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Solitary wave solutions for a higher order nonlinear Schrödinger equation

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Abstract

We consider a higher order nonlinear Schrödinger equation with third- and fourth-order dispersions, cubic–quintic nonlinearities, self steepening, and self-frequency shift effects. This model governs the propagation of femtosecond light pulses in optical fibers. In this paper, we investigate general analytic solitary wave solutions and derive explicit bright and dark solitons for the considered model. The derived analytical dark and bright wave solutions are expressed in terms of the model coefficients. These exact solutions are useful to understand the mechanism of the complicated nonlinear physical phenomena which are related to wave propagation in a higher-order nonlinear and dispersive Schrödinger system.

Keywords: Nonlinear Schrödinger equation; Solitary wave solution; Complex amplitude ansatz method

1. Introduction

The study of physical phenomena by means of mathematical models is an essential element in both theoretical and applied sciences [1]. In this context, there exists a special class of nonlinear wave equations that support soliton solutions in different nonlinear physical systems. Particularly, the study of soliton propagation in optical fibers has recently been the focus of many research groups [2–18]. This should not be surprising because the soliton pulses are used as the information carriers (elementary "bits") to transmit digital signals over long distances.

Hasegawa and Tappert [7,8], theoretically predicted the possibility of propagation of envelope solitons in optical fibers and it was experimentally demonstrated by Mollenauer et al. [12] in 1980. Since then, considerable attention has been paid theoretically and experimentally to analyze the dynamics of soliton pulses in optical fibers. In the absence of optical losses, the wave dynamics of nonlinear pulse propagation in a monomode fiber is described by the famous nonlinear Schrödinger (NLS) equation [3,6] given by

$$iE_z - \frac{\beta_2}{2}E_{tt} + \gamma_1|E|^2E = 0 \tag{1}$$

where $E(z, t)$ is a complex envelope amplitude, t represents the time (in the group-velocity frame), z represents the distance along the direction of propagation, β_2 describes group velocity dispersion (GVD), and γ_1 is the self-phase

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