Preface

Optical solitons play a vital role in optical communication and optical computation in which the solitons are treated as information carrying bits. Optical fibres are found to be the suitable choice of medium for information transfer due to their better transmission capacity, reliability, low transmission loss, etc. The dynamics of temporal optical solitons in single mode fibres and self trapping of intense coherent beam in (1+1)D are governed by single component nonlinear Schrödinger (NLS) type equations. But the governing equation for optical soliton propagation in multimode fibres and self-trapping of incoherent beam in a phorefractive media is a set of coupled nonlinear Schrödinger (CNLS) equations. Although the CNLS equations are nonintegrable in general, they become integrable for specific choices of system parameters. The interaction of a long interfacial wave and a short surface wave in a two layer fluid is governed by long wave-short wave resonance interaction system (LSRI) which is also an integrable model.

The important aspect in the above systems is the identification of shape
changing collision properties which arise during soliton interactions in the multicomponent cases. The primary aim of this thesis is to obtain multisoliton solutions of (1+1) and (2+1) dimensional systems and to investigate the shape changing collisions of bright solitons therein. The work reported in this thesis has been carried out during the period 2006-2011, under the supervision of Prof. M. Lakshmanan, Professor of Eminence and DAE-Raja Ramanna Fellow at the Centre for Nonlinear Dynamics, School of Physics, Bharathidasan University, Tiruchirappalli - 620 024.

The present thesis is divided into nine chapters. In Chapter 1, we give a brief introduction to the soliton concept and its appearance in optical fibers and in photorefractive media. Also we discuss the physical significance of the model equations studied in the thesis. In Chapter 2, we briefly review the results of focusing CNLS equations and we present the Gram type determinant form of the N-soliton solution (N: arbitrary). Also we explicitly prove that the determinant form indeed satisfies the corresponding bilinear equations. Similar studies are given in Chapter 3 for integrable mixed CNLS equations. The bright soliton solutions of the mixed CNLS equations with two components (2-CNLS) with linear self- and cross-coupling terms have been obtained in Chapter 4 by identifying a transformation that transforms the corresponding equation to the integrable mixed 2-CNLS equations. The study on the collision dynamics of bright solitons shows that there exists periodic energy switching, due to the coupling terms. This periodic energy switching can be controlled by a new type
of shape changing collision of bright solitons arising in a mixed 2-CNLS system.

In Chapter 5, mixed-type (bright-dark) soliton solutions of the integrable NC-NLS equations with mixed signs of focusing- and defocusing-type nonlinearity coefficients are obtained by using Hirota’s bilinearization method. Generally, for the mixed N-CNLS equations the bright and dark solitons can be split up in N-1 ways. By analyzing the collision dynamics of these coupled bright and dark solitons systematically we point out that for \( N > 2 \), if the bright solitons appear in at least two components, nontrivial effects, such as onset of intensity redistribution, amplitude-dependent phase shift, and change in relative separation distance take place in the bright solitons during collision. However their counterparts, the dark solitons, undergo elastic collision but experience the same amplitude-dependent phase shift as that of bright solitons. Also we present bright-dark soliton solutions of CNLS system with defocusing nonlinearity.

We obtain explicit bright one- and two-soliton solutions of the integrable case of the coherently coupled NLS equations by applying a nonstandard form of the Hirota’s direct method in Chapter 6. We find that the system admits both degenerate and non-degenerate solitons in which the latter can take single hump, double hump, and flat-top profiles. Our study on the collision dynamics of solitons in the integrable case shows that the collision among degenerate solitons and also the collision of non-degenerate solitons are always standard elastic collisions. But the collision of a degenerate soliton with a non-degenerate soliton induces switching in the latter leaving the former unaffected after colli-
sion, thereby showing a different mechanism from that of the Manakov system. Chapter 7 deals with the bright plane soliton solutions of an integrable (2+1)-dimensional (n + 1) wave system. First, the soliton solutions of a three-wave system consisting of two short-wave components and one long-wave component are found and then the results are generalized to the corresponding integrable (n + 1)-wave system with n short waves and a single long wave. Study of the collision dynamics reveals some interesting behaviour: the solitons which split up in the short-wave components undergo shape changing collisions with intensity redistribution and amplitude-dependent phase shifts. Even though a similar type of collision is possible in (1+1)-dimensional multicomponent integrable systems, to our knowledge we report this kind of collision in (2+1) dimensions for the first time. However, solitons which appear in the long-wave component exhibit only elastic collision though they undergo amplitude-dependent phase shifts. We present the bright-dark soliton solutions of an integrable (2+1)-dimensional multicomponent LSRI system in Chapter 8. We also present the shape changing and elastic collisions of bright and dark solitons, respectively. Finally, Chapter 9 provides a summary of the results and future outlook.