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The instability of the Amplitude modulator using Lithium Niobate crystal

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Abstract: This article discusses introducing a group of practical measurements that pinpoint one of the most important problem of amplitude modulation using Pockels cell, which is the instability of the modulator's output with the temperature.
Key words: Lithium Niobate crystal, Pockels cell, Amplitude electro-optical modulator, Half-Wave Voltage.

1-Introduction:

Pockels cell is an important tool in optical modulation. The simplest Electro- optical modulator setup is pockels cell between two polarizers, but this setup has many problems [1]. As a Pockels cell, Lithium Niobate is widely used because, it owns a big value of electro-optical coefficient [2].In this article, we introduce multiple practical measurements, which point out an important disadvantage of this cell as amplitude modulator, which is the instability of the cell optical output because of the dependency of the electro optic coefficient on both temperature and frequency, which effect the cell's half-wave voltage, which is an important parameter on determining the optical output [3]. In 2011, Dang Thanh Bui and two other published paper about Improving the Behavior of an Electro-Optic Modulator by Controlling Its Temperature. They obtained the improvement of the stability of an electro-optic modulator from its temperature control [4].In 2009, Wang Yan-Hong, Guo Pan and two other published paper about the Temperature sensibility for electro-optic modulator based on LiNbO3 crystal [5]. In this paper, the theoretical analysis and numerical simulation with regard to the temperature characteristics of LiNbO3 crystal electro-optic modulator are putted in practice by applying linear electro-optic effect coupling wave theory [5].

In 2004, P. GÓRSKI and two other published paper talked about the Temperature dependence of the electrooptic coefficients [6]. In this paper, the searcher done Measurements of temperature dependence of linear electrooptic coefficients defined in terms of the electric field $r22$ and the induced polarization $m22$ were made for $LiNbO3$ within the temperature range 25°C- 200°C [6].

3-Theoritical Study

The principal of electro-optical modulator based on linear electro- optical effect (pockels effect) [7]. The birefringence in this effect is proportional to the electric field ,and it is occurs only in crystal that lack inversion symmetry ,such as Lithium Niobate (LinbO3).where Lithium Niobate is a negative uniaxial crystal [8].

Transverse Pockels amplitude modulator was used in our work. In this cell, the field is applied perpendicular to the direction of propagation, and the half wave voltage is low when compared with longitudinal pockels cell [9].

If we started by applying DC voltage to determine a half wave voltage then we find that half wave voltage for transverse Pockels is given by [10]:

$$U_\pi = \frac{\lambda}{2n_0^3 r22}\left(\frac{d}{L}\right) \quad \text{....... (1)}$$

Now, when we apply (AC) voltage ($U_m \sin \omega t$) in addition to the DC voltage, we got Transmittance of the system given by:

$$T = sin^2\left(\frac{\pi}{2}\frac{U}{U_\pi}\right) = sin^2\left[\frac{\pi}{2U_\pi}(U_0 + U_m \sin \omega t)\right] \quad \text{....... (2)}$$

in the most times.$U_m \ll U_m$ Where

When we choose $U_0 = U_\pi/2$ as shown in figure (1), eq (2) becomes as follows[11]:

$$T \approx \frac{1}{2} + \frac{\pi U_\pi}{U_m}\sin \omega t \quad \text{....... (3)}$$

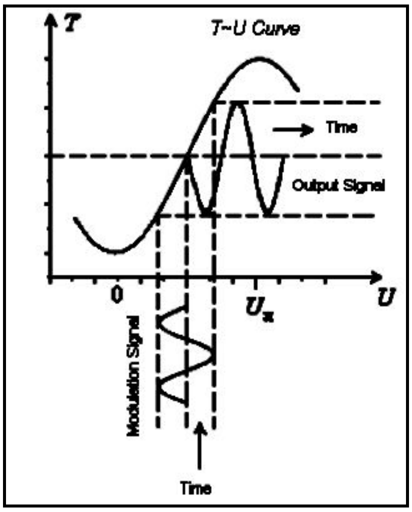

Figure (1): Applying DC voltage $U_0 = U_\pi/2$.

If we chose$U_0 = 0\ (orU_\pi)$, the output signal will suffer from frequency-doubling distortion, as shown in figure (2), and eq (2) will become:

$$T = \frac{1}{8}\left(\frac{\pi U_m}{U_\pi}\right)^2 (1 - \cos 2\omega t) \quad \text{....... (4)}$$

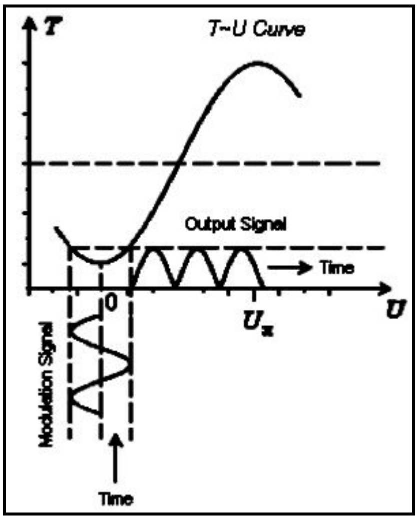

Figure (2): Applying DC voltage $U_0 = 0\ (orU_\pi)$

4-Experimental details:

4 -1- The experimental setup:

We arrange the system as shown in figure (3), where we put the laser He-Ne then we put a polarizer, which provides the polarization of the incoming light in the vertical axis. Then we put the Pockels cell with an angle of 45 with respect to the polarization of the light incoming from the polarizer, next we put the analyzer normal to the polarizer's axis[12]. At the end, The Optical Signal received with photo detector, which connected to Oscilloscope.

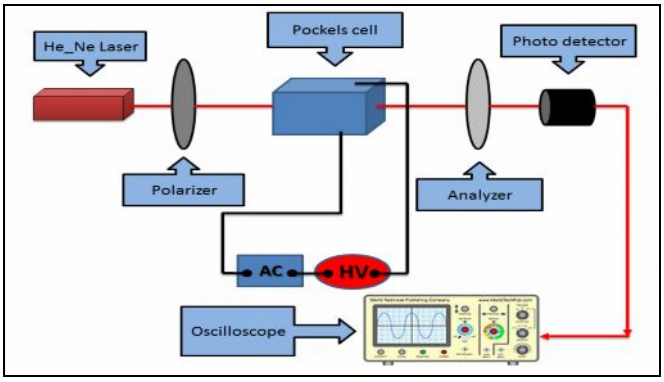

Figure (1)

4-2- The first stage: determination of half wave voltage.

In this stage, we connected pockels cell to a Dc power supply. Then we applied a Dc voltage on the cell and read the output voltage from a voltage meter.

In this step, we measured the half wave voltage in two different times, and the result was as it shown in the figures (4), (5):

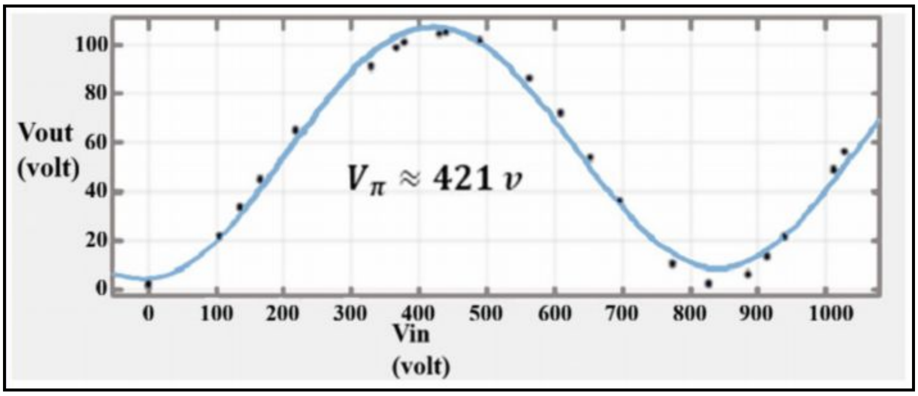

Figure (3): determination of half-wave voltage at time t_1.

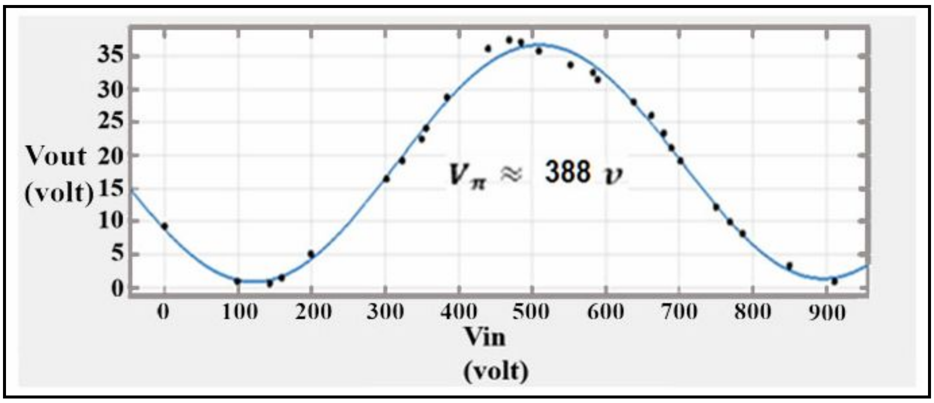

Figure (4): determination of half-wave voltage at time t_2 .

4-3- The Second stage: Modulate sinusoidal signal:

In this step we applied Dc voltage together with Ac signal (with different frequencies), but with the same peak- to-peak voltage.

1- By Applying sinusoidal signal (12.2 V peak-to- peak ,10.2 KH) , and Dc voltage changing starting from zero, we got the result as shown in figure (6):

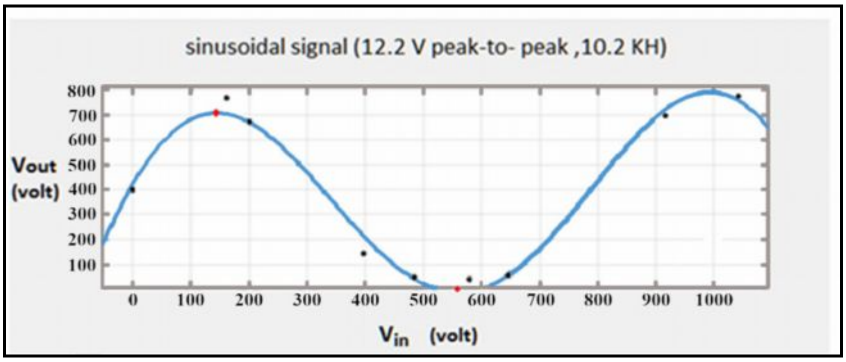

Figure (6): Applying sinusoidal signal (12.2 V peak-to- peak ,10.2 KH).

2- By Applying sinusoidal signal (12.2 V peak-to-peak , 7.143 KH) , and Dc voltage changing starting from zero, we got the result as shown in figure (7):

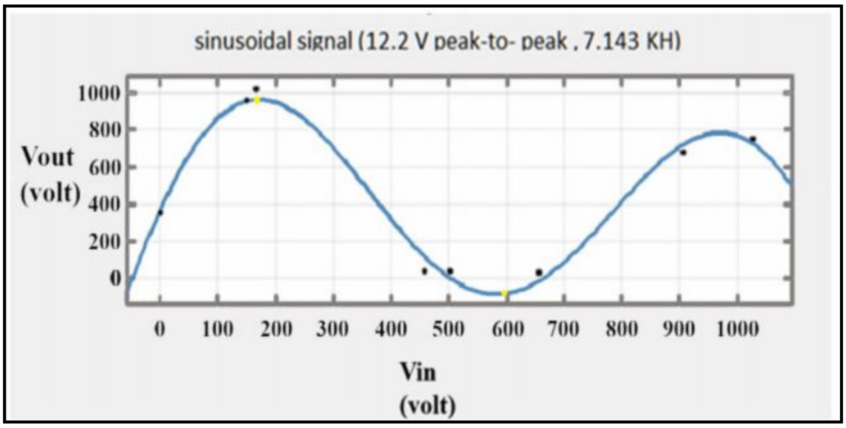

Figure (7): Applying sinusoidal signal (12.2 V peak-to- peak , 7.143 KH).

3- By Applying sinusoidal signal (12.2 V peak-to-peak , 5 KH) , and Dc voltage changing starting from zero, we got the result as shown in figure (8):

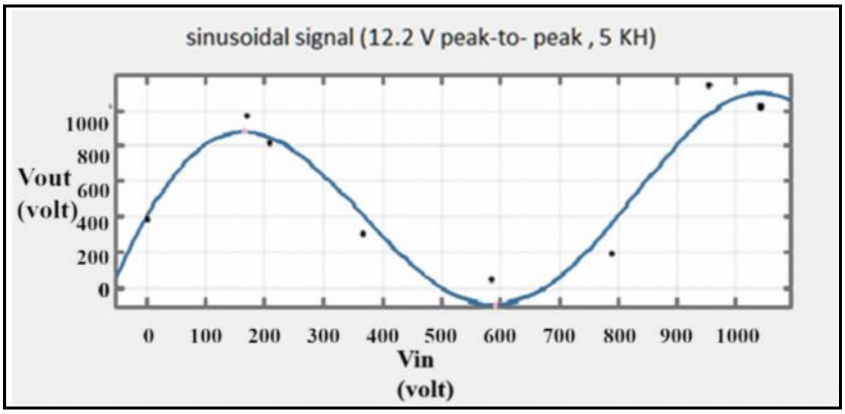

Figure (8): Applying sinusoidal signal (12.2 V peak-to- peak , 5 KH).

5-Discussion and results:

Based on the report of our practical measurements, we got important results: From the figure (1) and (2), we can see that the half-wave voltage is different from measure to other and from time to time, and we can explain that due to many causes, and the most important causes are:

A-The random temperature changes where when the changes in temperature lead to change the electro-optical coefficient r_{22} and this change consequently effect on the half-wave voltage and this is very clear from the eq (1). And it's the same results obtained by [6].

6-Conclusions

In this work we reported several measurement which proof the instability of Pockels cell in amplitude modulation, we supported the measurements with basic theoretical study and a discussion which may help the research on further work to improve the amplitude modulation of such cells in such setup.

c- There is s drift from the linear area towards left or right during these practical measurements. The important reason of this drift is the random change in temperature.

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