Peering into Darkness

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Ever wanted to look into a laser beam or to dim some other bright coherent light source to see the low-level light from other sources such as scatterers? By placing an optical vortex phase mask in the beam path, it has been shown that the relative contrast between a low-level near-axis light source and a high-intensity on-axis coherent source can be enhanced by many orders of magnitude.[1] This occurs because the on-axis coherent light undergoes destructive interference creating a dark vortex core, while the off-axis light from other sources diffracts into the core. Unlike interferometric nulling, this technique is simple to set up and is immune to vibrations in the apparatus. The effective size of the dark window increases with the topological charge created by the vortex mask. The topological charge is the number of 2π phase windings around the core, introduced by the mask.[2] Figure 1 shows the relative nulling effect on the bright source as the radial size of the viewing window is varied. These calculated values show, for example, that a vortex mask of topological charge $m = 4$ could allow 10 orders of magnitude reduction in the detected power of the bright source, assuming the window is one tenth the diameter of an Airy disk. In principle, this magnitude could allow the direct detection of light from a Jupiter-size planet orbiting a distant star at 1 AU. More terrestrial applications include techniques to quantify near-axis scattering, provide radiation protection from laser treats, and allow secure line-of-sight communications.

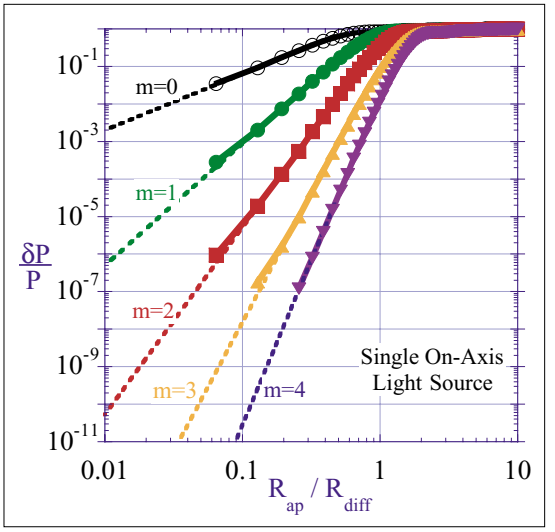

Figure 1. Power δP transmitted through an aperture of size R_{ap} normalized, respectively, by total beam power P and the characteristic diffraction size of the optical instrument, $R_{diff} = 1.22\ \lambda\ f$-number. Cases are shown for different values of the topological charge of the vortex ($m = 0$ implies a planar rather than a helical phase front).

References

1. G.A. Swartzlander, Jr., Opt. Lett. **26**, 497-9 (2001).
2. J. F. Nye and M.V. Berry, Proc. R. Soc. London Ser. A **336**, 165-90 (1974).