Vectorial high numerical aperture invariant beams

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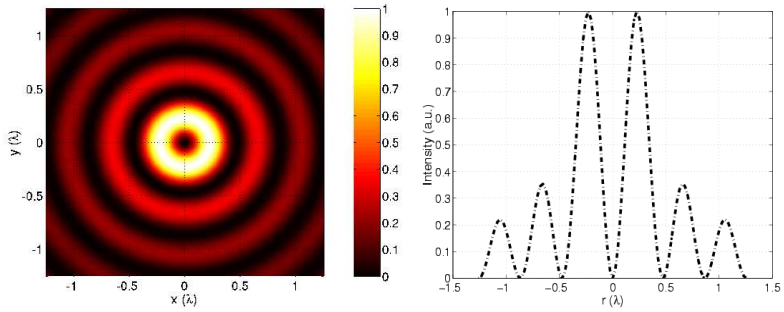
We present a novel closed form description of propagation invariant beams generated in the nominal focal region of a high numerical aperture lens. Such beams could have immediate application to stimulated emission depletion microscopy (STED) [1], precise positioning, and optical tweezers.



Intensity profile Cross section at y=0

Figure 1: Propagation invariant beam *NA*=0.8

Since their proposal by Durnin in the early 1980s [2] propagation invariant beams have remained an important area of interest both from a purely scientific perspective and in practical applications. A class of such beams, dubbed "Helicons" [3] which exhibit invariance within a rotating coordinate system have also been of great interest.

The desire to generate progressively smaller features necessarily implies the use of increasingly higher numerical aperture lenses. As the numerical aperture increases many of the approximations made within current formulations of propagation invariant beams begin to break down.

Starting from the well known Richards and Wolf integral we demonstrate that a class of vectorial propagation invariant and quasi propagation invariant beams exist even at extremely high numerical aperture.

Such a beam is displayed in figure 1where all dimensions are in wavelengths. The field, a sum of two Bessel functions of differing orders, clearly displays a zero of intensity on axis and in concentric rings. For this case of *NA*=0.8 the full width of this central dip is just 0.1λ.

[1] T. A. Klar, M. Dyba and S. W. Hell "Stimulated emission depletion microscopy with an offset depleting beam," *App. Phys. Lett.* **78**, 393-395 (2001)
[2] J. Durnin "Continuously self-imaging fields of infinite aperture," *J. Opt. Soc. of Am. A*. **2**, 110 (1985)
[3] C. Paterson and R. Smith. "Helicon waves: propagation-invariant waves in a rotating coordinate system," *Opt. Comm.*, 131- 140, (1995).