^{-6} increases by increasing power densities.

Conclusion

From the result of this experiment, we can concluded that, the number of diffraction patterns ring increases with increasing the laser intensity, this led to increase of nonlinear refractive index change $\Delta n_{nl,\,max}$ for hybrid SWCNT and silver NPs dispersed in acetone at volume fraction of 6×10^{-6}, 9×10^{-6} and 18×10^{-6}. Moreover, SWCNT and silver NPs acetone suspension at a volume fraction of 18×10^{-6} was higher optical nonlinearity than of others.

References

[1] F. W. Dabby, T. K. Gustafson, J. R. Whinnery, Y. Kohanzadeh, P. L. Kelley, Applied Physics Letters, 16, 9 (1970) 362-365.

[2] S. Brugioni and R. Meucci, Optics Communications, 206 (2002) 445-451.

[3] J. Wang, Y. Aihara, M. Kinoshita, J. Mamiya, A. Priimagi, A. Shishido, Sci. Rep., 5, 9890 (2015) 1-7.

[4] N. B. Abraham and W. J. Firth, J. Opt. Soc. Am. B, 7, 6 (1990) 951-962.

[5] S. Prusty, H. S. Mavi, A. K. Shukla, Phys. Rev. B, 71, 11 (2005) 113313-113316.

[6] S. Chavez Cerda, C. M. Nascimento, M. A. R. C. Alencar, M. G. A. Da Silva, M. R. Meneghetti, J. M. Hickmann, Ann. Opt., (2006).

[7] W. R. Callen, B. G. Huth, R. H. Pantell, Appl. Phys. Lett., 11, 103 (1967) 56-59.

[8] M. A. R. C. Alencar, C. M. Nascimento, S. Chávez-Cerda, M. G. A. da Silva, M. R. Meneghetti, J. M. Hickmann, Proc. SPIE - Int. Soc. Opt. Eng., 6103 (2006) 610306-610308.

[9] F. A. Almadhoob, M. A. Yousif, F. Z. Henari, P. S. Patil, Int. J. Exp. Phy, 1, 1 (2014) 182-188.

[10] R. Zamiri R. Parvizi, A. Zakaria ,A. R. Sadrolhosseini, D. G. Zamiri, D.M. Darroudi and M. S. Husin, J. Eur. Opt. Soc., 7 (2012) 2-5.

[11] M. D. Zidan, A. A. Mani, A. W. Allaf, Z. Ajji, A. Allahham, Acta Phys. Pol. A, 115, 5 (2009) 886-889.

[12] G. Wang, S. Zhang, F. A. Umran, X. Cheng, N. Dong, D. Coghlan, Y. Cheng, L. Zhang, W. J. Blau, J. Wang, Appl. Phys. Lett., 104, 14 (2014) 141909.

[13] M. D. Zidan, A. W. Allaf, M. B. Alsous,A. Allahham, Opt. Laser Technol., 58, November (2014) 128-134.

[14] F. A. Umran and M. M. Elias, Iraqi J. Laser, Part A, 15 (2016) 19-23.

[15] S. Pramodini, Deepika, Sandhya, A. Rao, P. Poornesh, Opt. Laser Technol., 62, March (2014) 58-62.

[16] X. Sun, R. Q. Yu, G. Q. Xu, T. S. A. Hor, W. Ji, Appl. Phys. Lett., 73, 25 (1998) 3632-3634.

[17] F. Z. Henari, J. Opt. A Pure Appl. Opt., 3, 3 (2001) 188-190.

[18] A. Haché and M. Bourgeois, Appl. Phys. Lett., 77, 25 (2000) 4089-4091.

[19] H. Badran, Appl. Phys., 1 (2012) 33-37.

[20] Z. Mao, L. Qia, F. He, Y. Liao, C. Wang, Y. Cheng, Chinese Opt. Lett., 7, 10 (2009) 949-952.

[21] P. C. Mishra, S. K. Nayak, S. Mukherjee, International Journal of Engineering Research & Technology, 2, 9 (2013) 734-745.

[22] R. Menzel, "photonics", 2nd Edition, Springer, Potsdam (2007).

[23] K. Abd Al-Adel and H. A. Badran, Eur. J. of Appl. Eng. And Scie. Res., 2, 1 (2012) 66-72.