LOCAL FIELD WITHIN A NON LINEAR THIN FILM ILLUMINATED BY A GAUSSIAN LASER BEAM

R. Chifahi & R. Mountasser
Laboratoy of Optoelectronics, Optical Analysis and Simulation,
University of Hassan II - Mohammedia, College of Sciences and Technics, PO Box 146, Mohammedia city, Morocco.
*Corresponding author. E-mail: mountasser@yahoo.com

ABSTRACT
In this communication, we present a numerical study of the nonlinear local electrical field within a nonlinear Kerr material thin film. The thin film is illuminated in oblique incidence by a strong gaussian laser beam.

Keywords: *optical Kerr effect, nonlinear thin film, all optical-switching.*

1. INTRODUCTION

We consider an optical thin Kerr layer with thickness *e* and an intensity-dependent refractive index, given by: $n = n_0 + n_2 I$, where n_0 and n_2 are respectively, the linear index and Kerr coefficient and I the local intensity. Two identical linear media whose index of refraction n_1 is slightly higher than n_0 surround the layer (figure.1). The layer is illuminated by a gaussian laser beam under an angle of incidence θ_1 slightly lower than the critical angle of incidence $\theta_c = \arcsin(n_0/n_1)$.

By increasing the intensity I, the optical refractive index n of the thin film increases. This leads to a sudden increase in the transittance of the thin layer.

This device is susceptible to play a very important role in ultra fast all optical switching, optical limitation, and optical logic gates [1, 2, 3, 4]. This configuration allows also the direct determination of the nonlinear refractive index (n_2) of non linear materials with a great sensibility [5].

Considering an average intensity I in the thin layer, the plane wave model allows the determination of the expression of the explicit non-linear transmittance of the thin layer [5, 6].

But a rigorous study needs an exact determination of the profile of the local luminous intensity in the cavity. In our case the incident wave has a gaussian profile and the study of the local field in the cavity can only be done numerically.

Several authors have studied numerically the propagation of a gaussian beam with oblique incidence in a nonlinear thin layer [2, 3, 7]. In their studies, they have considered only the case of total reflection at low incident intensities. They were particularly, interested by the variations of the nonlinear transmittance in function of the incident intensity. But they have not presented a munitious study showing how is the profile of the local electrical field within the nonlinear thin film.

In this work, we study the local field in the thin film illuminated by a gaussian laser beam in oblique incidence for the non resonant case.

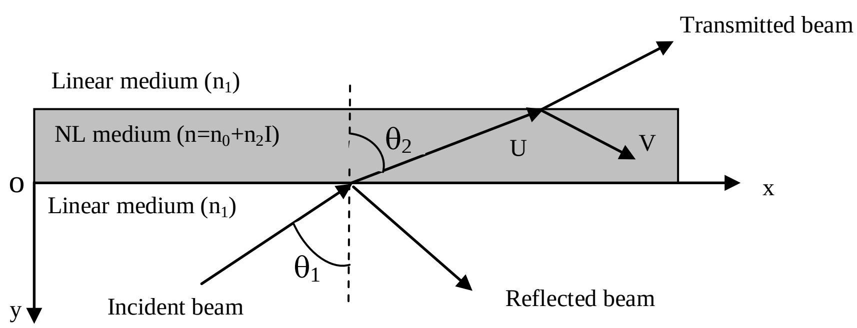

Fig.1. Nonlinear optical Kerr medium ($n = n_0 + n_2 I$) sandwiched between two identical linear medium ($n_1 > n_0$). U and V are respectively the Forward and Backward electrical field in the layer.

2. THEORETICAL MODEL

Following the thickness of the film and the beam-waist, we can distinguish two cases: the resonant case and the non resonant case. In the former there is an overlapping between transmitted and reflected beams within the thin film and in the second case there is no overlapping between beams.

In general, the electrical field in the cavity can be separated to its two components: forward field *U* and the backward field V. In a nonlinear medium, the two components are coupled and the Maxwell equations are given by [7]:

$$-2jk\frac{\partial U}{\partial y}+2j\beta\frac{\partial U}{\partial x}+\frac{\partial^2 U}{\partial x^2}=A_{NL}(|U|^2+2|V|^2)U^2 \qquad (1)$$

$$2jk\frac{\partial V}{\partial y}+2j\beta\frac{\partial V}{\partial x}+\frac{\partial^2 V}{\partial x^2}=A_{NL}(|V|^2+2|U|^2)V^2 \qquad (2)$$

With,

$$\beta=\frac{\omega}{c}n_1\sin(\theta_1)=\frac{\omega}{c}n_0\sin(\theta_2),$$

$$k=\left[(\frac{\omega}{c}n_0)^2-(\beta)^2\right]^{1/2},$$

$$A_{NL}=-2\frac{\omega^2}{c^2}n_0n_2.$$

3. RESULTS AND DISCUSSION

The numerical study presented here corresponds to the non resonant case. In effect, this case will play an important role in ultra-fast all-optical switching.

The solution of the forward field *U* in this case, is calculated numerically from equation 1 by taken $V=0$. The characteristic parameters of the thin film we used in calculation are:

$n_1=1.618$; $n_0=1.608$; $n_2=2.5\ 10^{-20}$ m^2/W ; $e = 3\ \mu m$.

The geometry of the domain in which the electric field propagates is relatively simple. So, the finite difference method is well adapted to determine a numerical solution of the PDE (equation 1). However, there arises the problem of stability of the solution. Mathematically, there is no explicit method for studying the problem of stability of nonlinear PDE. Thus, in the discretisation, we chose a very small step dy in function of *dx*. So the numerical solution evolves in a way that it has continued without big jumps

The initial condition is defined by the gaussian expression of the field amplitude:

$$U(x,y=0)=U_0e^{-(\cos(\theta_1)x/w_0)^2},$$

Where U_0 is the maximal amplitude, θ_1 is the angle of incidence, and W_0 is the beam-waist at the entry of the thin film. For numerical applications we have taken: $\theta_1=\theta_c-0.18°$ and $W_0 = 80\ \mu m$.

The boundary conditions have been taken such that the forward field vanishes in the thin film outside the propagation domain.

The figure 2 shows the profiles of the incident, the transmitted *(a, c, e)*, and the inside *(b, d, f)* pulses for three increasing values of the incident amplitude U_0. Figures *(a)* and *(b)* correspond to a relatively low value of U_0 ($U_0 = 10.\ 10^6$ V/m). In Figure *(b)* we see that the envelope propagates with constant amplitude with a slight compression, this is because of the effect of self-focusing. It is also noted a shift of the center of the transmitted beam in the figure *(a)*, this is simply due to the optical refraction. Figures *(c)* and *(d)* show the beginning of the pulse deformation for a relatively high incident amplitude $U_0 = 120.10^6$ V/m. Note that the deformation occurs at the peak of the pulse, which proves that this effect is due to the nonlinear effect. For a higher value of the incident amplitude $U_0 = 145.10^6 V/m$, the pulse is split *(Fig. e and f)*. This effect of chunking the transmitted beam (which begins inside the thin layer) was observed theoretically and experimentally by other authors [2, 3, 8]. For even higher amplitudes, the transmitted beam is divided into several sub-beams.

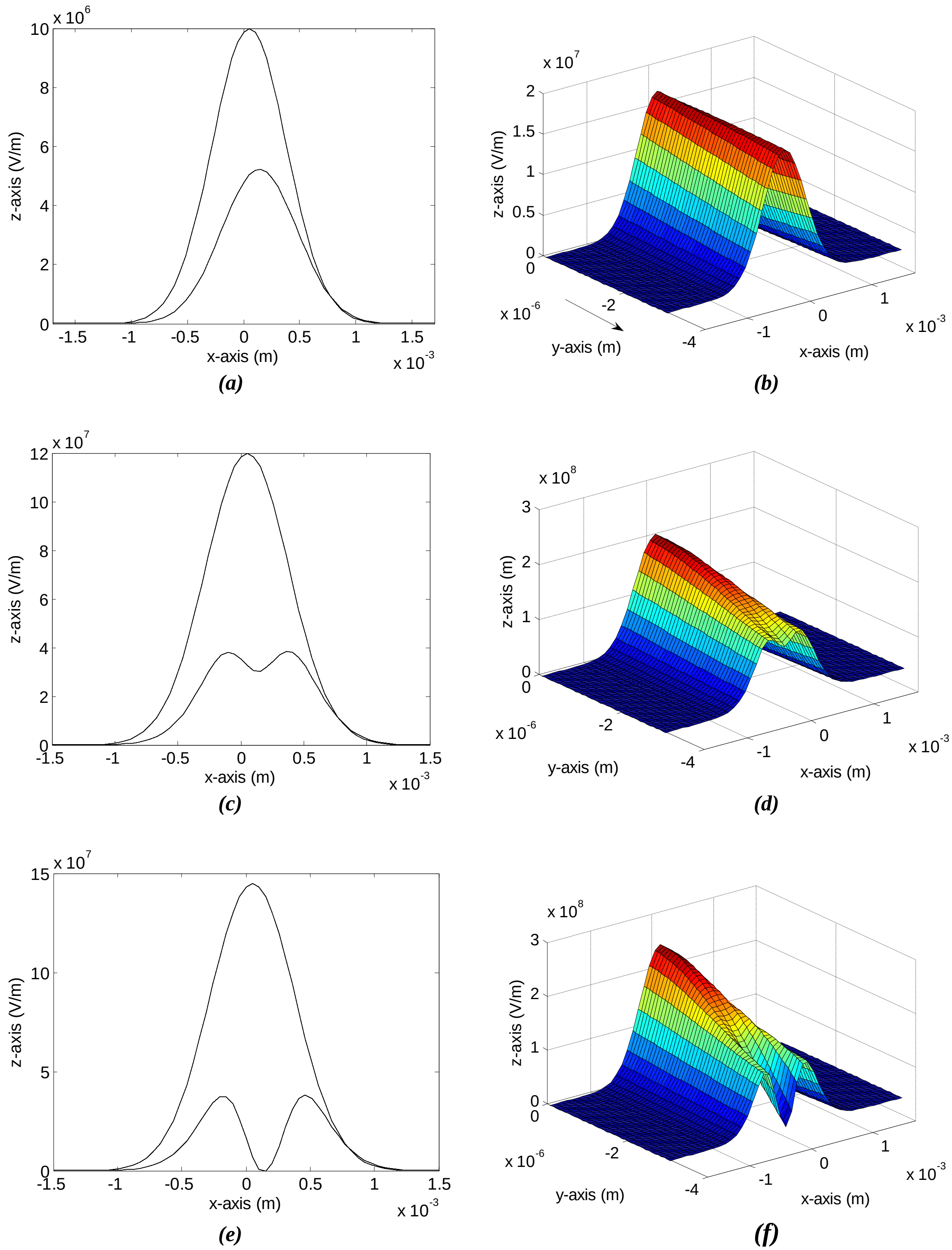

Fig.2. Profile of the incident and transmitted amplitude electric field (a, c, e) and amplitude distribution in the nonlinear layer (b, d, f)) at different incident pick amplitude U_0. The beam propagates in the direction decreasing y-axis direction. For (a) and (b): U_0 = 10 MV/cm, (c) and (d): U_0 = 120 MV/m, (e) and (f): U_0 = 145 MV/m.

CONCLUSION

We have realised a numerical study of the local field within a nonlinear thin layer. The incident beam used in this study has a gaussian profile (laser) and falls on the film in oblique incidence near the total reflexion. We have made in evidence that by increasing progressively the incident intensity the transmitted beam within the cavity is deformed and can be divided.

REFERENCES

[1]. A. E. Kaplan, ‘‘Hysteresis reflection and refraction by a nonlinear boundary’’, JETP, Lett, 24 (1976), p. 114.

[2]. P.W. Smith and W.J. Tomlinson, ‘‘Nonlinear Optical Interfaces: Switching Behavior’’, IEEE Journal of Quantum Electronics, Vol. QE-20, NO. 1, (1984), p. 30.

[3]. E Lantz, D. Métin, H. Cornet, A. Lacourt, ‘‘Transmission of a gaussian beam through a nonlinear thin film near the total reflection state’, J. Opt. Soc. Am. B, 11, 2 (1994), p. 347.

[4]. R. Mountasser, H. Maillotte, F. Cherioux & M. Ayadi, ‘‘Picosecond Optical Limiting Action through a Thin MMA-Octupole Copolymer Layer’’, Nonlinear Optic, Vol. 25 (2000), p. 373.

[5]. R. Mountasser, E. Lantz and. Maillotte, ‘‘Transmission through a nonlinear thin layer near the critical angle of incidence: application to the sensitive determination of the nonlinear refractive index’’, J. Opt. A: Pure Appl. Opt. 4 (2002), p. 303.

[6]. R. Chifahi, A. Taouri and R. Mountasser, ‘‘Analysis of the optical transmission through a nonlinear thin layer near the critical angle of incidence’’, Journal of European Optical Society – Rapid Publication 6, 11023 (2011).

[7]. G.Vitrant, M. Alternant, and R. Reinisch, ‘‘Transverse effects in nonlinear planar resonators, Modal analysis for normal and oblique incidence’’, J. Opt. Soc. Am. B,Vol.7,No.7, (1990), p.1320.

[8]. R. Mountasser, A. Lacourt, ‘‘Réfraction non linéaire au voisinage de l’angle limite’’, Annales de Physique, 20 (1995), p. 93.