Optik - International Journal for Light and Electron Optics 172 (2018) 772–776

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.com/locate/ijleo

Original research article

Chirp-free bright optical soliton perturbation with Chen–Lee–Liu equation by traveling wave hypothesis and semi-inverse variational principle

Anjan Biswas[a,b,*]

[a] Department of Physics, Chemistry and Mathematics, Alabama A&M University, Normal, AL 35762, USA
[b] Department of Mathematics and Statistics, Tshwane University of Technology, Pretoria 0008, South Africa

ARTICLE INFO

OCIS:
060.2310
060.4510
060.5530
190.3270
190.4370

Keywords:
Solitons
Traveling waves
Semi-inverse variation

ABSTRACT

Chirp-free bright optical soliton solutions are obtained for Chen–Lee–Liu equation by traveling wave hypothesis as well as the application of semi-inverse variational principle. The constraint conditions for the existence of these solitons are also presented.

1. Introduction

Optical soliton perturbation is one of the most active areas of research in fiber-optic telecommunications engineering. The dynamics of information transfer across inter-continental distances has marveled with the aid of several mathematical models that successfully describe its impact. There are several intricacies with the wide variety of models that describe this technology. While some models are integrable by Inverse Scattering Transform and others are not. Again, none of the modern methods of integration, that mushroomed up from every corner of the world, can secure soliton radiation, which is an important component of the complete solution spectrum of any given nonlinear evolution equation that models soliton transmission through optical fibers and PCF. The current paper will study one form of the popular derivative nonlinear Schrödinger's equation (DNLSE) that describe sub-pico second soliton transmission. It is DNLSE-III that is otherwise commonly referred to as Chen–Lee–Liu (CLL) equation [1–10]. This model has been extensively studied all across the globe and there is still a lot of work to be done with this model. This paper will study the perturbed CLL equation by two integration schemes to retrieve its chirp-free bright soliton solution. They are traveling wave hypothesis and semi-inverse variational principle (SVP). The details are jotted in the following sections and their sub–sections.

1.1. Governing model

The perturbed CLL equation in its dimensionless form is of the form [1]:

$$iq_t + aq_{xx} + i\,b\,|q|^2 q_x = i[\alpha q_x + \lambda(|q|^2 q)_x + \theta(|q|^2)_x q]. \tag{1}$$

* Correspondence to: Department of Physics, Chemistry and Mathematics, Alabama A&M University, Normal, AL 35762, USA.
E-mail address: biswas.anjan@gmail.com.

https://doi.org/10.1016/j.ijleo.2018.07.110
Received 28 May 2018; Accepted 25 July 2018
0030-4026/ © 2018 Elsevier GmbH. All rights reserved.

Here, in (1) $q(x, t)$ is the wave profile that is a complex-valued function and is a dependent variable. The independent variables are x and t that respectively represent spatial and temporal co-ordinates. The first term in (1) gives temporal evolution of the pulses, while a gives the coefficient of group velocity dispersion ad b is coefficient of nonlinearity. On the right hand side, α is the coefficient of inter-modal dispersion that is considered in addition to chromatic dispersion. Next, λ represents the coefficient of self-steepening while θ gives the effect of nonlinear dispersion. Here a, b, α, λ and θ are real-valued constants. Solitons are the outcome of a delicate balance that persists between dispersion and nonlinearity.

2. Mathematical analysis

The chirp-free amplitude-phase format assumption to integrate perturbed CLL equation is [1,3–6]:

$$q(x, t) = g(s)e^{i\phi(x,t)}, \tag{2}$$

Where

$$s = x - \mathrm{vt}, \tag{3}$$

and v is the soliton speed. The phase of the pulse has the following split:

$$\phi(x, t) = -\kappa x + \omega t + \theta_0. \tag{4}$$

Here, κ is the soliton frequency, ω is its wave number and θ_0 is the phase center.

Next, substitute (2) into (1). The real part yields:

$$ag'' - (\omega + \alpha\kappa + a\kappa^2)g + (b - \lambda)\kappa g^3 = 0 \tag{5}$$

where $g' = dg/ds$, $g'' = d^2g/ds^2$ and so on. The imaginary part implies:

$$v + 2a\kappa - \alpha - (b + 3\lambda + 2\theta)g^2 = 0. \tag{6}$$

From (6), velocity of the soliton is

$$v = -2a\kappa + \alpha \tag{7}$$

and the constraint condition comes out as:

$$b + 3\lambda + 2\theta = 0. \tag{8}$$

The real part equation, given by (5) will be further studied.

2.1. Traveling wave hypothesis

Multiplying both sides of (5) by g' and integrating gives

$$2a(g')^2 = 2(\omega + \alpha\kappa + a\kappa^2)g^2 - (b - \lambda)\kappa g^4 \tag{9}$$

when the integration constant is taken to be zero. Separating variables and integrating again, leads to

$$g(s) = A\,\mathrm{sech}[B(x - \mathrm{vt})] \tag{10}$$

where

$$A = \sqrt{\frac{2(\omega + \alpha\kappa + a\kappa^2)}{(b - \lambda)\kappa}}, \tag{11}$$

and

$$B = \sqrt{\frac{\omega + \alpha\kappa + a\kappa^2}{a}}. \tag{12}$$

Thus, the following chirp-free bright 1-soliton solution is yielded:

$$q(x, t) = A\,\mathrm{sech}[B(x - \mathrm{vt})]e^{i(-\kappa x+\omega t+\theta_0)} \tag{13}$$

where the amplitude A and the inverse width B of the soliton are indicated by (11) and (12) respectively. The velocity of the soliton is in (7). The expressions for amplitude and width of the soliton introduces the constraints:

$$\kappa(b - \lambda)(\omega + \alpha\kappa + a\kappa^2) > 0, \tag{14}$$

and

$$a(\omega + \alpha\kappa + a\kappa^2) > 0. \tag{15}$$

Download English Version:

https://daneshyari.com/en/article/7223015

Download Persian Version:

https://daneshyari.com/article/7223015

Daneshyari.com