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Determination of nonlinear refractive index of paprika oil and pepper oil under cw visible laser illumination

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Abstract:
We report the observation of multiple diffraction rings patterns in paprika and pepper oils using continuous wave laser beams .The patterns occur at relatively low intensities . The number of rings together with outermost ring diameter of each pattern increases monotonically with increasing input power . The total changes in refractive index , Δn ,and nonlinear refractive index,n_2 ,are determined using the number of rings observed in both samples and 473 nm and 532 nm laser beams . We obtained good values of Δn = 0.01 and n_2 = 10^{-6} cm^2/w . These large values are attributed to thermal effects .

Keywords: Diffraction rings, visible laser beams, nonlinear refractive index, vegetable oils.

Introduction

Changes in refractive index induced by optical fields give rise to variety of nonlinear phenomena in photoresponsive materials [1,2]. When a light beam passes through an absorbing medium whose refractive index decreases as a function of temperature , the medium behaves as a negative lens [3]. In the spatial domain , the interplay between divergence of the propagating beam and the nonlinear response of the medium can leads to a diverse range of self – action behavior such as optical self – trapping, soliton formation and spontaneous pattern formation due to modulation instability [4,5] . A related phenomena is the formation of spatial rings which is understood to be induced by spatial self-phase modulation arising from the laser induced refractive index . The multiple diffraction rings have been demonstrated for the first time back in 1967 by Callen et al ., [6]. A pump laser beam with Gaussian intensity extent can induced such diffraction rings due to the induced of phase shift with a bell – shaped transverse profile (Gaussian) [7].

The interference between light from two distinct points on the Gaussian curve that have the same transverse wave vector can leads to either a maximum constructive or minimu destructive interference point or cir

The rotation around the Gaussian curve should leads to bright or dark ring when the phase difference equal to (m π), m being even or odd respectively .Diffraction rings can be used to estimate the total change in refractive index , Δn , [$n = n_o + \Delta n$, n is the refractive index in the presence of laser beam and n_o is the linear or background refractive index]. Δn equals to $n_2 I$, n2 is the nonlinear refractive index and I is the laser beam intensity. During the last thirty years , tens of materials have been tested against diffraction rings for the sake of materials having the highest nonlinear refractive index, n2 , and fast response time [8-11] .

Very little , or almost no vegetable oil have been tested for the same purpose [12] . In the present article we are presenting comparative results of nonlinear response of paprika (red) oil and pepper (black) oil using visible (437 nm and 532 nm) c.w laser beams

Experimental:

Samples and UV – visible spectroscopic results

The paprika and pepper oils used in the experiments are available in the local market, their chemical structures are shown in figure (1).

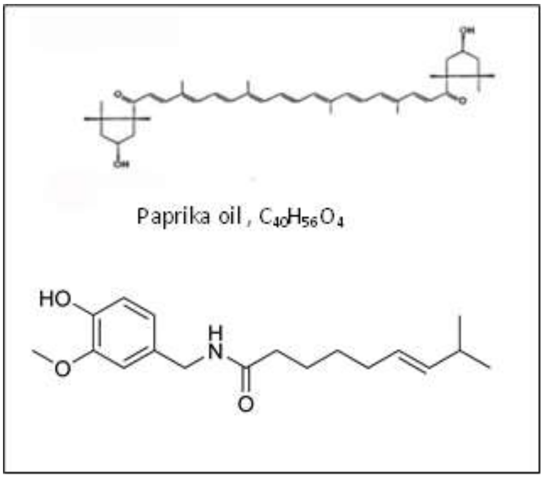

Fig . (1): Chemical structures and molecular formulas for paprika and pepper oils

A UV – visible spectroscopy have been used to characterizes paprika and pepper oils in the ranges (300 – 900 nm) . The absorption (A) of both oils measured using double UV – visible spectrophotometer (type 6800 UV / vis Jenway . England).These measurements were performed at room te n the sp

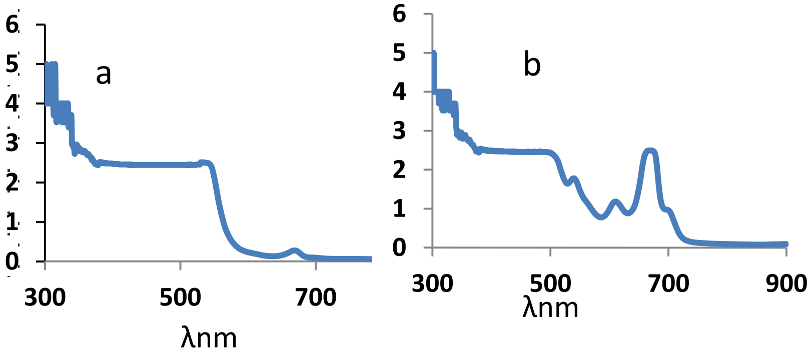

Fig.(2): Spectral absorbance of (a) paprika and (b) pepper oils

(b) **(**

(a) Experimental set – up

The experimental arrangement, shown in figure (3), comprised an paprika oil and pepper oil in a glass cell , 1 mm thick . Two conventimal solid state laser (SDL – 473 – 050 T) and (SDL – 532 – 100 T) emitting blue (473 nm) and green (532 nm) light beam operating on the lowest order transverse (TEMOO) modes given Gaussian spatial distribution , respectively . A glass lens of 50 mm focal length was used in the experiments and a digital camera (sony DSC -T99 - 8700 -82-25 mm) and a semitransparent 30 * 30 cm screen . The laser input power was measured using a power multi - range meter (type SDL -PM - 002).

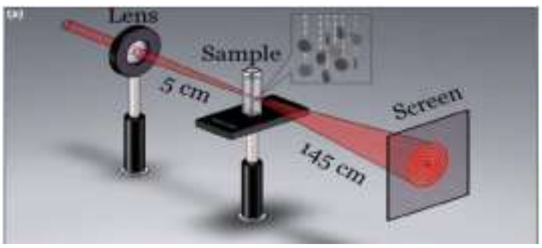

Fig. (3) : Experimental setup

Diffraction rings

Patterns measurements : The green laser output power can be varied

between zero and 102 mW while the blue laser output power varied between zero and 66 mW . Both laser beam spot sizes radius is 1.5 mm (at $1/e^2$) . The laser light intensity was calculated using the formula $I= 2P/\pi\omega2$ where P is the laser output power and ω is beam radius at each sample. Figs . (4) and (5) shows input power dependence of diffraction ring number for (A) paprika oil and (B)for pepper oil respectively where it can be seen that number of rings for both samples increases monotonically with increases of input light power at λ =532 nm and λ =473 nm respectively

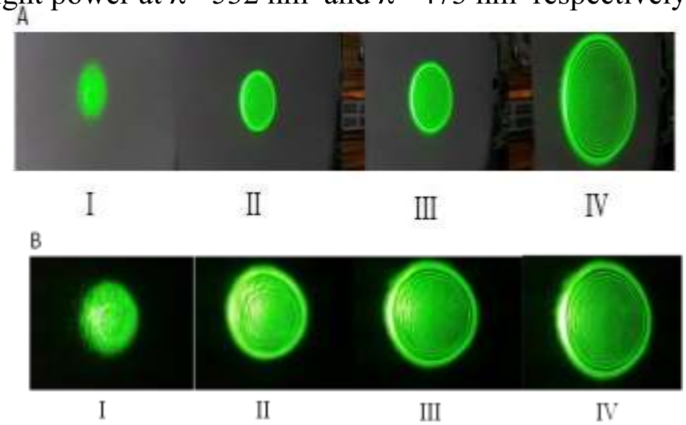

Fig (4). Variation of rings number in (A) paprika oil [I : 3.8 mW ,II: 15.2 mW , III: 30.4 mW , IV: 68.4 mW] and (B) pepper oil [I: 7.4 mW , II: 29.6mW , III: 66.6mW, IV: 81.4 mW] using light beam of λ= 532 nm against input power.

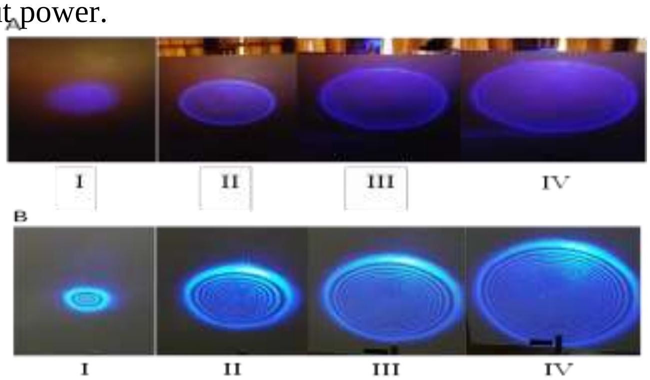

Fig. (5) : Variation of rings number in (A) paprika oil [I: 3.45 mW , II: 17.25 mW , III: 31.05 mW , IV: 37.95 mW] and(B) pepper oil [I: 11.25 mW , II: 26.25 mW , III: 41.25mW ,IV: 56.25 mW ,] using light beam of λ= 473 nm against input power.

Fig .(6)and Fig .(7) shows two graphs of the increase of ring number with input power for both samples at λ =532 nm and λ =473 nm respectively .

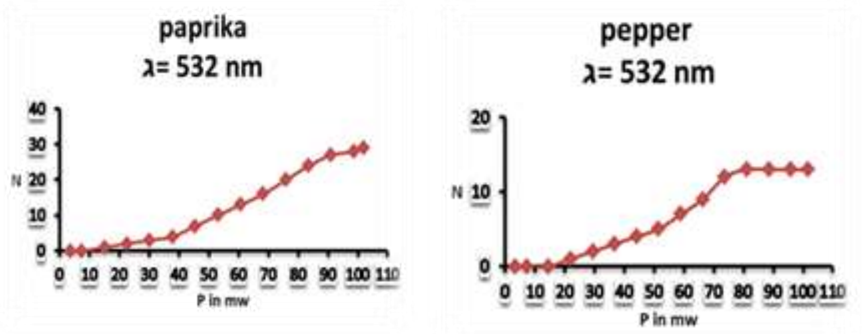

Fig (6):Variation of rings number oil against input power at λ =532 nm for paprika oil and pepper oil

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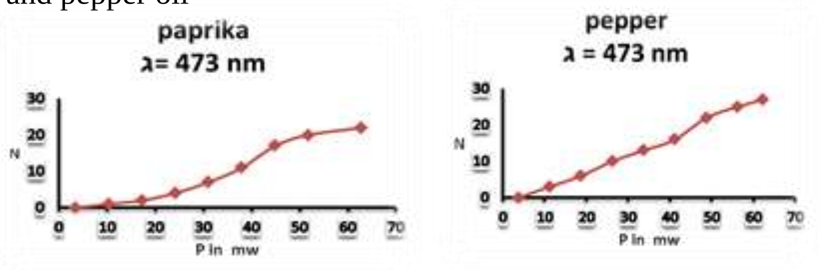


Fig (7):Variation of rings number against input power at λ =473 nm for paprika oil and pepper oil.

Figs.(8 and 9) shows the variation of diameter of external ring with input power for both samples at λ =532 nm and λ =473 nm respectively. It can be seen the increase of diameter for both samples monotonically .

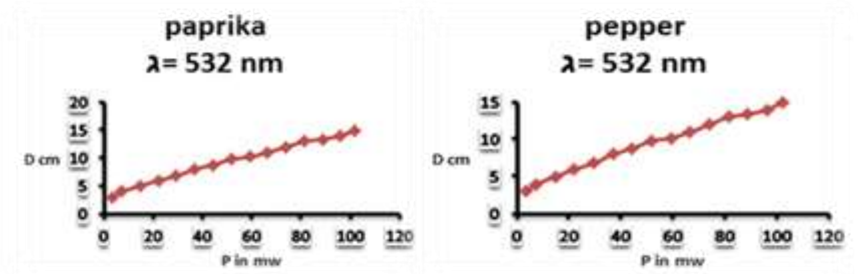
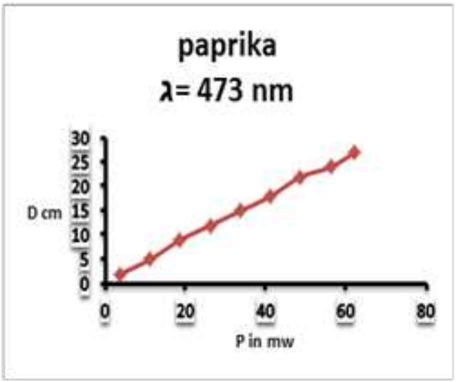


Fig (8):Variation of external ring diameter against input power at λ =532 nm for paprika oil and pepper oil .



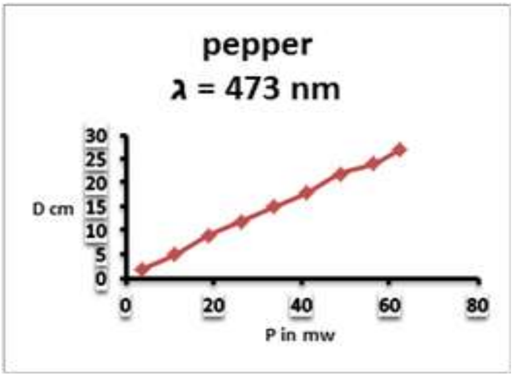


Fig (9):Variation of external ring diameter against input power at λ =473 nm for paprika oil and pepper oil .

With the positive 50 mm lens in its place , the beam radius , ω, at the 1 mm cell when the latest is at the focal point of the lens can be calculated using the formula , ω = 1.22 f λ/ ω0 [13] where λ is the laser beam wavelength , f is the focal length of the lens and ω0 is the laser beam radius strikes the lens so that ω depend on the laser light wavelength i .e ., ω= 19.24 μm for λ = 473 nm and ω= 21.63 μm at532 nm .

To meet the nonlinear thin medium requirement case , the cell thickness must be less than the Rayleigh range (length) , ZR for positive lens ,ZR = πω2 / λ [14] where ω and λ have the same definitions mentioned earlier so that (ZR = 2.76 mm) >1mm cell length at λ = 532 nm and (ZR = 2.65 mm > 1mm at . λ = 473 nm) .

Estimation of nonlinear refractive index for both samples: We estimated the induced refractive index change , Δn ,and the magnitude of the effective nonlinear refractive index , n2 , from the diffraction rings pattern data obtained earlier . The number of bright rings , N , can be approximated as [8]:

$$N = \frac{(\Delta\Phi)_{max}}{2\pi} \ldots\ldots\ldots\ldots\ldots (1)$$

Where , $(\Delta\Phi)_{max} = k\Delta$, is the phase change of the laser beam as a result of light traversing a distance (d) in the nonlinear medium , k is the wave vector = $\frac{2\pi}{\lambda}$ and Δ = d Δn is the optical path difference in the nonlinear and Δn is the total change in the medium and refractive index. $\Delta n = In_2$, n_2

is the nonlinear refractive index , and I is the laser beam intensity .

$$(\Delta\Phi)_{max} = 2\pi N = \frac{2\pi}{\lambda} d\Delta n$$

so that

$$\Delta n = \frac{\lambda N}{d} \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$n_2 = \frac{\Delta n}{I} \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

According to equations (2) and (3) tables (1- 4) summarizes the values of Δn and n_2 as functions of input powers. The obtained results are explained as follows : For varying input power from zero and above there exist thresholds for obtaining the first ring from both samples which are different in magnitude depending on the amount of absorption from both samples and based on the wave - length used . As the input power increased so does the amount of power absorbed by the samples, hence local increase in temperature occurs in the shape of bell like shape
as a result of the Gaussian distribution of the laser beam . The amount of temperature near the peak of the laser beam is higher than those around the wings of Gaussian distribution. Hence more reduction in refractive index occurs on the axis of the beam direction and more rings born around the central part of the beam i .e, the laser beam diverge or self- defocused around the central part of the beam . This is why the external ring is more intense than the inner ones. The change in diffraction rings radius , shown in fig(7), increased with increasing input power .

Table (1) : Variation of the nonlinear refractive index , n_2,and change in refractive index , Δn, for paprika oil with increasing input power atλ = 473 nm

P_{in} mw	$n_2 * 10^{-7}$ cm^2/W	$\Delta n * 10^{-6}$

10.35	2.654	473
17.25	3.185	946
24.15	4.549	1892
31.05	6.192	3311
37.95	7.962	5203
44.85	10.412	8041
51.75	10.616	9460
62.79	10.499	11352

Table (2) : Variation of the nonlinear refractive index , n2 , and change in refractive index , Δn, for paprika oil with increasing input power at λ=532nm

P_{in} mw	$n_2 * 10^{-7}$	$\Delta n * 10^{-6}$
15.2	2.571	532
22.8	3.429	1064
30.4	3.858	1596
38	4.114	2128
45.6	6.001	3724
53.3	7.348	5320
60.8	8.358	6916
68.4	9.143	8512
76	10.286	10640
83.6	11.222	12768
91.2	11.575	14364
98.8	11.869	15960
102	11.913	17024

Table (3) : Variation of the nonlinear refractive index , n_2,and change in refractive index , Δn, for pepper oil with increasing input power at λ = 473 nm.

P_{in} mw	$n_2 * 10^{-7}$ cm^2/W	$\Delta n * 10^{-6}$
22.2	1.761	532
29.6	2.640	1064
37	3.169	1596
44.4	3.521	2128
51.8	3.773	2660
59.2	4.622	3724
66.6	5.282	4788
74	6.339	6384
81.4	6.242	6916

Table (4) : Variation of the nonlinear refractive index , n_2 , and change in refractive index , Δn, for pepper oil with increasing input power at λ=532nm.

P_{in} mw	$n_2 * 10^{-7}$ cm^2/W	$\Delta n * 10^{-6}$
11.25	7.326	1419
18.75	8.790	2838
26.25	10.465	4730
33.75	10.580	6149
41.25	10.655	7568
48.75	12.395	10406
56.25	12.696	12298
62.25	12.796	13717

In general the obtained nonlinear refractive index in this work can be well compared with those obtained in many materials obtained by z scan techniques , thermal lens techniques and diffraction rings techniques . (1.94 x 10^{-7}) cm^2/W was obtained by Mao etal [10] , 10^{-8} cm^2/W by Milan chian[15] , 7.7 x 10^{-8} cm^2/W by Henari [16] , Krishnamurthy etal [17],1.17x10^{-10} cm^2/W by Henari and Cassidy [18], (-4.4 x 10^{-8}) cm^2/W by Vinitha and Ramalingam [19] , (1.63 x 10 $^{-7}$) cm^2/W by Ali and palanisamy [20] , 10^{-7} cm^2/W by Majles etal.,[21]., 10^{-7} – 10^{-6} cm^2/W by Majles etal ., [22]and 10^{-5} cm^2/W by Qi etal .,[23].The only available result in vegetable oil

is the one published by Zamiri etal.,[12],using palm oil doped with silver nanoparticles to enhance the nonlinearity in this material .Their value of n_2 was 3.07 x 10^{-5} cm^2/W.et al.,

Conclusion:

We have demonstrated diffraction ring patterns in two vegetable oils viz ., paprika and pepper using two low power continuous wave visible laser beams . It appear to us that the increase in number of rings reaches saturation at high input power . The observed ring patterns are attributed to thermal effects as a result of the high absorption coefficients in the two samples and interference occurring on the observation screen in the far field .

Reference

1-T.Y. Chang , Fast self – induced refractive changes in optical media : a survey , Opt. Eng. ,20,220-233 (1981)

2-R.L. Sutherland , Handbook of nonlinear optics , Marcel Dekker , Inc , New York , Basel (2003)

3-V. Pilla , E. Munin , and M.R.R. Gesualdi , Measurements of the thermo-optics coefficient in liquids by laser induced optical diffraction and thermal lens technique , J. Opt. A : Pure Appl. Opt . , 11, 105201 (7PP) , (2009).

4- E.V. Garcia - Ramirez , M.L. Arroyo- Carrasco , M . M . Mendez - Otero , S. Chaves- Cerda , and
M.D. Iturbo- Castillo , Far field intensity distribution due to spatial self phase modulation of a Gaussian beam by thin nonlocal nonlinear media , Opt . Exp. , 18 , 22067-22079 (2010)

5- A.B. Villafranca and K . Saravnamuttu , Spontaneous and sequential transition of Gaussian beam into diffraction rings , single ring and circular array of filaments in photopolymer , Opt . Exp. , 19, 15560-15573 (2011).

6- W.R. Callen , B.G. Huth , and R.H Pantell , Optical patterns of thermally self defocused light , Appl. Phys. Lett ., 11,103-105 (1967).

7- S.D. Durbin , S.M. Arakelian , M.M. Cheung , and Y.R. Shen , Highly nonlinear optical effects in liquid crystals , J . De Physique , C2 , 161-169 (1983).

8- K. Ogusu , Y. Kohtani , and H. Shao , Laser induced diffraction rings from an absorbing solution , Opt. Rev. , 3,232-234 (1996).

9- M. Trejo – Duran , E. Alvaro – Mendez , and V.M. Castano , Self – organized patterns by optical nonlinearity in 4 – (4 – penteny loxy) benzonitrile , Appl. Phys. Lett., 94 , 023304 (2009).

10-Z. Mao, L. Qiao , F. He, Y. Liao , C . Wang , Y . Chang , Thermal – induced nonlinear optical characteristics of ethanol solution doped with silver nanoparticles , Chin . Opt. Lett ., 7,949-952 (2009).

11- H.A. Badran , Q.M.A. Hassan , A.Y. Al-Ahmed , and C.A. Emshary , Laser-induced optical nonlinearities in orange G dye : polyacrylomide gel , Can . J . Phys., 89,1219-1224 (2011).

12 - R. Zamiri , R . Parvisi , A. Zakaria , A.R. Sadro – lhosseini , G. Zamiri , M. Darroudi , and , M.S.Husin ,Investigation on nonlinear – optical properties of palm oil / silver nanoparticles J . Europ . Opt . Soc . Rap . public, 7 , 12020 (4 pp), (2012).

13-A .Y .Al -Ahmad , M .F .Al – Mudhaffer , H . A . Badran , and C .A . Emshary , Nonlinear optical and thermal properties of B C P : PMMA films determined by thermal lens – diffraction , Opt . Las ., Tech . 54 , 72 – 78 (2013).

14 -S . A . Self , Focusing of spherical Gaussian beams , Appl . Opt ., 22 , 658 - 661(1993).

15- K. Milanchian, H. Tajalli, A. Chavadzadeh Gilani, and M. S. Zakerhamidi, Nonlinear optical properities of two oxazine dyes in aqueous solution and poly-acrylamide hydrogel usingsingle beam z-scan, Opt. Mat., 32,12-17 (2009).

16-F. Henari, Nonlinear characterization and optical switching in bromophenol blue Solutions, Nat. Sci., 3, 728-732 (2011) .

17-R. R. Krishamurthy and R. Alkondan ,Nonlinear characterization of mercurochrome dye for potential applications in optical limiting, Opt. Act., XL., 187-196 (2010).

18- F. Z. Henari, and S. Cassidy, Nonlinear optical properties and all optical switching of congo red in solution, Optik , 123, 711-714 (2012).

19- G. Vinitha and A. Ramalingam, Spectral and nonlinear studies of an aniline blue dye in liquid and solid media, Las. Phys., 18, 1159-1163 (2008).

20 - Q. M. Ali and P. K. Palanisamy, Investigation of nonlinear optical properties of organic dye by z-scan technique using He-Ne laser, Optik, 116, 515-520 (2005).

21 - M. H. Majles Ara, E. Koushki, S. Salmani, and S. H. Mousavi, ϰ(3) measurement in "5- oxo-4, 5-dihydroindeno [1, 2-b] pyrans " using the z-scan and the moire reflectometry techniques, Opt. Commun., 278, 418-422 (2007).

22- M. H. Majles Ara, S. Salmani, M. Esmaeilzadeh, S. H. Mousavi, E. Koushki, and Kh. Shakouri, Optical characterization of erioglaucine using z-scan technique ,beam radius variations and diffraction pattern in far- field, Current Appl. Phys. 9, 885-889 (2009).

23- S. Q., C. Zhang, X. Yang, K. Chen, L. Zhang, Y. Lin, T. Xu and J. Tian, Effective indexes of refraction and limiting properties of ethyl red, Optik, 118, 425-429 (2007).

تعيين معامل الانكسار اللاخطي في زيت الفلفل الاحمر وزيت الفلفل الاسود تحت الاضاءة بحزمتي ليزر مرئيتان ومستمرتان

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الخلاصة : لاحظنا نماذج حلقات حيود متعددة في زيت الفلفل الاحمر وزيت الفلفل الاسود باستعمال حزمتي ليزر مرئيتان ومستمرتان . هذه النماذج تحدث عند شدات دخل واطئة نسبيا كما وان عدد الحلقات وقطر الحلقة الخارجية في كل انموذج تزداد باضطراد مع زيادة قدرة الدخل . تمت عملية الحساب لكل من التغير الكلي في معامل الانكسار Δnومعامل الانكسار n_2 مستفيدين من عدد الحلقات باستعمال حزمتي ليزر عند الطوليين الموجيين $\lambda=473$ nm و$\lambda=532$ nm وحصلنا على قيم جيدة للاثنين بمقدار $\Delta n= 0.01$ و $n_2= 10^{-6}$ cm^2/ W وتعزى هذه القيم المرتفعة الى التأثيرات الحرارية.

الكلمات المفتاحية : حلقات الحيود ، حزم ليزر مرئية ، معامل الانكسار الاخطي ، زيوت نباتية.