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Multisoliton Perturbation Theory for the Manakov Equation

Sajjad Eskandar*
Vali-e-Asr University of Rafsanjan

Seyed Mohammad Hosseini
Vali-e-Asr University of Rafsanjan

Fatemeh Ahmadi zeidabadi
Vali-e-Asr University of Rafsanjan

Abstract

he effect of small perturbations on the collision of vector solitons in the Manakov equations is studied in this paper. The evolution equations for the soliton parameters (amplitude, velocity, polarization, position, and phases) throughout collision are derived. The method is based on the completeness of the bounded eigenstates of the associated linear operator in L_2 space and a multiple-scale perturbation technique.

Keywords: Manakov equation, Soliton solution, IST method, Soliton perturbation theory
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1 Introduction

Nonlinear pulse propagation in optical fibers has been studied over 30 years. The idea of using optical solitons as information bits in high-speed telecommunication systems was first proposed in 1973, and then demonstrated experimentally in 1980.
In an ideal fiber, optical solitons can be modeled approximately by the nonlinear Schrödinger (NLS) equation, whose solution behaviors are completely known. But in reality, optical fibers are birefringent. Pulses travel at slightly different speeds along the two orthogonal polarization axes. If the birefringence randomly varies along the fiber due to bending, twisting, and the environmental perturbations, the pulses evolve according to the Manakov equations with corrections caused by polarization mode dispersion.
The collision of vector solitons is critical in many optical switching devices and nonlinear optical telecommunication networks. A rigorous analytical theory describing the collision process has still been lacking. In this paper, we present such an analytical theory. We study the collision of two vector solitons, based on the perturbed
Manakov equations:

$$iA_t + A_{xx} + (|A|^2 + |B|^2)A = \varepsilon M(A, B, \partial_x, \partial_t), \quad (1)$$
$$iB_t + B_{xx} + (|A|^2 + |B|^2)B = \varepsilon N(A, B, \partial_x, \partial_t). \quad (2)$$

Here A and B are complex functions, and $\varepsilon \ll 1$. When $\varepsilon = 0$ Eqs. (**??**-**??**) are the integrable Manakov equations. Vector solitons collide with each other elastically, except

*Speaker