Helmholtz spatial solitons: towards a theory of ultranarrow optical beams

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Spatial optical solitons are self-localizing and self-stabilizing beams of light that propagate with a stationary (invariant) intensity profile. Such nonlinear wave states may arise when a beam's natural tendency to diffract is exactly compensated by local refractive-index changes that are written into the host medium by the beam itself. The standard theory of 'broad' spatial solitons is based upon a Schrödinger-type picture, with all its advantages and disadvantages [2]. Our Group has refined this approach, lifting some key (e.g., angular) limitations of conventional models by retaining more natural Helmholtz-type governing equations [2]. However, there is a clear need to understand how beams behave when the envelope waist (w_0) becomes 'narrow' on the wavelength (λ) scale (see figure 1); such considerations are important in the progressive miniaturization of optical devices. Various authors throughout the world have considered this class of problem, but their approaches are often restricted in some quite subtle ways. We have recently taken steps toward constructing the first Helmholtz-based theory for ultranarrow beams by deploying an order-of-magnitude analysis of nonlinear vector Maxwell's equations. This approach appears to be fully-consistent with Helmholtz broad-beam theory [2], and lacks the unphysical features that can creep into other ultranarrow-beam models. Semi-analytical bright and dark solitons have already been derived, leading to some surprising conclusions.

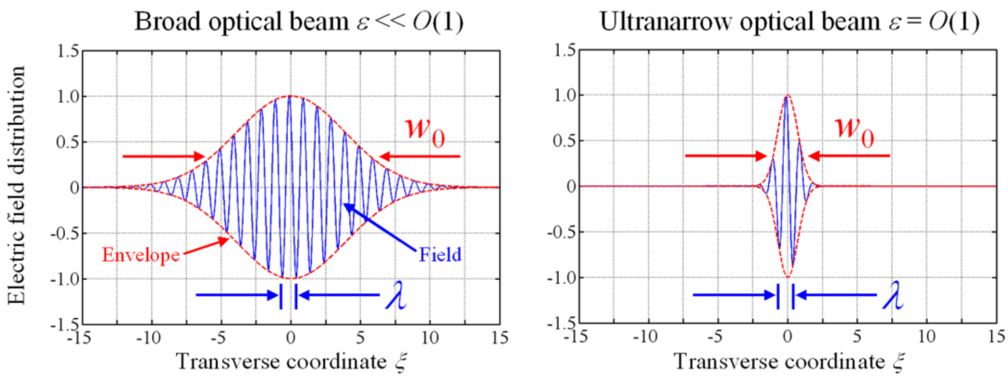

Figure 1. Schematic diagram illustrating broad (left) and ultranarrow (right) beams (note that the parameter $\varepsilon \sim \lambda/w_0$).

References

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