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SIMULATION OF GAUSSIAN BEAM AT NON-LINEAR INTERFACE FOR TOTAL INTERNAL REFLECTION AND REFRACTION

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Abstract: In this paper, an investigation of the propagation of Gaussian beam at interface of the two nonlinear homogeneous Kerr Media is presented. Firstly, an equation is designed to define the interface condition then with the help of Split-step Fourier Method (SSFM) the equations are solved for two different conditions out of which one results in total internal reflection and the other in transmission. The results presented here may find application in all optical switching devices.

AMS Subject Classification: 78A97, 78A60
Key Words: split-step Fourier Method, nonlinear optics, photonics

1. Introduction

There has also been a lot of interest in the problem of reflection and refraction and switching of light beams at the interface of two nonlinear media [1], [2], [3], [4], [5] for all-optical devices. Here, we have investigated the refraction and reflection of a Gaussian beams at the interface of two nonlinear media. Following the approach of ref.[2] we have scaled the Nonlinear Schrdinger Equation (NLSE) using proper transformations regarding the interface condition. In the end of this paper we have shown the 3-D grayscale plots to provide the intuitive visuals of interface reflection and refraction.

2. Theory

The propagation of beam through nonlinear interface is governed by Nonlinear Schrdinger Equation (NLSE)[2]:

$$2i\beta\frac{\partial F}{\partial z}+\frac{\partial^2 F}{\partial x^2}-\left[\beta^2-n^2\left(x,|F|^2\right)\right]F=0 \tag{1}$$

where, $F(x,z)$ stands for the electric field envelop, β is the effective index of propagating wave given as ($\beta = 2n_0\cos\psi_i$) and

$$n^2\left(x,|F|^2\right)=\begin{cases} n_1^2+\alpha_1|F|^2 & \text{for } x<0 \\ n_0^2+\alpha_0|F|^2 & \text{for } x>0 \end{cases} \tag{2}$$

$$F(x,z)=\sqrt{\frac{2}{\alpha_0}}\sigma_0\varphi(\sigma,t)\exp\left[-i\left(\beta^2-n_0^2\right)t/\sigma_0^2\right] \tag{3}$$

where $t=\sigma_0^2 z/2\beta$ and $\sigma=\sigma_0 x$

here, σ_0 is the parameter related to the beam width. On substituting equation (3) in equation (1) and using equation (2). We obtained the following solution.

$$\frac{i\partial\varphi}{\partial t}+\frac{\partial^2\varphi}{\partial\sigma^2}=\begin{cases} 2|\varphi|^2\varphi & x<0 \\ \frac{\Delta}{\sigma_0^2}\varphi+\frac{2}{\alpha}|\varphi|^2\varphi & x>0 \end{cases} \tag{4}$$

where, $\alpha = {}^{\alpha_0}/_{\alpha_1}$; $\Delta = n_0^2 - n_1^2$

Equation (4) can be solved numerically by using the Split Step Fourier Method (SSFM) with the initial condition equation (5).

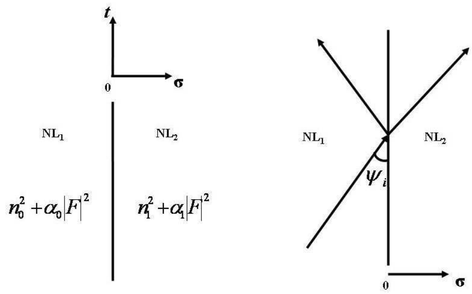

Figure 1: Considered situation a Gaussian beam across the interface NL_1 and NL_2.

3. Numerical Model

Let us consider an interface separating two nonlinear surfaces NL_1 and NL_2 as shown in Fig.1. The angle is the complimentary to the usual angle of incidence in Snell's law.

We, considered a wave packet having initial form

$$\varphi(\sigma, 0) = \sqrt{I} \exp\left[-\left(\frac{\sigma - \sigma_0}{w_0}\right)^2\right] \exp\left(-i\frac{\theta\sigma}{2w_0}\right) \tag{5}$$

where, $\theta = 2n_0 \sin\psi_i$ and $\sqrt{I}$ is the peak amplitude of the beam The chosen set of parameters for investigating the propagation of beam profile of equation (4) are $n_1 = 1.5$, $n_2 = 1.4$, $\theta = 0.9$, $X_0 = -50$, $\alpha = 0.87$, and the interface is assumed at $\sigma = 0$.

Here, one can observe that, how the reflection and transmission of the beam are affected by the variation of I (peak intensity of wave packet). We found that the optical beam which is in the mode of total internal reflection could be switched to solitonic transmission mode merely by increasing its power, i.e. all-optical switching. For example, if we substitute $I = 0.0588$ in equation (5) and propagate it through equation (4) beam reflects back to the initial medium (NL_1) as shown in fig.2. One can also observe here that the total internal reflection is not a surface phenomenon that is why certain penetration depth is needed for the total internal reflection. This is why we requires cladding in fiber optics and the modes confined in cladding is known as evanescence modes.

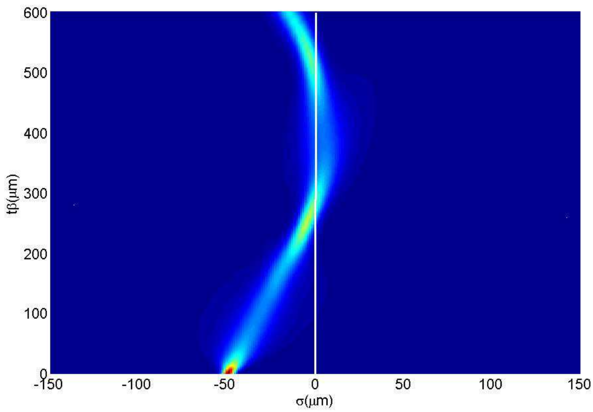

Figure 2: Low intensity beam reflected through the interface.

If the intensity of the beam is increased to $I = 0.106032$, the beam propagates in the nearly solitonic mode (where the diffraction of beam is compensated by the nonlinear focusing) and behaves as if there is no interface as shown in fig. 3.

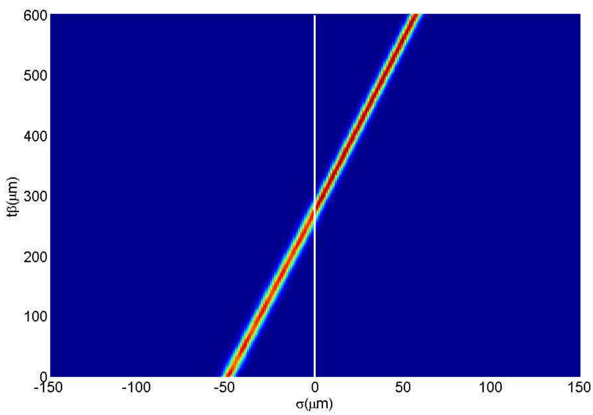

Figure 3: Beam remained unaffected to the interface.

4. Conclusion

We have analyzed the phenomenon of reflection and transmission of a Gaussian beam at the interface of two nonlinear media and have presented some very interesting features of the same. The results presented here may find application in all optical switching devices.

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