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Bright and dark solitons in the unidirectional long wave limit for the energy transfer on anharmonic crystal lattices

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Abstract

The problem of energy transportation along a cubic anharmonic crystal lattice, in the unidirectional long wave limit, is considered. A detailed process, in the discrete lattice equations, shows that unidirectional stable propagating waves for the continuum limit produces a coupled system between a nonlinear Schrödinger (NLS) equation and the Korteweg-deVries (KdV) equation. The traveling wave formalism provides a diversity of exact solutions ranging from the classical Davydov's soliton (subsonic and supersonic) of the first and second kind to a class consisting in the coupling between the KdV soliton and dark solitons containing the typical ones (similar to the dark-gray soliton in the standard defocusing NLS) and a new kind in the form of a two-hump dark soliton. This family of exact solutions are numerically tested, by means of the pseudo spectral method, in our NLS-KdV system.

Keywords and phrases: NLS-KdV system, Davydov's soliton, dark-gray soliton, two-humps dark soliton, pseudo spectral method.

1 Introduction

Since the introduction of the polaron (or quasiparticle) concept, first by Landau in 1933 [1] and then by Pekar in 1951 [2], much work has been done in the problem of transference of electrons or atoms in polarizable media. The pioneering work of A. S. Davydov on protein chain deformation, due to the transference of energy, provided the first estimates in the lifetime of propagating coherent structures (a mechanical deformation of the protein, in the form of a classical soliton, plus a localized wave function both forming an entity, the so-called Davydov's soliton), in concordance to the polaron concept, at zero temperature [3], [4], [5]. Due to temperature effects and