Bright soliton of nonautonomous cubic-quintic nonlinear Schrödinger equation model with repulsive nonlinearity

Ritu Pal, Shally Loomba and C.N.Kumar *

Soliton refers to a nonlinear pulse or wave packet which travels without spreading. There are two types of envelope solitons called dark and bright solitons which propagate in the nonlinear dispersive media. The fundamental cause of their generation is modulation instability (MI). The basic soliton formation is described in nonlinear systems by various nonlinear evolution equations and one-dimensional cubic nonlinear Schrödinger equation (NLSE) is one of those fundamental equations. The nature of the soliton is governed by the two factors, namely, the dispersion D and the nonlinear N parameters. The D signifies the curvature of the frequency versus wave number dispersion and N represents the change in the carrier frequency with signal amplitude. In general the sign of the product of the dispersion and the nonlinearity parameter determines which kind of soliton is exhibited by the nonlinear medium. It has been shown that when $DN < 0$, one has attractive nonlinearity and yields the formation of bright soliton while for $DN > 0$, one has repulsive nonlinearity and admits dark soliton formation in a nonlinear dispersive media [1]. Recently, there has been a renewed interest in studying the solitons in magnetic yttrium iron garnet (YIG) film strips. A number of experimental studies took place in this regard and they have successfully demonstrated the emergence of solitons in YIG films.The existence of bright solitons with attractive nonlinearity in YIG films has been shown in 2005 [2]. Very recently, Wang et al. have demonstrated the formation of bright soliton with repulsive nonlinearity [3]. They have reproduced the experimental results through numerical simulations by using constant coefficient modified NLSE. We are extending it and are considering modified NLSE with variable coefficient as it may be the starting point for a more realistic system, mentioned above [4]. The modified NLSE with time dependent coefficients is given as

$$i\psi_t - \frac{D(t)}{2}\psi_{xx} + N(t)|\psi|^2\psi + S(t)|\psi|^4\psi + iv_g(t)\psi_x + iG(t)\psi = 0, \qquad (1)$$

We are interested to find the exact bright soliton solution for Eq. (1). To do so we are choosing the ansatz

$$\psi(x,t) = \rho(t)\exp(i\theta(x,t))\phi[\eta(x,t)] \qquad (2)$$

with the phase $\theta(x,t)$ as

$$\theta(x,t) = bx + c(t), \qquad (3)$$

*Department of Physics, Panjab University, Chandigarh 160014, India, email: maan.ritupal@gmail.com

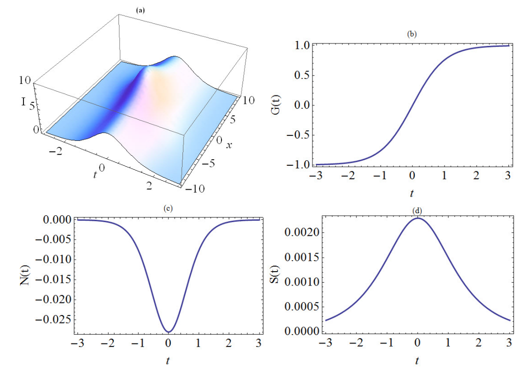

Figure 1: (a) Representative profile of bright soliton (b) gain profile (c) profile of cubic nonlinearity (d) profile of quintic nonlinearity.

where b is an arbitrary constant. The $\rho(t)$, $\theta(x,t)$, $\phi[\eta(x,t)]$ and $c(t)$ are real functions.
On substituting Eq. (2) along with Eq. (3) in Eq. (1), it reduces to

$$\phi_{\eta\eta} + \delta\phi + \beta\phi^3 + \gamma\phi^5 = 0. \qquad (4)$$

Eq. (1) has been reduced to Eq. (4) for the set of conditions and Eq. (4) can be mapped onto ϕ^6 field equation which is well known to admit bright soliton, dark soliton, kink, double kink and bell shaped solutions, hence one can obtain a variety of solutions for Eq. (1). Being motivated by the experimental evidence on the existence of bright solitons with repulsive nonlinearity in YIG thin films [3] and in Bose-Einstein condensate [5], in this work we are analytically obtaining the bright soliton solutions with repulsive nonlinearity. Intensity of Bright soliton s with repulsive cubic nonlinearity and attractive quintic nonlinearity has been shown in Fig. 1.

References

[1] M. Remoissenet, *Waves Called Solitons: Concepts and Experiments*,Springer-Verlag, Berlin, 1999.

[2] M. M. Scott, M. P. Kostylev, B. A. Kalinikos, and C. E. Patton. *Phys. Rev. B* **71**, 174440(2005).

[3] Z. Wang, M. Cherkasskii, B. A. Kalinikos, L. D. Carr, and M. Wu, *New J. Phys.* **16**, 053048(2014).

[4] Shally Loomba, Ritu Pal, and C. N. Kumar, *Physical Review A*, 92, 033811 (2015).

[5] B. Eiermann, Th. Anker, M. Albiez, M. Taglieber, P. Treutlein, K. P. Marzlin, and M. K. Oberthaler, *Phys. Rev. Lett.* **92**, 230401(2004).