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Helmholtz Solitons in Non-Kerr Media

J. M. Christian and G. S. McDonald,

Joule Physics Laboratory, School of Computing, Science and Engineering, Institute of Materials Research,
University of Salford, Salford M5 4WT, U.K.

P. Chamorro-Posada,

Departamento de Teoría de la Señal y Comunicaciones e Ingeniería Telemática, Universidad de Valladolid,
ETSI Telecomunicación, Campus Miguel Delibes s/n, 47011 Valladolid, Spain.

1. Introduction

Spatial optical soliton propagation in a planar waveguide is often modelled by a Non-Linear Schrödinger (NLS) type equation. Such systems are paraxial in nature, and cannot describe accurately off-axis propagation at *non-trivial angles*. The NLS equation typically allows for a Kerr non-linearity, but *real optical materials* often possess a response that deviates from this idealization [1]. We report, for the *first* time, exact analytical soliton solutions to a generalized Non-Linear Helmholtz (gNLH) equation. Solutions, and accompanying simulations, thus account for *both* the inherent symmetries of propagation problems *and* more realistic (polynomial-type) non-linearities.

2. Generalized Non-Linear Helmholtz Equation

Models based on the NLH equation are suitable for describing accurately the angular aspects of wave propagation [2]. Since the assumption of beam paraxiality is omitted, such descriptions can support both travelling- and standing-wave solutions. We will present distinct novel families of solutions of the gNLH equation. These will include: *sech-shaped* and *algebraic* (e.g. Lorentzian) *solitons*, and also *spatially-extended* (transverse periodic) *nonlinear waves*.

3. Stability as Robust Attractors

Thorough numerical investigations will demonstrate the role of gNLH solitons as attractors of the system. With few exceptions, we have found that dynamics exhibit limit-cycle qualities (perturbed initial conditions give rise to self-sustained oscillations in the long term). Departure from pure Kerr non-linearity will also be shown to result in much stricter conditions on how closely a launched beam needs to match the corresponding exact soliton solution.

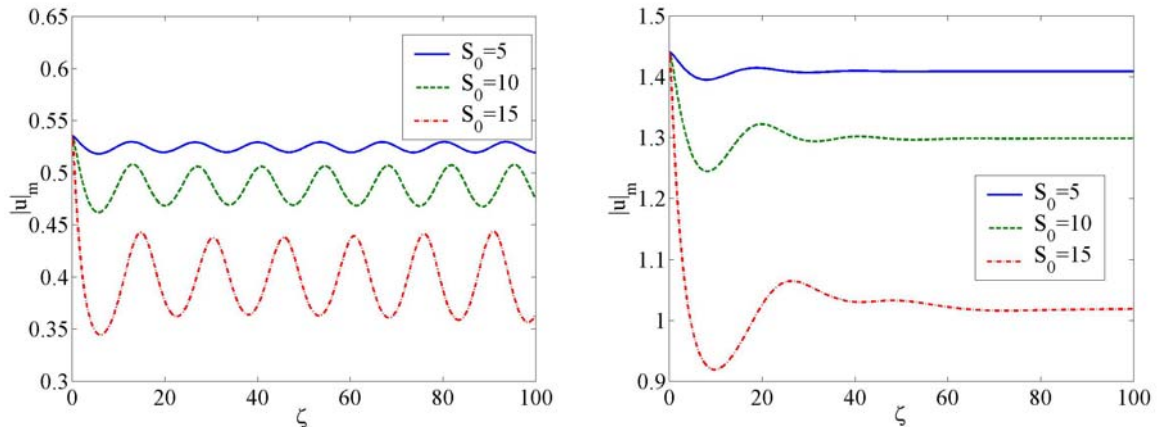


FIG. 1. Reshaping simulations for (left) *sech-shaped* solitons in the pure-focusing regime, and (right) algebraic solitons close to threshold. Initial conditions, corresponding to exact solutions of the corresponding paraxial system [1], do not necessarily give rise to (propagation-invariant) asymptotic Helmholtz solitons.

4. References

- [1] R.W. Micallef, V.V. Afanasjev, Y.S. Kivshar and J.D. Love, “Optical Solitons with Power-Law Asymptotics,” *Phys. Rev. E* **54**, 2936 (1996).
- [2] P. Chamorro-Posada, G.S. McDonald and G.H.C. New, “Exact soliton solutions of the nonlinear Helmholtz equation: communication,” *J. Opt. Soc. Am. B* **19**, 1216 (2002).