Scattering of Helmholtz spatial optical solitons at material interfaces

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Abstract

The behaviour of light at the interface between different materials essentially defines the entire field of Optics. Indeed, the reflection and refraction properties of plane waves at the boundary between two dissimilar linear dielectrics are analysed in many classic textbooks on electromagnetism (e.g., Ref. 1). Our research tackles geometries that involve the interplay between diffraction (linear broadening) and self-focusing (nonlinear material response) when the incident light is in the form of a spatial soliton (self-collimated, self-stabilizing optical beam). Such systems are driven and dominated by complex light-medium feedback loops.

The pivotal work of Aceves and co-workers [2] some two decades ago investigated spatial solitons impinging on the interface between Kerr-type materials. Whilst these ground-breaking studies were highly instructive, their paraxial approach restricts angles of incidence, reflection and refraction to small values. Our recent proposal of a generalised Snell law [3], based on analysis of a nonlinear Helmholtz equation, lifts the angular limitation inherent to paraxial theory. This generalisation comprises a single multiplicative factor that allows for both transverse effects and discontinuities in material properties.

Here, we will detail our latest research into bright spatial soliton refraction. In particular, our interest lies with arbitrary-angle scattering at the planar boundary between optical materials with universal non-Kerr nonlinearities: single power-law [4] and cubic-quintic [5]. This is the first time that arbitrary-angle refraction phenomena have been considered within these new material contexts. The derivation of our novel Helmholtz-Snell law will be described, and simulations demonstrating excellent agreement with theoretical predictions presented (see Fig. 1).

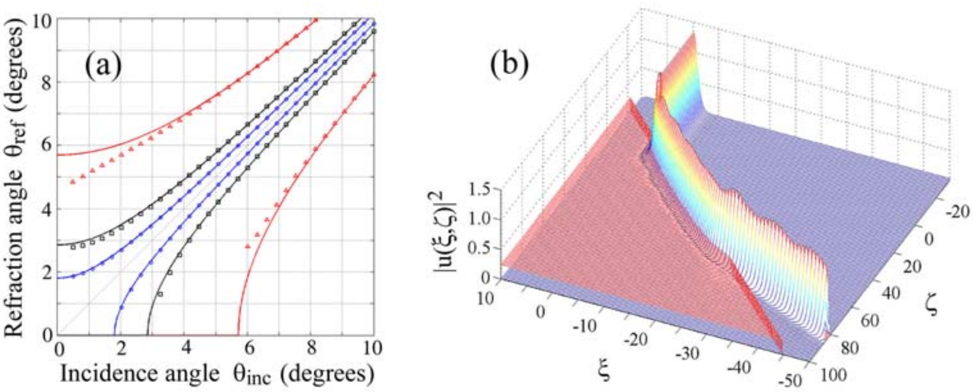

Figure 1. (a) Comparison of Snell Law predictions (solid lines) against full numerical simulations (points) for a range of linear interface parameters. (b) Non-trivial Goos-Hänchen shift for an incident Helmholtz soliton close to the critical angle.

References

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