FUNDAMENTAL PROPERTIES OF (1+1)D AND (2+1)D NONPARAXIAL OPTICAL SOLITONS

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Beam paraxiality is often assumed when studying light propagation in nonlinear media; for instance, when the (exactly integrable) Nonlinear Schrödinger Equation (NLS) is used to model (1+1)D beam propagation in self-focusing Kerr media. We showed that, for many commonly found situations, NLS-based analyses lead to unphysical results [1]. Moreover, when two transverse coordinates are considered, the inclusion of nonparaxial effects is known to remove the unphysical beam collapse of (2+1)D paraxial theory.

In this presentation, we will focus on novel fundamental properties of nonparaxial solitons, derived using a range of analytical and numerical techniques. Analytical results for the (1+1)D case allow direct comparison with well-known NLS predictions, providing profound insight into the role of nonparaxial effects. The NLS is invariant under the Galilean transformation which describes a rotation of the beam axis. Unphysical features are found within this framework, such as an invariance of beam cross-section with respect to rotation angle. On the other hand, the Nonparaxial Nonlinear Schrödinger Equation (NNLS) is invariant under a more general transformation which yields fully consistent and physical beam properties. We will show that energy flow is conserved (in contrast to the paraxial beam area law). This also generalises previous work [2] in which only fast (on-axis) phase variations were accounted for.

Our exact analytical solutions have permitted development and validation of accurate nonparaxial beam propagation methods. In conjunction with other new techniques [3], generic properties of soliton splitting in (near-integrable) perturbed systems have been explored. An empirical exclusion principle will be highlighted which suggests that solitons are analogous to fermions. Furthermore, we have uncovered new quantum properties of the numerical solutions of (2+1)D systems which appear to parallel space quantisation.

References

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