Spatial Soliton Refraction at Cubic-Quintic Material Interfaces

E. A. McCoy, J. M. Christian, and G. S. McDonald

Materials & Physics Research Centre, University of Salford, Greater Manchester, M5 4WT, U.K.

In their most general form, wave–interface problems are inherently angular in nature. For instance, the interaction between light waves and material boundaries essentially defines the entire field of optics [1]. The seminal works of Aceves *et al.* [2,3] considered scalar bright spatial solitons impinging on the interface between two Kerr-type media with different dielectric parameters. While these classic analyses paved the way toward understanding how self-collimated light beams behave at medium discontinuities, they suffer from a fundamental limitation: the assumption of slowly-varying wave envelopes means that, in the laboratory frame, angles of incidence, reflection and refraction (relative to the interface) must be of vanishingly small magnitude.

Over the last few years, the angular restriction of conventional (paraxial) nonlinear-Schrödinger modelling has been lifted by deploying a more flexible nonlinear-Helmholtz approach [4]. This mathematical platform is ideally suited to capturing the oblique-propagation aspects of interface scenarios

We will report our latest research involving arbitrary-angle soliton refraction in more general classes of *cubic-quintic* materials [8], for which exact analytical bright [9] and dark [10] Helmholtz solitons are now known. A novel Snell's law will be detailed: $\gamma \cos\theta_{\mathrm{inc}} = \cos\theta_{\mathrm{ref}}$, where θ_{inc} and θ_{ief} are the (laboratory frame) angles of incidence and refraction, respectively, and γ is a factor that allows for both finite-beam effects and medium mismatches. Numerical computations test analytical predictions of soliton refraction and critical angles over a wide range of parameter regimes. Qualitatively new phenomena are also uncovered by simulations in both small- and large-angle regimes (see Fig. 1).

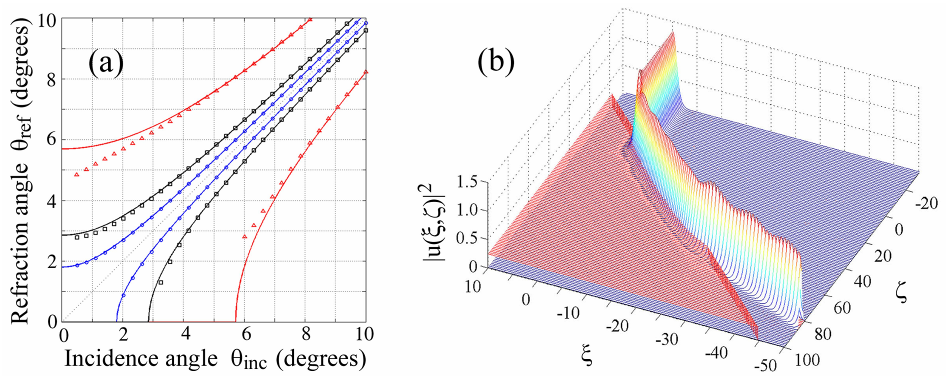

Fig. 1 (a) Comparison of Snell's-Law predictions (solid lines) against full numerical simulations (points) for a range of linear interface parameters. (b) Non-trivial Goos-Hanchen shift for an incident Helmholtz soliton close to the critical angle.

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