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The Sapience

Stable Solitons in One Dimensional Photonic Crystal with Defocusing Nonlinearity

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Abstract

We present a study about a photonic crystal fibre whose strands are filled by defocusing nonlinear medium. The strength of defocusing nonlinearity grows towards the periphery of the fibre. The nonlinearity considered of uniform defocusing type and for a nonzero growth rate of defocusing nonlinearity also considered separately. We have obtained that stable bright and vortex soliton exist in PCF infiltrated with an inhomogeneous defocusing nonlinearity without any modulation of linear refractive index and it is self sustained too.

Keywords: Defocusing Nonlinearity, Soliton, Photonic Crystal

1. Introduction

The one, two and three dimensional periodic microstructure which contain sufficient band gap is addressed as photonic crystal. Localised nonlinear excitation or optical soliton exists in many areas of science[1] for example optical & photonic crystal. medium is homogeneous than focusing and defocusing nonlinearities are supported by spatial bright and dark soliton respectively. However this situation is completely different when refractive index is a transversely modulated. In recent, fabrication evolves a rapidly varying nonlinear refractive index[5] which has motivated the study of nonlinear Schrodinger equation (NLSE) with a spatial variation nonlinear coefficient i.e. nonlinear microstructure. Which corresponds to media where refractive index is periodically modulated in transverse[3,4] direction. Periodic modulations in transverse and longitudinal direction will affect the strength and even polarity of the diffraction of the propagating light beam, so that, under appropriate situation, bright gap soliton may emerge in defocusing medium[2,7].

The local nonlinearity of periodic lattice can be homogeneous and inhomogeneous too. The propagation of beam of light in such type of nonlinear medium has drawn much attention in recent. The inhomogenity depends on intensity of light beam and soliton shows abnormal behaviour in such type of microstructure. In contrast the localised linear wave guiding structure with periodic defocusing nonlinearity does not support bright soliton[6].

In this paper it is assumed that nonlinearity increases from center towards the periphery of the material. Recently it was shown that in the presence of this type of nonlinearity we get stable bright soliton for three dimensional[8, 10] photonic crystal. The method adopted in ref[8, 9] require the local strength of defocusing nonlinearity to grow toward the periphery faster than r^D, where r is radius & D represents dimension of PCF. Inhomogeneous nonlinear with doped photorefractive materials have been studied[9]. We get stable solitons due to nonlinear microstructure of the medium.

In this paper we present that soliton existence is also possible in the presence of inhomogeneous defocusing nonlinearity. In this type of medium local nonlinearity of the material varies in step like manner, even in the presence narrow defocusing alternate areas with linear domain in transverse direction. We thus predict that stable bright one dimensional fundamental and vortex soliton exist in photonic crystal whose medium are filled by dielectric matched material with a suitable combination defocusing nonlinearity.

In this paper, we represent the more appealing analogy[11, 12] between the behaviour of electromagnetic wave (EMW) propagation in artificial, one dimensionally periodic dielectric photonic material in place of more familiar behaviour of electron wave propagation in natural crystal.

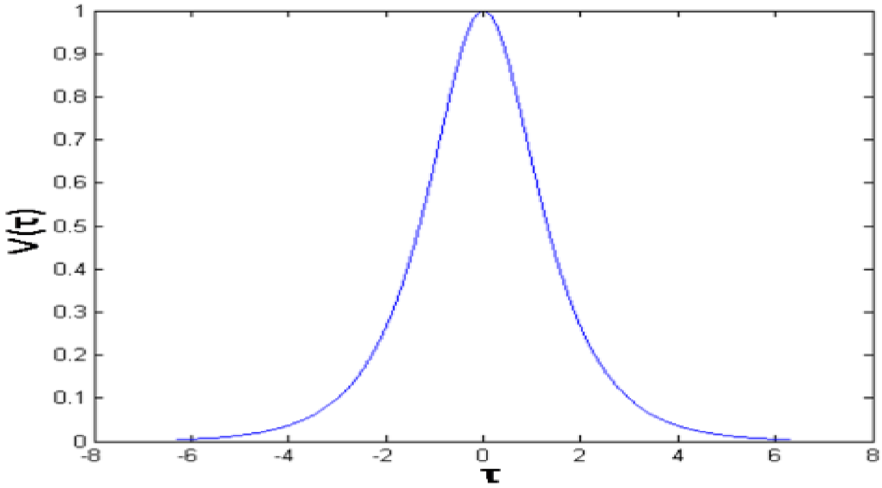
2. Solution in Presence Of Inhomogeneous Medium

We start with picoseconds optical pulses propagating inside an optical fibre in absence of fibre loss

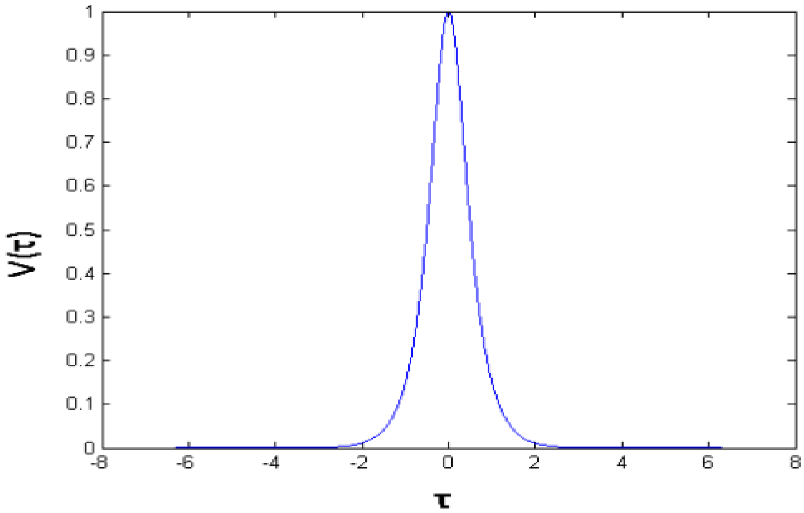
$$i\frac{\partial u}{\partial \xi} = -\frac{1}{2}\frac{\partial^2 u}{\partial \tau^2} - \exp(\alpha r_{km})|u|^2 u \tag{1}$$

Where u is the dimensionless field amplitude, ξ represents propagation distance traveled in optical, τ is 1-D transverse coordinate normalized with to characteristic transverse scale dimension. The exponential function describes nonlinearity profile of dielectric function. The holes in designated photonic crystal [PC] are arranged into a perfectly periodic hexagonal structure. We assume that they are filled in such a manner that nonlinearity coefficient in the central hole is -1 and its index profile grows towards PCF periphery as a function of $\exp(\alpha r_{km})$ where r_{km} is the distance between center and the hole with indices k,m. Here we set the pitch of the nonlinear photonic crystal (hole-to-hole separation) to d = 1.5, the hole radius r_0 = 0.6 and rate of nonlinearity growth to α = 1.5, and we have also verified that results remain qualitatively similar for other values of these parameters.

We search for soliton solution of equation (1) in the form $u(\tau,\xi)$ = V(τ)exp(iφ(ξ,τ)), where V(τ) is amplitude while function φ(ξ,τ) is phase.

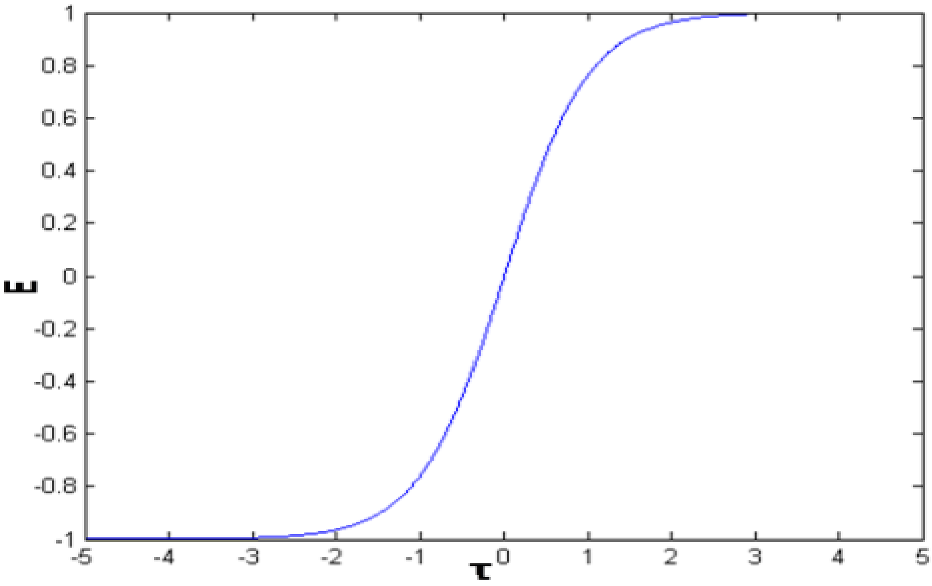


(a)



(b)

Fig.1. Variation of soliton amplitude versus transverse distance. The upper panel (a) shows the amplitude for α = 0 and lower panel (b) shows the amplitude for α = 1.5 and r_{km} = 0.6.



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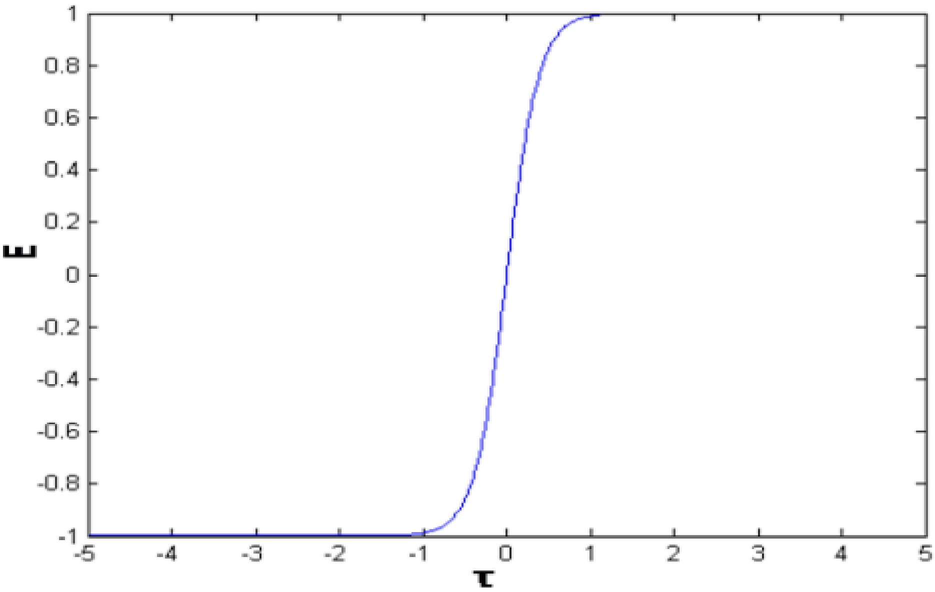
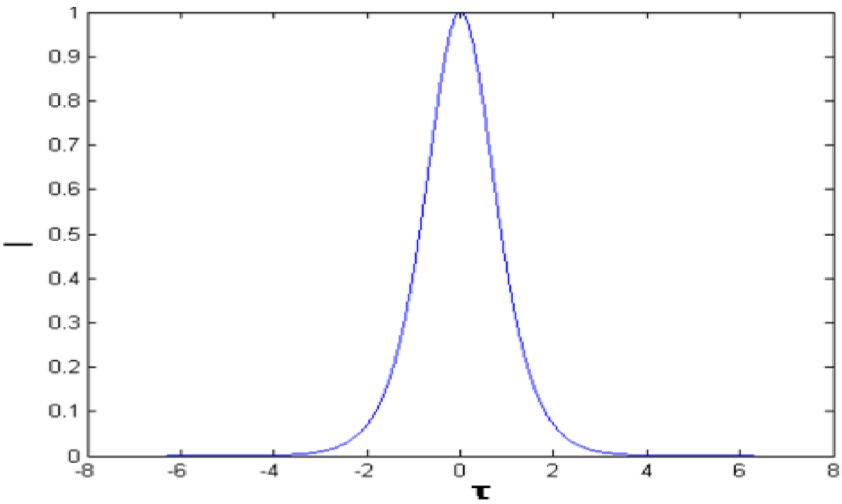
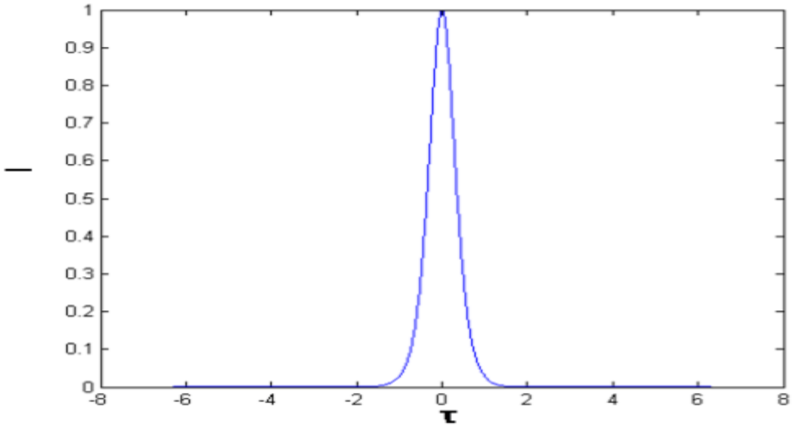


(b)

Fig.2. Energy flow of fundamental soliton versus transverse distance. The upper panel (a) shows the energy for α = 0 and lower panel (b) shows energy for α = 1.5 and r_{km} = 0.6.



(a)



(b)

Fig.3. Variation of intensity of soliton with transverse distance. The upper panel (a) shows the intensity for α = 0 and lower panel shows intensity for α = 1.5 and r_{km} = 0.6.

3. Results and Discussion

The objective of the study of this work based on equation (1) is to understand what kind of soliton can be supported by the interplay of different nonlinearity growth. In fig. (1a) the width of soliton is broader than in comparison to fig. (1b). It means width of soliton decreases on increasing defocusing nonlinearity. Figure (2a) is for zero defocusing nonlinearity while figure (2b) is for nonzero growth of defocusing nonlinearity. In this case we set PCF pitch to d = 1.5, the radius of hole to r_0 = 0.6 and rate of nonlinearity growth to α = 1.5 but we have verified that result remain qualitatively similar for other value of these parameter. By comparison of fig. (2a) and (2b) it is obvious that energy compresses on increasing defocusing nonlinearity. It means compression of fundamental soliton occurs. A typical example of dependence of soliton intensity on transverse dimension has been shown in figure (3). It is obvious that width of intensity is broader for zero nonlinearity growth.

4. Conclusion

In summary, in this work we have shown that stable bright and vortex solitons exist in PCF in the presence inhomogeneous defocusing nonlinearity with the condition that the defocusing nonlinearity grows exponentially from center towards the periphery of the without any local modulation of index profile. The central part of our result is that bright solitons may be self modulated in the presence of nonlinear inhomogeneous defocusing media.

5. Acknowledgement

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