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Theoretical Study of Optical Field Distribution of TeO_2 Modulator Diffraction

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Abstract

In this paper, attention is focused on the analysis of the modulation transfer function form and its dependence on the normalized distance along the crystal (ξ) and peak phase delay (α). The numerical calculations show that the diffracted beam profile has very complicated waveform structure depending on both acoustic and optical parameters.

Keywords: Optical Field Distribution, transfer function, TeO_2 Modulator.

Introduction

For each application in optical single processing, the optical carriers are conditioned to have a required degree of spatial and temporal coherence [1]. However, during the propagation of the carriers through inhomogeneous media, and hence their initial recorded, means have to be provided to reduce this propagation noise, i.e. to decrease the speckle structure in the propagated signals. One of the possible solutions is to add artificially, dynamically changing fluctuations, using moving diffusers, exploiting mechanical vibration of optical media, using liquid crystals, etc allows smoothing the phase characteristics of the optical field [2]. It is evident that the speed of the phase change of the separate rays of the optical beam (i.e. the speed of destroying the spatial coherence) has to be much large than modulation speed of the transmitted signal [3]. The possibility of the application of sound-light interaction for optical image structure control was first pointed out in 1984 [4]. It has been proved that the TeO_2 cell operates as a modulator of spatial frequencies with respect to the input optical signal (optical image). The particular form of the transfer function depends on the structure of the acoustic field in the cell and on the interaction geometry [5].

Theory

For the theoretical description we will use the plane wave approach which was developed in several publications. Where the sound-light interaction is considered however the beam profile is described via the introduction of the transfer function[6]. In case when only one order is consider, the following set of equations can be derived for the amplitude of the diffracted waves [7]:

$$\frac{dE_1}{d\xi} = -i\frac{\alpha}{2}\exp(iQ\xi\delta/2)E_0 \quad \text{..........................(1)}$$

where E_0, E_1 is the complex amplitude of the plane wave of the 0^{th},1^{st} order, respectively $\xi = L/z$ is the normalized distance along the crystal, L is the length of the crystal; $\alpha = CkSL/2$, C is the effective elasto-optic coefficient of the material; k is the propagation constant of light into the media; S : is the amplitude of the sound; $Q = 2\pi L\lambda/\Lambda^2$ is the Klein-Cook parameter; λ and Λ : are the wavelengths of light and sound, respectively and δ; is the angular deviation with respect to the Bragg angle[8].

The solution of this system for the +1 diffraction order is:

$$E_1(\xi) = E_{incident}\exp\left(\frac{i\delta Q\xi}{4}\right)\left(-i\frac{\alpha}{2}\frac{\sin\left[\left(\frac{\delta Q}{4}\right)^2+\left(\frac{\alpha}{2}\right)^2\right]^{1/2}}{\sqrt{\left(\frac{\delta Q}{4}\right)^2+\left(\frac{\alpha}{2}\right)^2}}\xi\right) \quad \text{..(2)}$$

The solution of equation (1) at the boundary conditions:

$E_1(0)=0$; $E_0(0)= E_{incident}$

The form of (2) allows introducing the transfer function of the plane wave propagated through the cell [9,10]. This function can be defined as:

$$H_1(\delta) = \frac{E_1(\xi)\big|_{\xi=1}}{E_{incident}} \quad \text{.................................} (3)$$

and the optical field distribution of the 1^{st} order can be written as:

$$E_1(r) = \int_{-\infty}^{\infty} E_{incident}(\delta) H_1(\delta) \exp\left(i2\pi \frac{\delta}{2\Lambda} r\right) d\left(\frac{\delta}{2\Lambda}\right)$$

.....................................(4)

The expression (4) allows deducing the profile of the diffracted beam on the basis of the distribution of the incident beam.

If the incident beam is Gaussian, which distribution is described as:

$$E_{incident}(\delta) = E_{incident} \exp\left[-\frac{1}{2}\left(\frac{\pi\sigma}{\Lambda}\right)^2 \delta^2\right]$$

...................................(5)

where σ is the half-width of the beam, so equation(5) with taking into account (3) transforms into:

$$E_1(r) = \int_{-\infty}^{\infty} E_{incident} \exp\left[-\frac{1}{2}\left(\frac{\pi\sigma}{\Lambda}\right)^2 \delta^2\right] \left\{\left(-i\frac{\alpha}{2}\right) \exp\left(\frac{i\delta Q}{4}\right) \sin c\left[\left(\frac{\delta Q}{4}\right)^2 + \left(\frac{\alpha}{2}\right)^2\right]^{1/2}\right\} \exp\left(i2\pi \frac{\delta}{2\Lambda} r\right) d\left(\frac{\delta}{2\Lambda}\right)$$

...(6)

where r and $\delta/2\Lambda$ can be considered as the variables of the Fourier transform.

Simulation Results:

This paper contains some result on the computer simulation of optical field distribution for modulator diffraction.

Fig.(1) presents a number of transfer functions(H_1) calculated in accordance with equation3 for different normalized distance along the cell (ξ). It is clear that maximal peak is introduced by increasing length of the cell and a maximal value of transfer function that can be got at increases in the normalized distance along the cell (ξ) [5, 11].

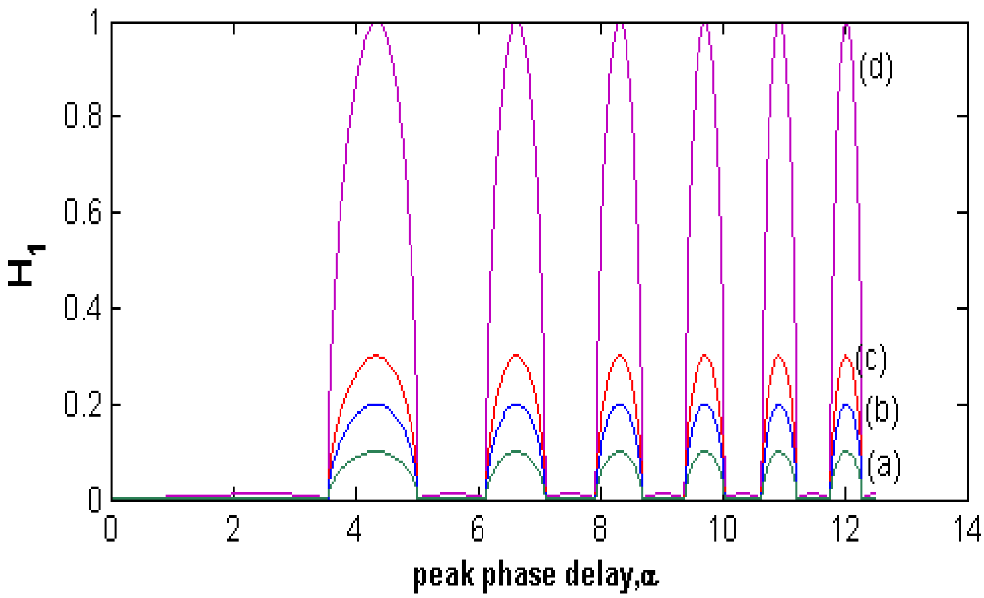

Fig.(1) Transfer function versus with peak phase delay(α) with ξ : (a) 0.1, (b) 0.2 ,(c) 0.3 , (d) 1.

Fig.(2) show transfer function versus the normalized distance along the cell (ξ) at different peak phase delay(α) .Thus, as the normalized distance along the cell is increased, transfer function increases to maximum, after increase in normalized distance, the transfer function starts to decreases value.

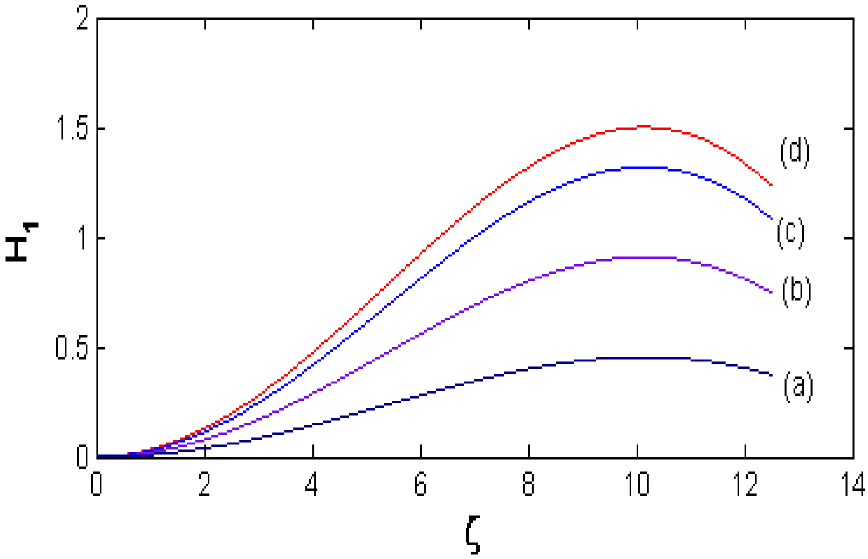

Fig.(2) Transfer function versus with the normalized distance along the cell (ξ) with α :(a) 0.1, (b) 0.2 ,(c) 0.3 , (d) 0.4.

The simulation result for optical field distribution of crystal diffraction as shown in Fig.(3). Note from the figure a gradual increase in peak phase delay (α) produces approximately increase in the optical field distribution until reaching at α=1.7 after this value, the optical distribution remains nearly constant value until reaching at value α=12 , after then increase as the peak phase delay increases.

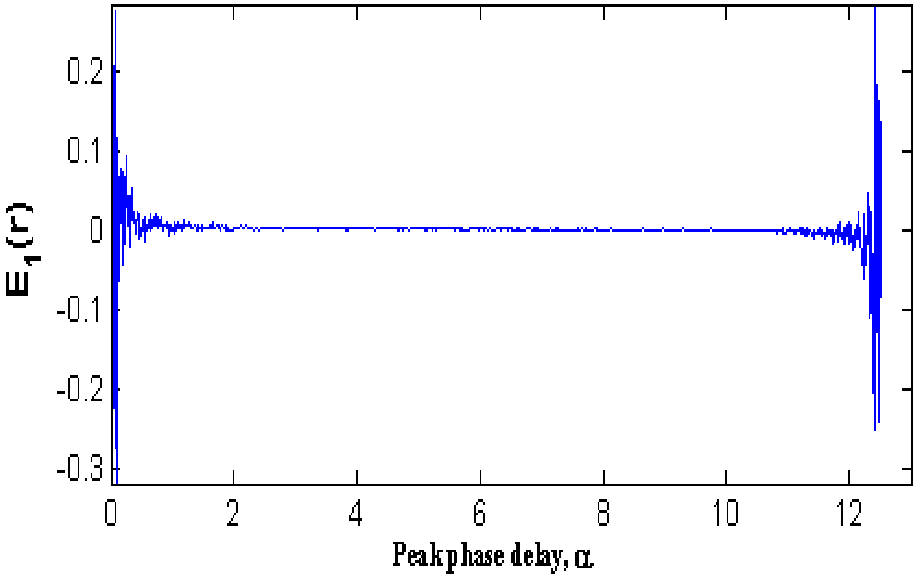

Fig.(3) Optical field distribution of crystal diffraction versus peak phase delay (α) at values $E_{incident}$ ***=1, Q=1, δ=0.93 mrad.***

As compared with optical field distribution versus normalized distance along the cell (ξ), we noted the transfer function is slightly decreases to zero as shown in Fig.(4).

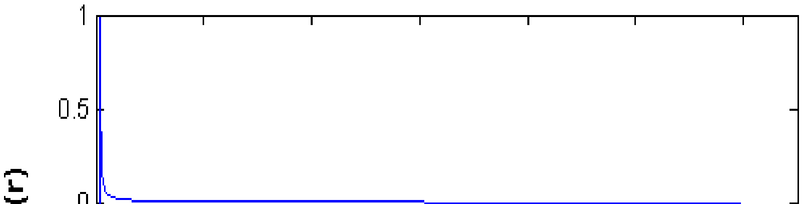

Fig.(4) Optical field distribution of crystal diffraction versus the normalized distance along the cell (ξ) at values $E_{incident}$ ***=1, Q=1, δ=0.93 mrad.***

Conclusion

The transfer function describes those changes in the signal spectrum that are caused by the selectivity of the electric, acoustic effect. It noticed that the transfer function does not give a complete solution of the problem of optical signal propagation through the crystal because the function does not take into account a finite normalized distance along the cell. It has been shown that variations of normalized distance a long the cell (ξ) and peak phase delay lead to improve the optical field distribution.

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الخلاصة

تركز الاهتمام في هذا البحث على تحليل شكل دالة النقل المضمن واعتمادها على المسافة الطبيعية على طول البلورة (ξ) وتأخير قمة الطور (α). لقد بينت الحسابات العددية ان هيئة الحزمة المنحرفة شديدة التعقيد من حيث تركيب جبهة الموجة اعتمادا على كل من المعلمات الصوتية والبصرية .