Nondiffracting Hankel Beams in Linear and Nonlinear Optics

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Abstract

A travelling representation of nondiffracting beams, based on Hankel functions, and its implications for linear *and* nonlinear optics are presented. Classes of periodic beams possessing finite angular momentum are also predicted.

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Summary

It was shown by Durnin et al [1] that the Helmholtz equation for the free space propagation of light beams possesses exact eigenmode solutions that, in principle, describe beams which propagate indefinitely without any distortion due to diffraction. The problem is that these "nondiffracting" solutions, the simplest of which is proportional to the zero order Bessel function, are of infinite transverse extent and energy, and therefore cannot be realised in practice. However, Durnin et al were able to demonstrate in experiments with beams of *finite* size that the characteristics of nondiffraction could be sustained over long distances [1].

We propose a more general (Hankel) representation of nondiffracting beams. This allows a consistent description of travelling wave features and also has implications for the applications of such beams. A generic description of the full transverse profile, in experimental configurations which include finite aperture effects, is deduced. Using the Hankel formulation, we will demonstrate that the superposition of two distinct non-

diffracting beams can result in a periodically reconstructing beam with rotating and spiral wave features (see Fig. 1). The complexity of the transverse intensity profiles of such beams, and the speed at which they rotate, can be prescribed for any particular application. Indeed, the transverse scale of the rotating patterns can be as small as the optical wavelength. Applications involving the manipulation of small particles can be envisaged.

We have found that the master equation, from which the above free space results are deduced, also arises as a solvability condition at the threshold for modulational instability in *nonlinear* Kerr medium when radial symmetry is assumed. Results will be presented demonstrating the spontaneous and induced formation of these radially-symmetric modulational instability modes (see Fig. 2 and 3).

References

[1] J. Durnin, J. J. Miceli, Jr. and J. H. Eberly, Phys. Rev. Lett. 58 (1987) 1499; J. Durnin, J. Opt. Soc. Am. A4 (1987) 651.

[2] S. Chávez-Cerda, G. S. McDonald and G. H. C. New, “Nondiffracting Beams: Travelling, Standing, Rotating and Spiral Waves” (to appear in Opt. Commun.)

Figure Captions

1. Snapshot of the rotating spiral intensity pattern – “The Optical Drill”.
2. Spontaneous formation of a nonlinear Bessel mode (comparison of simulation and theory).
3. Induced formation of a nonlinear Bessel mode.