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Investigating the possible thermal-induced nonlinearities inLinseed,Rose and Chamomile oils using visible laser beam

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Abstract:

Possiblenonlinear optical characteristics in Linseed,Rose and Chamomile oils are investigated. Large thermal-induced third order nonlinear refractive index,n_2,(10^{-7}- 10^{-6})cm^2/W has been obtained in rose and chamomile oilsat532 nm continuous wave (cw) laser radiation. Number of rings as well as the diameter of the outer most ring in each ring pattern is found to increased monotonically with increasing input power.Diffraction ring pattern resulted in Linseed oil by the simultaneous irradiation of the green andbluelight beamsat 532 nmand 473 nm respectively.

Keywords: Vegetable oils, diffraction ring pattern, nonlinear refractive index.

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استقصاء احتمالية اللاخطيات المحتثة حراريا في زيوت بذور الكتان والورد والبابونج باستعمال حزمة ليزر مرئية

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الخلاصة :

تم استقصاء احتمالية الخصائص البصرية في زيوت بذور الكتان والورد والبابونج حيث وجد معامل الانكسار اللاخطي ذو المرتبة الثالثة والمحتث حراريا بمقدار 10^{-7} (10^{-6}) cm^2 / W –باستعمال شعاع ليزر بطولموجي 532 nm فيمادتي الورد وبذور الكتان . بدا لدينا ان كل من عدد الحلقات وقطر الحلقة الخارجية في كل انموذج حلقات حيود يعتمدان طرديا على شدة الضوء الساقط .تم انتاج حلقات حيود في زيت بذر الكتان باستعمال الضوء الاخضر باستعمال التشعيع المتزامن بضوء ازرق عند الطول الموجي 473 nm .

الكلمات المفتاحية : الزيوت النباتية ،نمط حلقات الحيود ، معامل الانكسار اللاخطي

1-Introduction:

Owing to the needs for new optical devices, the search for new materials is an important matter. These materials should behave nonlinearly with input laser light and respond in very short times.

To examine the existence of nonlinearities in any material there exist number of methods. The most important methods are diffraction ring pattern [1], thermal lens (TL) [2] and the Z- scan [3]. Each method can be easily carried out, they required a laser source with low variable output power, < 1 W, working in the lowest order transverse Gaussian mode (TEM_{00}).

So many materials have been tested for nonlinearities [4-9] for various objectives using the three techniques mentioned above [10-14].

To our knowledge, no attempt hasbeen carried out to investigate any types of nonlinearities in vegetables oils except one experiment that studied the nonlinear properties of palm oil via diffraction rings technique in the thepresence of silver nanoparticles by Zamiri et al., [15] .Another experiment has been carried out by Al- Dergazly et al., [16] to calculate olive oil Kerr constant for electro-optical applications and a recent work by the present authors on paprika and pepper oils [17] .

In the present workthe study of possible nonlinear properties has been presented i.e. estimation of the nonlinear refractive index, n_2, and the total change of refractive index, Δn, in linseed oil, rose oil and chamomile oil via diffraction ring technique using a green (532 nm)cwvisible laser beam.

2-Experimental:

(a) Samples and UV- visible spectroscopic studies:

The linseed oil, rose oil and chamomile oil those used in the experiments are available in the local markets.Their chemical structures are not available since each of them is made of number of chemical components such as the one shown in the Fig (1) for linseed oil where a triglyceride found in a linseed oil, a trimester (triglyceride) derived of (1) linoleic acid, (2) alpha- linleic acid, and (3) oleic acid. These are applicable to rose oil as well as chamomile oil. Table (1) shows some basic properties of these oils. These oils together with all known oils are nonpolar.

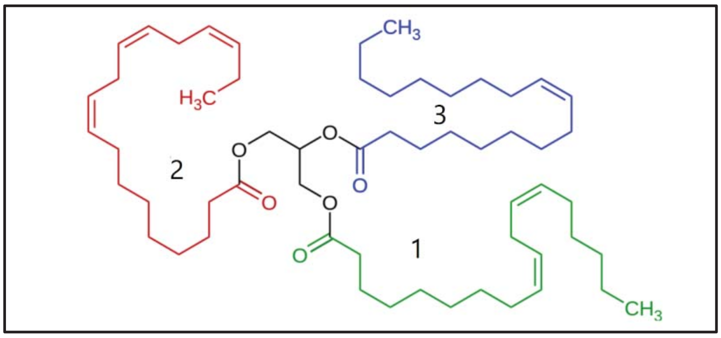


Fig (1): A triglyceride found in linseed oil, a triester (triglyceride) derived of (1) linoleic acid, (2) alpha- linolenic acid, and (3) oleic acid.

Table (1): Some basic properties of linseed, Chamomile, and rose oils.

Property	linseed oil	chamomile oil	rose oil
polarity	nonpolar	nonpolar	nonpolar
density	0.93 g/ml at 20°C	0.902 g/ml at 20°C	0.964 g/ml at 20°C
refractive index	1.4795	1.44-1.45	1.457- 1.463

A UV- visible spectroscopy have been used to characterized in the absorption lines in the spectral range (300- 900) nm. The absorbance (A) for all three samples measured using a 6800 UV- visible spectrophotometer (Jenway-England). These measurements were all performed at room temperature. Fig. (2) shows the spectral distribution of absorbances (A)of these oils in the spectral range (300-900) nm. Table (2) shows the calculated absorption coefficient (α) using the relation α =2.303(A/d) and d is sample cell thickness .

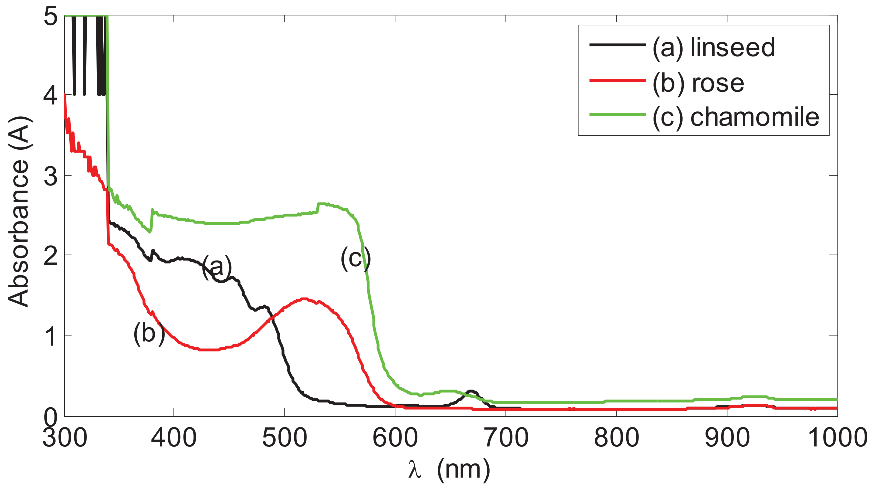


Fig (2): The absorption spectrum of (a) linseed oil, (b) rose oil and (c) chamomile oil.

Table (2): Absorption coefficient of linseed, chamomile, and rose oils at λ = 532 nm

Oil	α (cm^{-1})
linseed	4.42
chamomile	60.75
rose	32.56

(b) Experimental setup:

The experimental arrangement is shown in Fig .(3) comprised an linseed oil, chamomile oil, and rose oil each in a glass cell 1mm thick. A conventional solid state laser operating on the lowest spatial distribution TEM_{00} mode, with wavelength 532 nm (type SDL-532-100T) green light , a glass positive 50 mm focal length lens is used, and a digital camera (type Sony DSC-T99-8700-82-25 mm). The input power from each laser was measured using amulti-wavelength power-meter(type SDL-Pm-002). A 30x30 cm semi-transparent screen was used to cast the diffraction ring patterns.

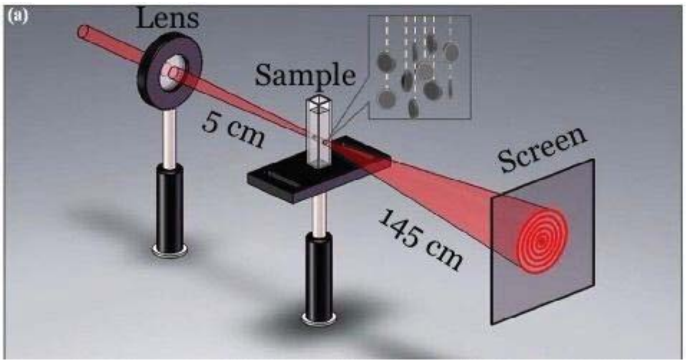


Fig (3): Experimental setup .

3-Diffraction ring patterns measurement:

The beam radius, ω, at each sample entrance can be calculated using the relation [13]:

$$\omega = 1.22\ f\lambda/\omega_K \qquad \ldots(1)$$

f is the positive lens focal length, λ is the laser beam wavelength and ω_K is the laser beam radius as it leaves the output coupler of the laser. According to equation (1) the beam radius striking the sample is dependent on the light wavelength, λ, so that for f=50 mm, λ=532 nm and ω_K=1.5 mm (at $1/e^2$), ω_{532}=21.625 µm .

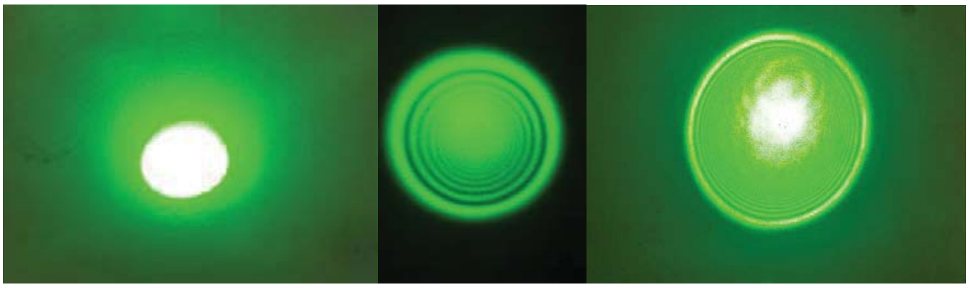
To meet the nonlinear thin medium criteria, the cell thickness, d, must be less than the Rayleigh range (or length), Z_R, which can be calculated using the relation [18]:

$$Z_R = \pi\omega^2/\lambda \qquad \ldots(2)$$

where $\omega = \omega_{532}$ and λ has the same definition so that $(Z_R)_{532}$-=2.76 mmi.e, thin cell criteria is satisfied, d <$(Z_R)_{532}$.

Sample results of the diffraction ring patterns,which appears instantaneously post irradiation,obtained for the rose and chamomile oilsat the same input power at 532 nm are shown infig (4).It can be seen the dependence of number of rings, N, on the level of absorption coefficient. No rings appeared at 532 nm where α_{532}=4.42 cm^{-1} for linseed oil while as we move from rose oil α_{532}=32.56 cm^{-1} to chamomile oil, α_{532}=60.75 cm^{-1}, one can notice the increasing in number of rings with the absorption coefficients. Fig (5) shows the variation of the number of rings and diameter of the outer- most ring in each pattern against input power from each sample at λ=532 nm.In a subsequent experiment using the green light together with a blue , 473 nm ,light obtained from another conventional solid state laser cw 473 nm laser beam (type SDL.473 – 66T)in the TEM_{oo}

transverse mode simultaneously green diffraction ring pattern was produced together with a blue diffraction ring pattern as can be seen in F.ig (6) .The blue laser beam power was 30 mW while of the green was 5 mW . The green rings number does not affected by the variation of the green laser power while both the green and blue rings patterns number were affected by the variation of the input power of the blue beam . The pump ,blue beam , and the probe , green beam, were crossing each other in the entrance side of the sample cell with an angle 20° between the two beams . see Fig .(7)



(a) (b) (c)

Fig (4): Sample results of diffraction ring patterns for(a) linseed oil, (b) rose oil, (c) chamomile oil at λ=532 nm

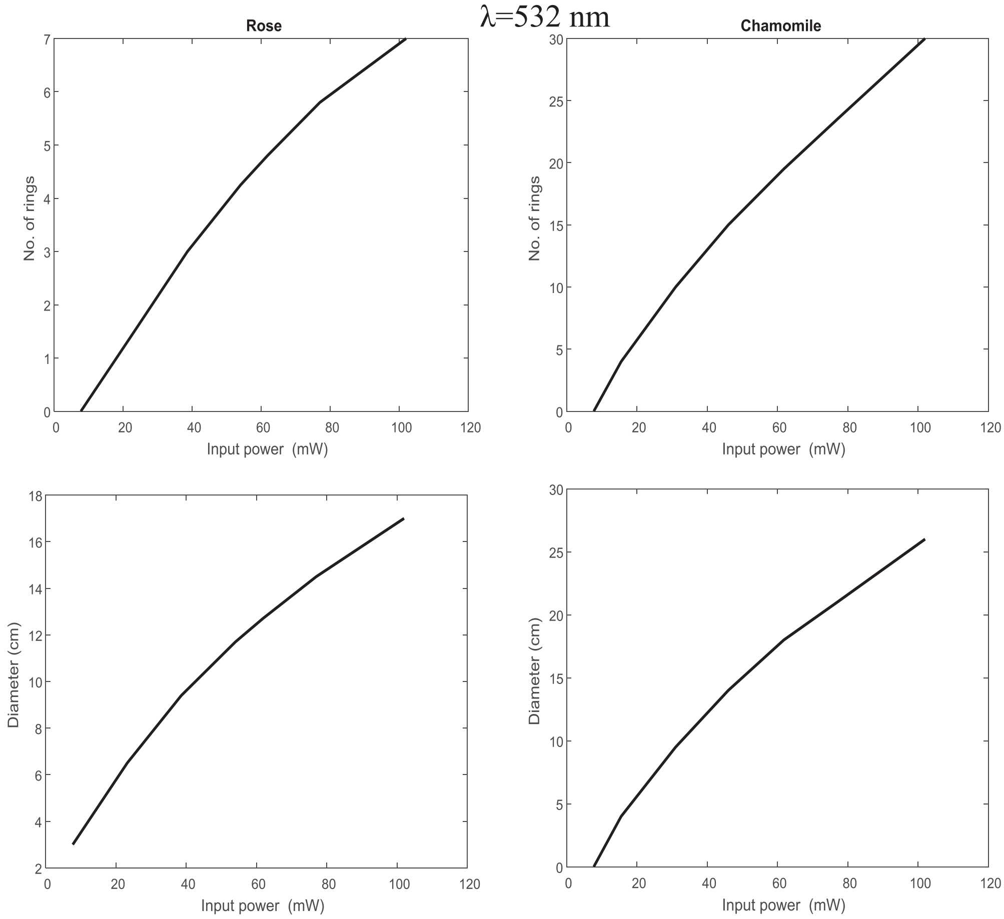
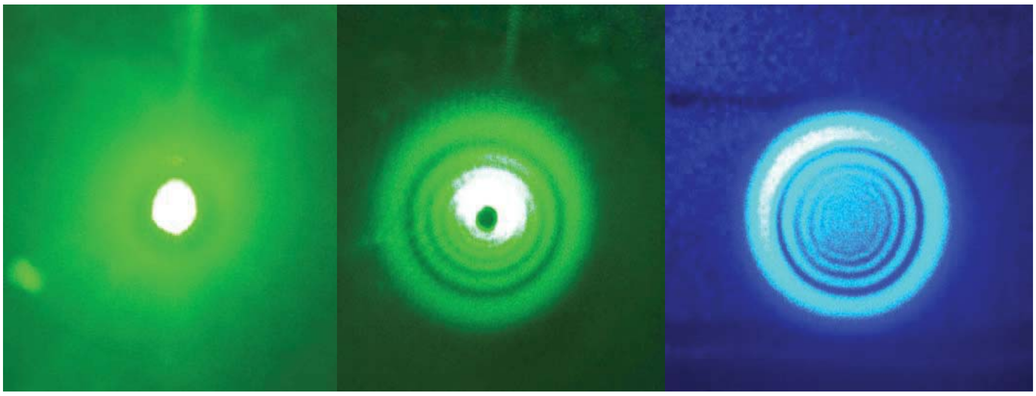
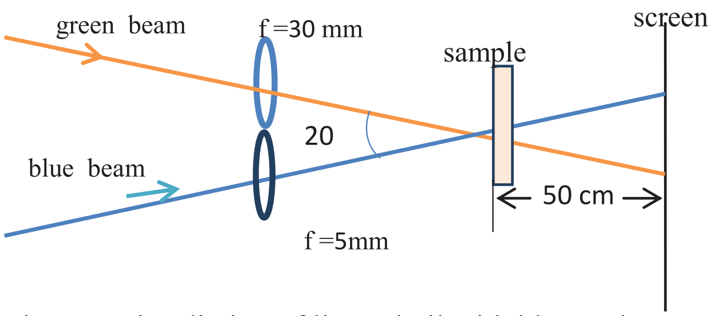


Fig (5): Number of rings, and diameters of outer-most ring for rose and chamomile oils respectively at λ=532 nm.



(a) (b) (c)

Fig(6):spot sizes in linseed oil of green beam in the absence of the blue beam (a) , in the presence of the blue beam (b)and that of the blue beam (c).Notice the birth of green ring pattern (b) in the presence of the blue beam only.



Fig(7): Simultaneous irradiation of linseed oil with blue and green laser beams.

4-Estimation of the nonlinear refractive index, n_2:

The induced refractive index change,Δn, and the magnitude of the effective nonlinear refractive index, n_2, were estimated for chamomileand rose oils via the diffraction ring patterns obtained earlier. The number of bright rings, N, can be approximated as[4]:

$N = (\Delta\phi)_{max} / 2\pi$ …(3),

Where $(\Delta\emptyset)_{max} = k\Delta$ is the phase shift suffered by the laser beam as it traverses a distance, d, in the nonlinear medium, k ($=2\pi/\lambda$) is the light wave-vector and λ is the light wavelength and Δ is the optical path difference, $\Delta = d\Delta n$, so that[4]:

$$\Delta n = \lambda N/d \qquad \ldots(4)$$

and

$$n_2 = \Delta n/I \qquad \ldots(5)$$

I is the laser light intensity (=$2P/\pi\omega^2$ and P is the laser light power) inside the medium. According to equations (4) and (5), Table (3) summarizes the values of Δn and n_2 for rose and chamomile oils at λ = 532 nm.

Table (3): Number of rings,Δn and n_2 for the three samples atλ=532 nm.

Sample	Input power mW	Input intensity W/cm^2	No. of rings	Δn	n_2 (x10^{-6}) cm^2/W
rose oil	102	16636	8	0.004256	0.2558
linseed oil	102	16636	-	-	-
chamomile oil	102	16636	20	0.01064	0.6396

5- Causes of obtained results:

A pump beam having Gaussian intensity distribution is able to stimulate a phase shift, Δϕ, in the shape of bell in the transverse direction with respect to the beam direction [19] as the one shown in fig (8).

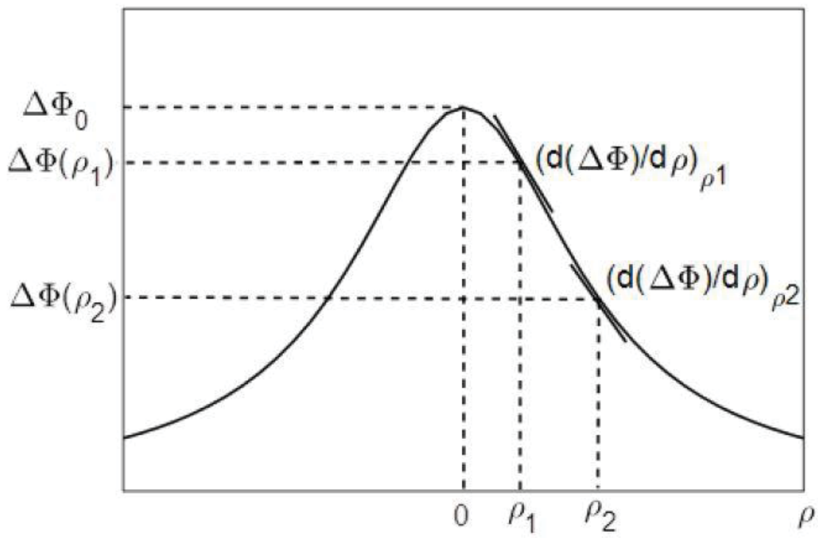


Fig (8): Distribution of phase relation in nonlinear medium [19]. Light diffracted at points ρ_1 and ρ_2 has the same wave- vector and interferes.

For any point, ρ_1, on the Gaussian curve, there always exists another point, ρ_2, on the same curve, having the same slope. The radiation fields from the regions around $\rho_1$and ρ_2 having the same wave vector, should interfer. Maximum destructive and constructive interferences occurs when the change in phase in the point ρ_1, $\Delta\phi(\rho_1)$ and the one from the point ρ_2, $\Delta\phi(\rho_2)$, must verify the relation$\Delta\phi(\rho_1)$-

$\Delta\phi(\rho_2)= m\pi$ where m is a constant being odd or even integer for destructive or constructive interferences respectively.

The total number of rings, N, produced is given by $\Delta\phi_0/2\pi$, where $\Delta\phi_0$is the induced phase shift on the beam axis which increases with the increase of light power, as can be seen in figs (5) . The diameter of the outermost ring in each pattern at each power is determined by $(\partial($ ¿ r ¡/ $)\emptyset_{max}$ [19] once again increases with the increase of light power as shown in fig (5). The outermost ring intensity in each and every pattern is large than the inner ones or compare to the spot size at the screenwhen the input power is low as an indication of self- defocusing or thermal lens occurrence as shown in fig (5) in all ring patterns for all samples examined.

The large absorption coefficients for rose and chamomileatλ= 532 nm (except for linseed) ensures that thermal effects are responsible for the diffraction ring patterns obtained. The low absorption coefficient of linseed oil at λ=532 nm proves our explanation, i.e. disappearance of rings in linseeds oil at this wavelength shown in fig (4a), even for high input power.The green ring pattern in linseed oil appears when a simultaneous irradiation with green and blue laser beams see fig.(6) . The blue beam acts as a pump beam which write a blue ring pattern that was read by the probe green laser beam that appears in a green ring pattern .

6- Conclusion:

The nonlinear refractive index of rose and chamomile oils have been measured. A large thermal-induced third- order nonlinear refractive index, n_2, of the order of $(10^{-7}$-$10^{-6})$ cm^2/W with diffraction ring pattern technique are obtained. The high absorption coefficients of the rose and chamomile oils ensures that thermal effects are responsible for these results. These oils are available worldwide ,they need no solvents ,cheap and shows high nonlinear refractive in comparison with known materials .Green diffraction ring pattern appeared in linseed oil via the simultaneous irradiation with the green and blue laser beams.

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