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Optical soliton refraction & Goos-Hänchen shifts at interfaces with $\chi^{(5)}$ susceptibility

E. A. McCoy, J. M. Christian, and G. S. McDonald
Materials & Physics Research Centre,
University of Salford, Greater Manchester M5 4WT, UK

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ABSTRACT

Solitons are universal self-localizing wavepackets that pervade nonlinear science. They are fundamental to our understanding of non-dispersing waves in complex systems, and their interplay with boundary conditions is of elementary importance in a wide range of problems. In optics, the refraction of self-collimated laser beams (spatial solitons) at the planar interface between dissimilar nonlinear materials is a building-block geometry that has been extensively investigated over recent decades [Aceves *et al.*, Phys. Rev. A vol. 39, 1809 (1989)].

We will present the first analysis of spatial soliton refraction in higher-order material systems, with novelty arising from two distinct elements: (i) inclusion of finite $\chi^{(5)}$ susceptibility (supplementing the classic $\chi^{(3)}$ contribution) in the constitutive relations of electromagnetic theory; (ii) relaxation of the historic paraxial approximation to accommodate arbitrary angles of incidence, reflection, and refraction relative to the interface. A universal Snell's law has been derived, facilitated by deployment of known exact analytical bright soliton solutions to the underlying nonparaxial governing equations [Christian *et al.*, Phys. Rev. A vol. 76, 033833 (2007)]. Theoretical modelling has shown generally excellent agreement with full simulations involving soliton refraction at both linear and weakly-nonlinear interfaces. New and potentially exploitable qualitative phenomena have also been uncovered through numerical calculations in regimes involving relatively high-intensity light and a defocusing quintic nonlinearity. Finally, we will summarize recent results from computations (guided by critical-angle predictions from our new Snell's law) that have uncovered truly giant Goos-Hänchen shifts [Goos & Hänchen, Ann. Phys. vol. 1, 333 (1947)] in the cubic-quintic material context.