Computational Nonlinear Physics and Applications

Researcher Contact Info :

Assoc. Prof. Dr. Bakhram Umarov

Email : bakhram@iium.edu.my

Tel No. :+609 5705170

Address : Department of Physics,
Kulliyah of Science,
International Islamic University Malaysia,
Bandar Indera Mahkota,
25200 Kuantan, Pahang,
Malaysia.

Theory of nonlinear wave structures is the attractive domain of current science and engineering with numerous applications. The main tools of theoretical research in this field are numerical experiment and approximate analytical methods. The formulation of the problems in terms of the differential equations plays a crucial role in science and engineering. In physics nearly all basic laws are presented as the differential equations for time and space evolution of physical quantities. Examples are: the Newton equations of classical mechanics, the Schrödinger equation in quantum mechanics, the Einstein equations of general relativity and so on. While in early stages emphasis were given to analytical solutions of linear equations, more recently the development of fundamental and applied physics made it important to consider nonlinear problems, which are described by a systems of nonlinear partial or ordinary differential equations, in full complexity. It was found that some nonlinear equations with significant applications in physics have property of exact integrability, and as a consequence their solutions can be found and described in details. The mathematical development of the theory of integrable nonlinear equations was essential for many fields of physics. It was found that these kind equations may have localized solutions (solitons), and the interaction of solitons looks like particle interaction, so after collision they can preserve their shape and velocity. Unfortunately not all important for applications nonlinear equations are exactly integrable. The integrable equations may become nonintegrable if one takes into account the physical effects which were neglected in a preliminary, simplified consideration. Nonintegrable nonlinear equations may still have soliton like solutions, but their interactions in general become more complex. Also an exact analytical solutions of a nonintegrable equations can be found only for some very limited cases, so one have to apply approximate or numerical methods. The aim of this project is to examine some problems related to interaction and dynamics of localized objects (solitons) in the physical systems theoretically described by nonlinear differential equations. The physical objects we are going to concentrate on are the Bose-Einstein condensate in the one dimensional trap and nonlinear optical system. The dynamics of these physical systems can be considered based on the nonintegrable modifications of the one dimensional Nonlinear Schrödinger equation. We study both continuous and discrete nonlinear systems. Continuous systems in our research are represented by the nonlinear partial differential equations. Discrete systems described by a system of coupled ordinary nonlinear differential equations. We consider the following research questions: The search of exact soliton like solutions of the nonintegrable discrete and continuous systems. An existence and stability conditions for these solutions. Dynamical evolution and interaction of the solitons under the action of different type of perturbations. Scattering of solitons on the potential barriers and wells of a different shape and amplitude. Management of soliton dynamics via application of external forces.

The objective of this project is at exploring the possibilities, offered by solitons and multi-soliton complexes for storage, transfer and processing of information. The main idea consists in employing the soliton as a confining medium and transporter of bit of information. In this project we shall be concerned mainly by transmission and beam splitting phenomena involving solitons in two types ofphysical systems: optical solitons in fibers and matter-wave solitons in Bose-Einstein condensates. Mathematically these systems are described by nonintegrable nonlinear evolution equations. Beam splitters, switches and other logic devices based on optical solitons were proposed in the literature. In this project we shall extend these ideas for matter-wave solitons and recently found soliton molecules.