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Determination of Olive Oil Kerr Constant for Electro Optical Applications

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Abstract:

Electro optics effects are important branches of nonlinear optics. In this research olive oil has been chosen to study its electro optical properties. Olive oil as an organic compound has a centro symmetric molecular structure which means that it has quadratic electro optical properties represented by Kerr effect. These electro optical properties such as transmittance versus applied voltage and birefringence versus the square value of the applied electric field were measured. These properties are obtained for the two types of olive oil (virgin and refined) by analyzing of these properties, the Kerr constant and Kerr coefficient for two types of olive oil have been found at different wavelengths.

Keywords: **Kerr constant, Chromatic dispersion, GVD, Nonlinear coefficient, Optical properties, Olive oil.**

Introduction

The electro optic effect is the change in refractive index of a dc (or low frequency) electric field. In some materials, the change in refractive index depends linearly on the strength of the applied electric field. This change is known as the linear electro optic effect or Pockels effect. Since the linear electro optic effect can be described by a second-order nonlinear susceptibility, a linear electro optic effect can occur only for materials that are noncentrosymmetric. Although the linear electro optic effect can be described in terms of a second order nonlinear susceptibility; a very different mathematical formalism has historically been used to describe the electro optic effect. In centrosymmetric materials (such as liquids and glasses) , the lowest-order change in the refractive index depends quadratically on the strength of the applied dc (or low-frequency) field. This effect is known as the Kerr electro optic effect [1]. A technique based on the Kerr electro optic effect is used for the measurement of electric field strength in dielectric liquids such as olive oil. It utilizes a polarized laser beam as an incident light with the applied dc voltage. Using this technique, it will be able to measure low level electric fields in liquids with small Kerr constants using a short electrode length [2].

Electro optics:

The refractive index of an electro optic medium is a function n(E) of an applied steady electric field E [3]. If the material is centrosymmetric, as is the case for gases, liquids, and certain crystals, n(E) must be an even symmetric function since it must be an even symmetric function since it must be invariant to the reversal of E as :[3]

$$n(E) \approx n - \frac{1}{2} sn^3E^2 \quad \text{………………..(1)}$$

The material is the known as Kerr medium (or Kerr cell). The parameter s is called the Kerr coefficient or the quadratic electro optic coefficient [3].

The applied electric field induces birefringence with an optic axis parallel to the applied field. Light traversing the cell thus encounters two refractive indices for polarizations parallel and perpendicular to the optic axis, and phase retardation results become [4]:

$$\frac{1}{n^2} = \frac{1}{n_o^2} sE^2 \text{or} |\Delta n| = sn_o^3E^2 \text{ ………….(2)}$$

where s is Kerr or quadratic or electro optic experimental coefficient, the birefringence which is the difference between ne (extraordinary refractive index) and no (ordinary refractive index) is found to obey a relation of the form [4]

$$\Delta n = KE^2\lambda \text{ ………………………… (3)}$$

where k is Kerr constant equations.

From eq (2) and eq (3), we find the relationship between K and s to be:

$$K = \frac{sn_o^3}{2\lambda} \text{ …………………………….. (4)}$$

The relative phase retardation for the ordinary and extraordinary components is:

$$\Phi = \frac{2\pi}{\lambda} L\Delta n \text{ ……………………….... (5)}$$

where L is the length of optical path through the electric field E and introducing the Kerr constant:

$$\Phi = \frac{2\pi KV^2L}{d^2} \text{ ………………………. (6)}$$

we have set E = V/d and d is the interelectrode distance. The phase retardation could be measured practically from [3, 4]

$$T = \frac{I}{I_m} = sin^2(\frac{\Phi}{2}) \text{ ……………..…. (7)}$$

where T is the transmittance, I instantaneous value of the transmitted light and I_m denotes the maximum intensity of the transmitted light when the polarizer and analyzer are in perfectly uncrossed position [4].

Measurements:

The olive oil transmission spectrum using UV-VIS spectrometer was measured. Figure 1 shows the transmission spectrum of olive oil.

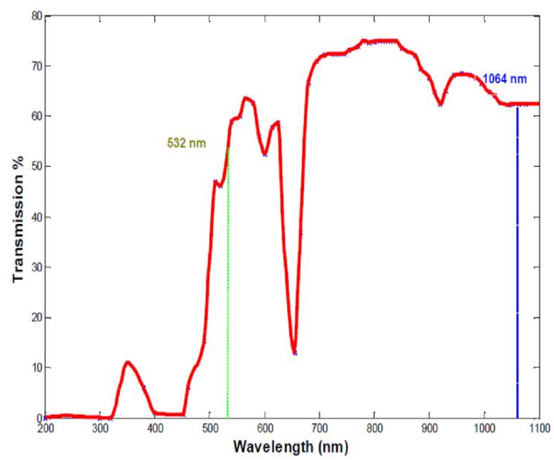

Figure 1: UV-VIS transmission of olive oil

The experimental work based on measuring the olive oil electro optical properties. These can represented by measuring the transmittance of samples at 532nm (100mW), 632.8nm (1mW) and 660nm (200mW) lasers due to varying of the applied external voltage by using Kerr experimental setup.

Two different laser wavelengths (SHG Nd:YAV 532 nm and semiconductor 660 nm) were used to ensure accuracy and study the behaviour of material. A convex lens with focal length 15 cm was used to focus the laser beam. Two linear polarisers have been used which possess the ability to rotate the angle of polarization to 360^0 when the first one set at angle $+45^0$ and located at front of Kerr cell while the second one set at angle 135^0 (-45^0) and located behind the cell. A small glass vessel (L=5.5 cm, D=2.5 cm and H=5.3 cm) was filled with olive oil in which two parallel metal electrodes are placed inside (separation distance d=1 mm and length l=1.8 cm and d/l=0.0555) it is called Kerr cell as shown in Figure 2.

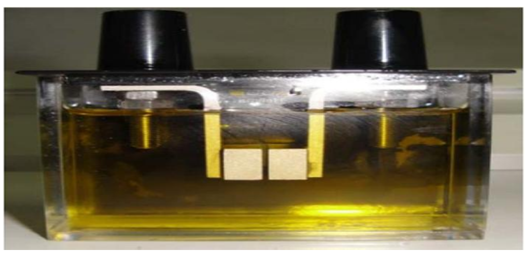

Figure 2: Photograph of Kerr Cell

The Kerr cell was located between two crossed polarizers, each one of them was put at 45^0 as shown in Figure 3, and when laser light beam passes through the first polarizer, it becomes a linearly polarized light beam. The light beam becomes elliptically polarized when passing through the Kerr cell if there is an external applied electric field. When there is no electric field, the output power could be measured approximately equals to zero, which means that the field of view becomes bright, and the output power can be measured which may increase proportionally with the electric field.

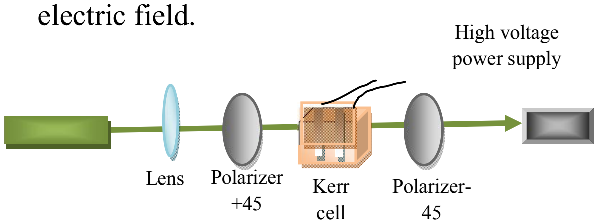

Figure 3: Experimental setup

After building the system shown in figure 3, the laser was turned on and the output laser power was measured by varying the applied voltage from 0 to 10 KV when polarizer's phase difference is 90^0. The maximum power was recorded when the polarizer's phase difference is 0^0. The transmittance was obtained by dividing the instant value of output power by the maximum power.

Calculations and Results:

Figures 4 and 6 show the transmittance T of the virgin and refined olive oil, and figure 5 and 7 show the birefringence Δn versus Square of applied electric field using 660nm, 532nm wavelengths laser sources respectively.

From figures 4 to 7, one can notice that the refined olive has transmittance and birefringence greater than virgin olive oil due to high absorption at this wavelength for virgin olive oil. The transmittance and birefringence for refined and virgin at 532nm are greater the 660nm due to linear absorption is less than 660nm.

Increasing of transmittance for refined olive oil from zero to 1000V for 532nm and to 2000V for 660nm is relatively high because of molecules change their orientation causing nonlinear polarization.

The phase shift is shown in figures 8 and 9 for 660nm and 532nm wavelength respectively.

The Kerr constant was calculated at any wavelength from eq. (3) and Kerr coefficient was calculated from eq. (4).

Where n_0 is the ordinary refractive index of olive oil. It was calculated using Sellmeier equation for different wavelengths [5, 6].

The refined olive oil has maximum Kerr constant at 532nm wavelength that could be used as total internal reflection switch material which costly effective material as shown in Table 1.

Conclusion:

1- The Kerr constant for virgin and refined olive oil is very high compared with other organic compounds that have similar structure like palm oil fatty acid ester which has Kerr constant of $5.2x10^{-17}$ m/V^2 [7]. It's greater than in magnitude from some liquid crystals like MBBA K=$-9.5x10^{-12}$ m/V^2 and EBBA K=$-1.66x10^{-12}$ m/V^2 [6].
2- A self focusing effect appears at wavelength 532nm due to high Kerr constant laser intensity. Causing nonlinear parameters appear self-focusing can obtained when the nonlinear refractive index is positive in sign.
3- The maximum transmittance in Kerr experimental at any wavelength is lower than 1 due to losses caused by reflection, absorption, and scattering. The maximum transmittance is higher than zero because of misalignment of the direction of polarizations relative to the Kerr cell and the polarizer.

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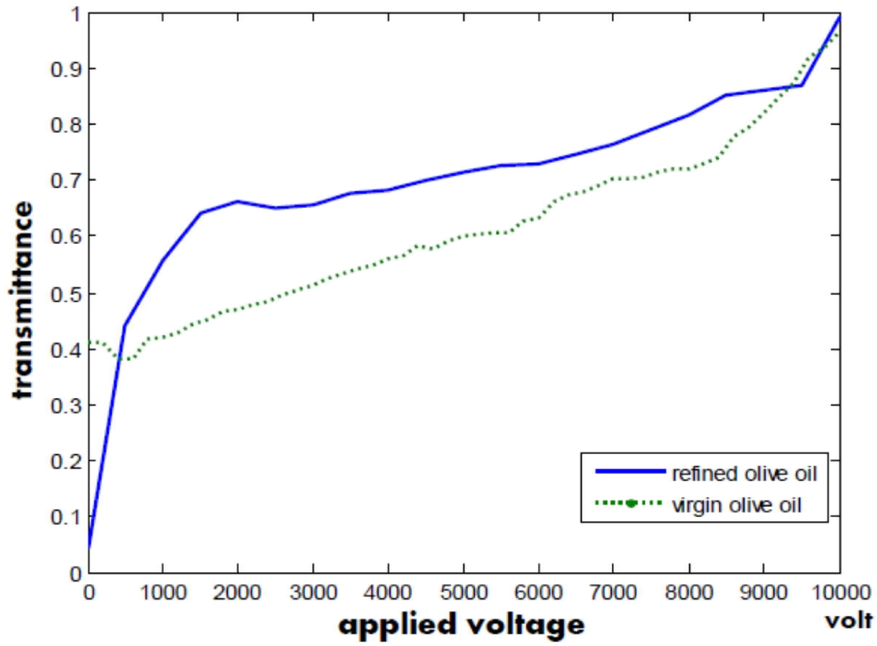

Figure 4: The transmittance of virgin and refined olive oil versus the applied voltage at 660nm.

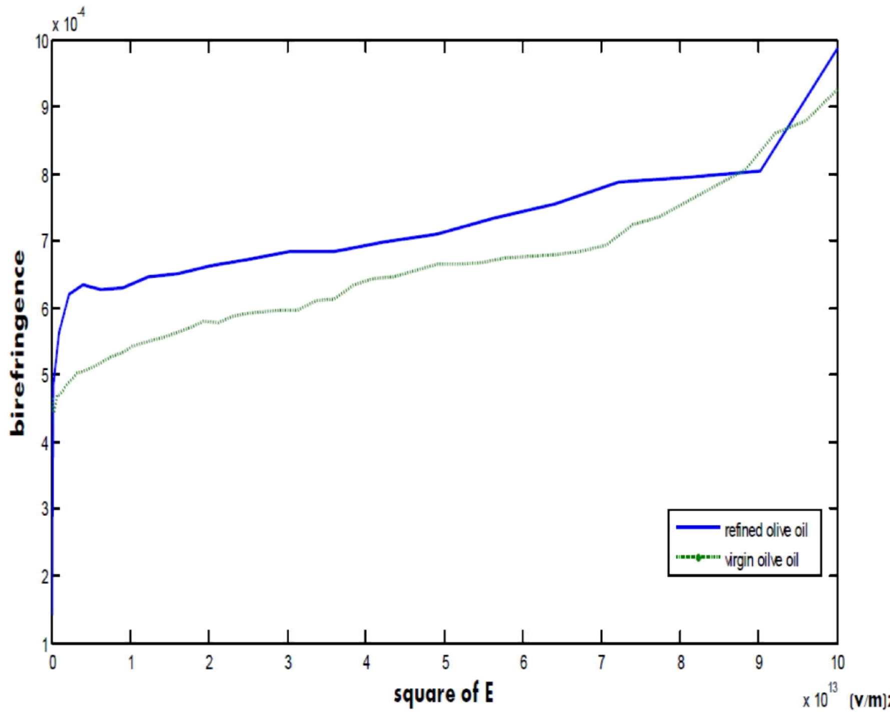

Figure 5: The birefringence Δn versus Square of applied electric field using 660nm.

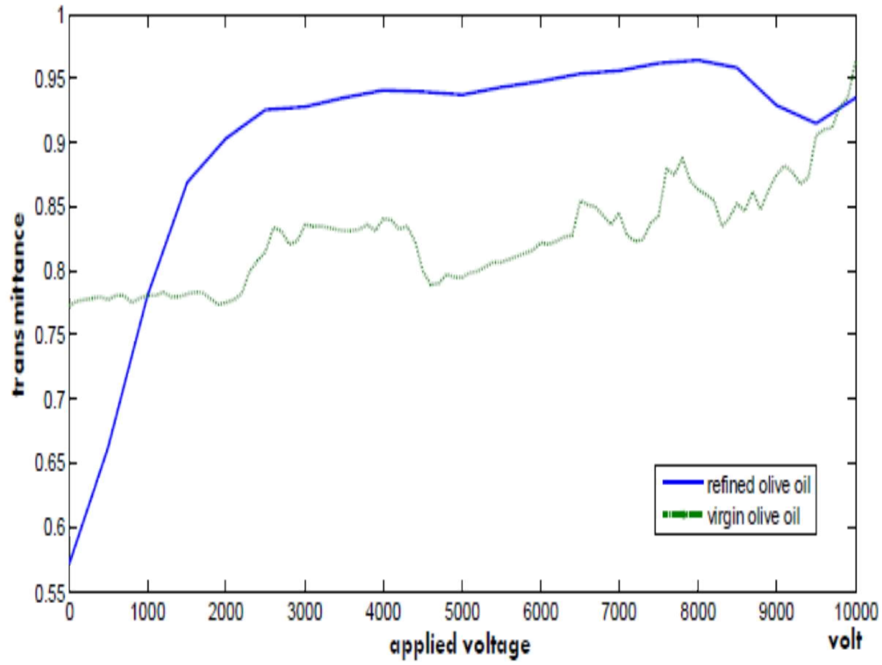

Figure 6: The transmittance of virgin and refined olive oil versus the applied voltage at 532nm.

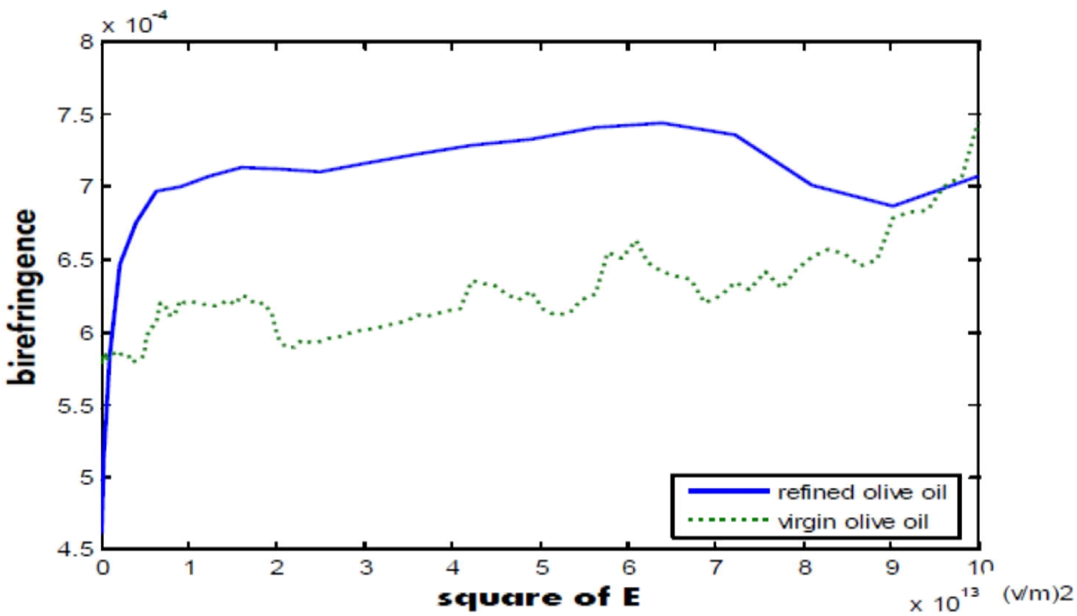

Figure 7: The birefringence Δn versus Square of applied electric field using 532nm.

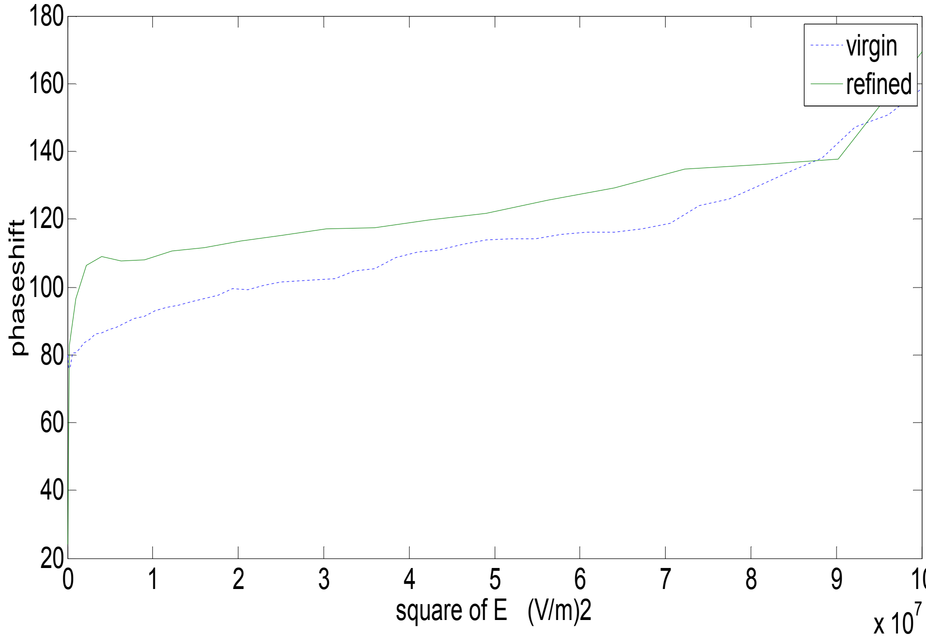

Figure 8: The phase shift versus Square of applied electric field using 660nm.

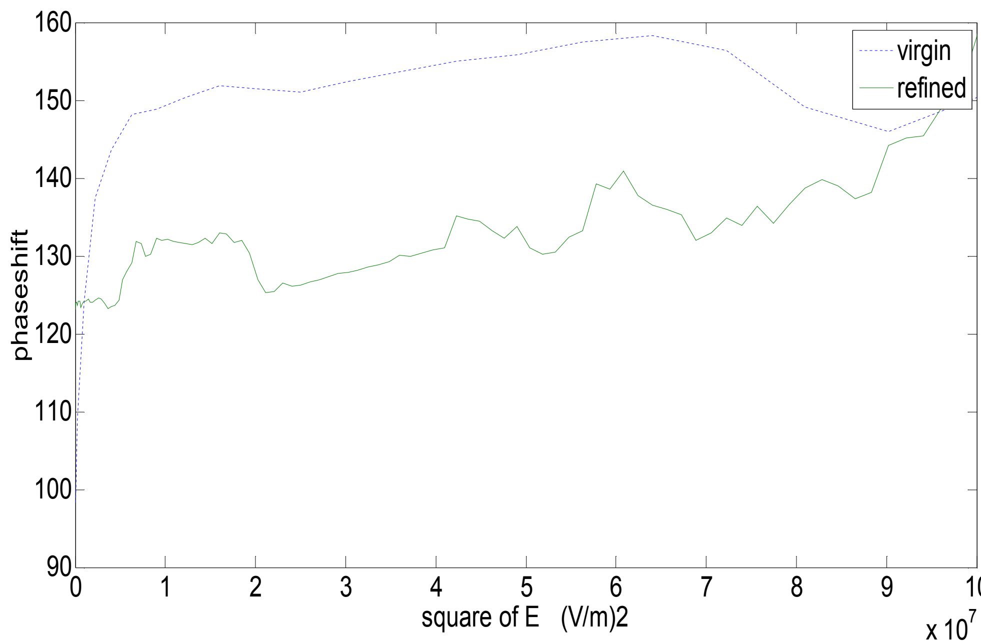

Figure 9: The phase shift versus Square of applied electric field using 532nm.

Table 1: Ordinary refractive index, Kerr constant, and coefficient for virgin and refined olive oil at 660nm and 532nm wavelengths

Laser λ nm	Olive oil type	n_0	Kerr constant $x10^{-12}$ m/v^2	Kerr coefficient $x10^{-18}$ m^2/v^2
660	Virgin	1.4637	17.526	7.3773
660	Refined	1.4637	18.603	7.8306
532	Virgin	1.4721	19.860	6.6239
532	refined	1.4721	21.400	7.1375

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حتساب ثابت كير لزيت الزيتون المستخدم في التطبيقات الكهروبصري

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الخلاصة:

تعتبر الظواهر الكهروبصرية من الفروع المهمة في البصريات اللاخطية. في هذا البحث اختير زيت الزيتون لدراسة خصائصه الكهروبصرية واستعمال هذه الخصائص في التطبيق الفوتوني ليكون مفتاح الانعكاس الداخلي الكلي.ان زيت الزيتون كمركب عضوي يمتلك بناءً جزئياً متناضرا جزئيا الذي يعني انه يمتلك خصائص كهروبصرية تربيعية تتمثل بظاهر كيير. من هذه الخصائص هي النفوذية مقابل الفولتية المطبقة، والانكسار المزدوج مقابل تربيع المجال الكهربائي المطبق. هذه الخصائص قيست لنوعي زيت الزيتون (بكر ومكرر). من تحليل هذه الخصائص اوجد ثابت كيير ومعامل كيير لنوعي زيت الزيتون في اطوال موجية مختلفة. هذه القيم لثابت كيير مفيدة لتحقيق تصميم مفتاح الانعكاس الداخلي الكلي باستعمال زيت الزيتون المكرر خصوصا ان لهذه المادة تصرف بلوري سائل.