Measurement of the Electro-Optic Coefficients In Electro-Optic Crystals using Compensated Sénarmont System

M. A. Rahma H. L. Saadon

College of Science\ University of Basrah

1. Introduction

Electro-optic crystal have received considerable attention for many application due to their large electro-optic (EO) and nonlinear optical coefficients [1,2]. Several techniques have been designed for the characterization of the electro-optic properties of bulk samples [3,4]. The disadvantage of these systems are that it require a high ac modulated voltage (up to 300 V_{p-p}) and the material be made with a large EO coefficients.

In this letter, it is proposed and demonstrated that compensated Sénarmont system measure accurately EO coefficients of, not only bulk sample, but also sample thin films. With this technique, we have used two crystals, the first crystal is delivered by a dc voltage (up to KV) and the other crystal was used to modulated He-Ne laser which delivers by an ac modulated voltage (up to 8 V_{p-p}). Also, here it can be used a crystal thin film instead of the second sample.

2. Electro-Optic characterization

The experimental setup which is proposed and demonstrated for the determination of the linear electro-optic (pockels) coefficients is shown in Fig.1. A dc electric field is applied a cross the first sample S_1 (the first sample can be the KDP or $LiTaO_3$ crystal). An ac electric field is applied on the second sample S_2 (the second sample is $LiTaO_3$ crystal).

A He–Ne laser beam (λ = 632.8 nm) is passed through a polarizer (P) with its polarization direction at 45^o to the birefringence axes of the crystal. The light propagates along the crystal operating as a transverse or longitudinal configuration (propagation direction normal or parallel to the axis of the applied electric field). Behind the sample S_2 is a quarter wave plate $\lambda/4$ (Q) has been rotated with 45^o from the angle which allows the minimum light to reach the photodetection system. The analyzer (A) that oriented at an azimuthal angle β .

In this work we used a photodetection system with high gain photodiode amplifier PDAM, then, the output signal can be recorded on the oscilloscope screen.

For increasing and improving the sensitivity of the method, it is necessary to separate the two voltages by the application of the dc voltage onto the first sample S_1 and ac voltage onto the second sample S_2. This limitation allowed us to use small alternating voltage about (6-8) Volts instead of using ac voltage nearly 300 Volts as done in the other systems [2,4].

Also, this modification has given us the ability to increase the dc voltage without taking any attention of the ac voltage.

With this system which is shown in Fig.1, the field−induced phase retardation Γ (E) can be directly compensated in relation to the angle β of the analyzer and is given by

$$\Gamma(E) = 2\beta \quad (1)$$

Then, the EO coefficient in this case can be expressed as

$$r = \left(\frac{\lambda d}{\pi n^3 L}\right)\left(\frac{\beta_E}{V_{dc}}\right) \quad (2)$$

3. Result and discussion

In this work, we have used two samples with different configurations the first sample is congruent $LiTaO_3$ crystal with dimension 6x5x10 mm^3 and the other one is KDP crystal with 5x10x4 mm^3. Here, we determined the parameters r_{22}, r_{41}, and V_π. These parameters have been done when the output laser reaches intensity minima.

Figs.2 and 3 show that the analyzer angle β as a function of a dc voltage V_{dc}. To reduce the effect of the random error, the results were fitted by a linear least square method and which led to straight lines. By using of the slopes $d\beta/dV_{dc}$ from the curves in Eq. (2), the EO coefficients r_{22} = 0.13 pm/V for $LiTaO_3$ crystal and r_{41}=8.74 pm/V for KDP crystal. Hence, the obtained values of its electro−optic coefficients showed a good agreement with those reported in the literature with other system [5, 6].

With this system, we can determine the frequency dependence of EO coefficient for a crystal. The dependence of the coefficient on frequency for KDP can be shown in Fig.4. The obtained results now that the EO coefficient r_{41} decreases with increasing the frequency up to 100 kHz.

4. Summary and Conclusion

In this paper, compensated Sénarmont system was present. This system can be used to measure EO coefficients of, not only bulk crystal, but crystal thin films, corresponding to the laser beam incidence being parallel or vertical to the modulation electric field direction. Furthermore, the tensor components, both r_{13} and r_{33}, of EO coefficient, can be measured simultaneously. In comparison with the compensated Sénarmont and other measurement methods, this method has any advantages, such as simple experimental configuration, easy operation, high measurement precision in crystals even if they posses small length to width ratio. The most outstanding advantage is that the second sample does not need a high ac voltage, while the first sample under study can be delivered by a high dc voltage. Therefore, it is especially suitable to measure EO coefficients of bulk and thin film samples.

References

[1] S. Juodkazis, V. Mizeikis, M. Sudzius, H. Misawa, K. Kitamura, S. Takekawa, E. G. Gamaly, W. Z. Krolikowski, and A. V. Rode, "Laser induced memory bits in photorefractive $LiNbO_3$ and $LiTaO_3$ ", Appl. Phys. A 93, 129, 2008.

[2] H. L. Saadon, M. A. Rahma, A. F. Marhoon, N. Theofanous, and M. Aillerie, "Thermo-optic characterization of KDP single crystals by a modified Sénarmont setup for electro-optic modulation system", Chinese Opt. Lett. 7, 632, 2009.

[3] N. G. Theofanous, M. Aillerie, M. D. Fontana, and G. E. Alexakis, "A frequency doubling electro-optic modulation system for Pockels effect measurements: Application in $LiNbO_3$ ", Rev. Sci. instrum. 88, 1997.

[4] M. Aillerie, N. Theofanous, and M. D. Fontana, "Measurement of the electro-optic coefficients: description and comparison of the experimental techniques", Appl. Phys. B 70, 317, 2000.

[5] P. V. Lenzo, E. H. Turner, E. G. Spencer, and A. A. Ballman, "Electro-optic coefficients and elastic-wave propagation in single-domain ferroelectric lithium tantalate", Appl. Phys. Lett. 8, 81, 1966.

[6] G. W. C. Kaye and T. H. Laby, Tables of physical and chemical constants (Longman Group Ltd, London, 1995).

FIGURE CAPTION

Figure 1 Compensated Sénarmont system

Figure 2 Analyzer angle β as a function of the dc applied voltage of $LiTaO_3$ crystal

Figure 3 Analyzer angle β as a function of the dc applied voltage of KDP crystal

Figure 4 Frequency dependence of EO coefficient in KDP crystal

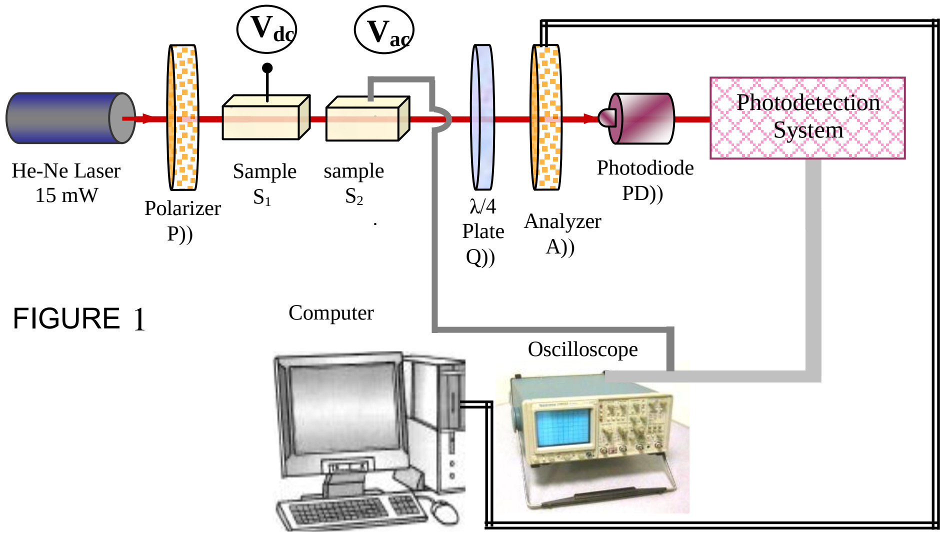

FIGURE 1

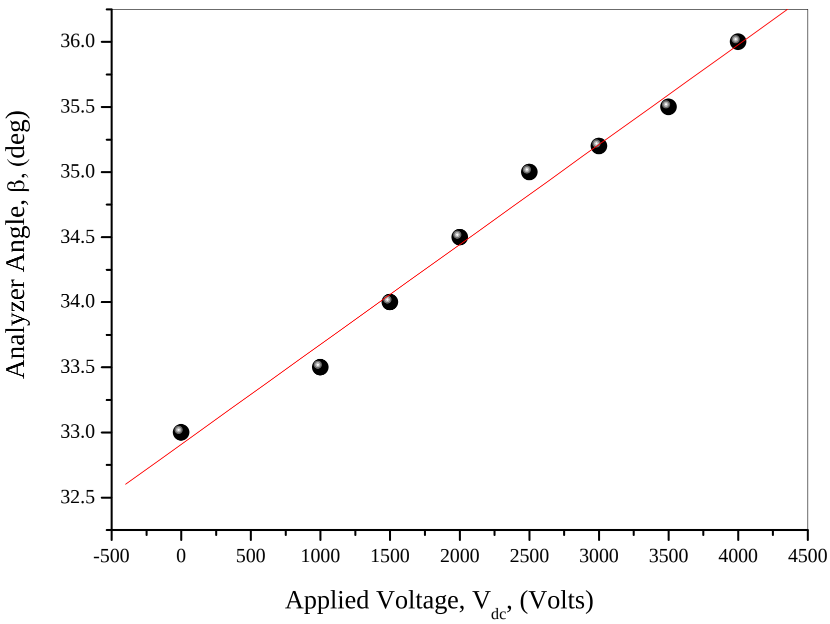

FIGURE 2

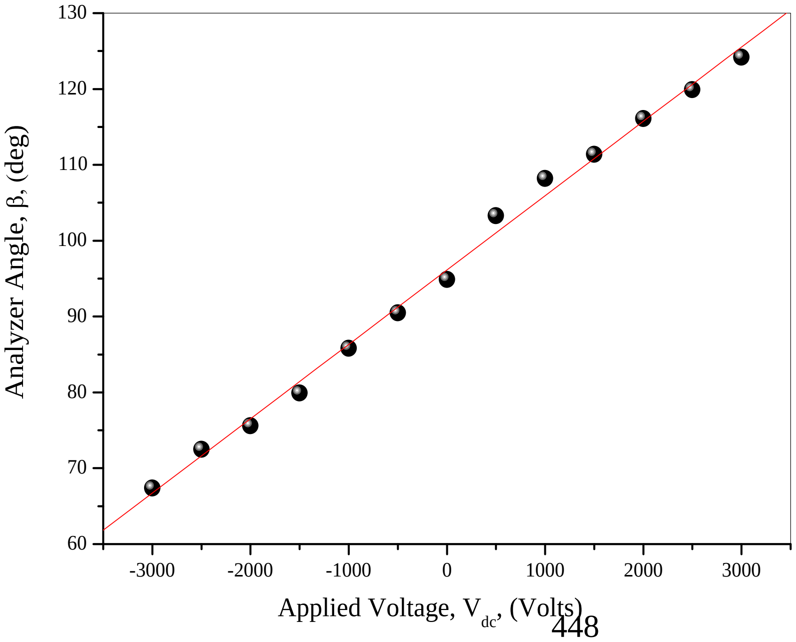

FIGURE 3

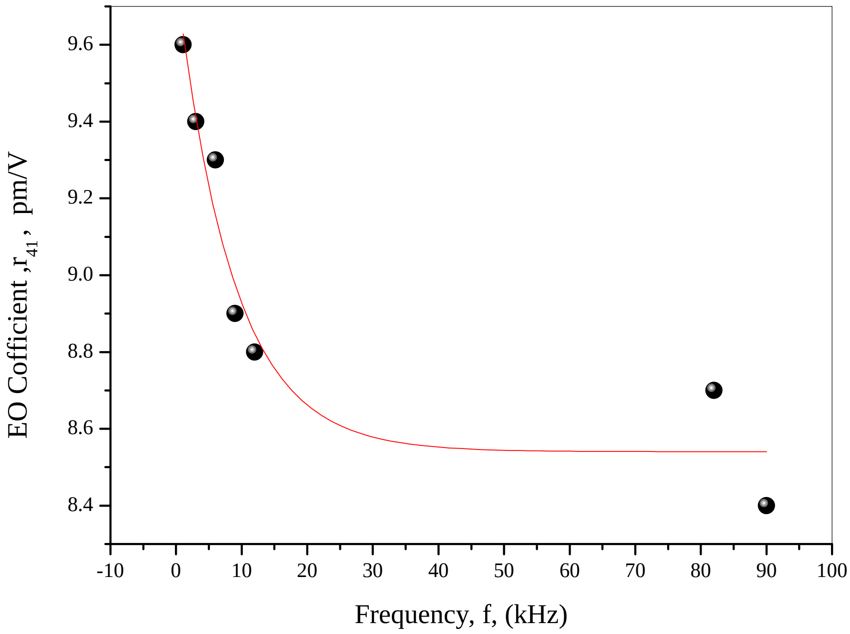
EO Cofficient ,r41 , pm/V
9.6
9.4
9.2
9.0
8.8
8.6
8.4
-10
0
10
20
30
40
50
60
70
80
90
100
Frequency, f, (kHz)

FIGURE 4