

Diffraction of a conical wave and a Gaussian beam by a spiral phase plate

V.V. Kotlyar^{1,2}, A.A. Kovalev^{1,2}, S.N. Khonina^{1,2}, R.V. Skidanov^{1,2}, V.A. Soifer^{1,2}, J. Turunen³

¹Image Processing Systems Institute of RAS;

²Samara State Aerospace University named after academician S.P. Korolev;

³University of Joensuu, Finland

Abstract

An analytical expression is obtained for the diffraction in the far zone of a conical wave on a spiral phase plate (SPP) with an arbitrary integer order of singularity n . Diffraction of a conical wave by an SPP is equivalent to the diffraction of a plane wave on a screw axicon. The diffraction of a conical wave and a Gaussian beam by an SPP is compared analytically. It is shown that in both cases a light ring is formed and the intensity function for small values of the radial variable ρ increases in proportion ρ^{2n} , and for large ρ decreases as $n^2\rho^{-4}$. A 32-level second-order SPP with a diameter of 5 mm was made by way of direct recording with an electron beam on a resist. Using this SPP, a beam of a helium-neon laser was converted into a beam with a phase singularity and an annular intensity distribution.

Keywords: Gaussian beam, conical wave, spiral phase plate, axicon, diffraction of a conical wave, helium-neon laser

Citation: Kotlyar VV, Kovalev AA, Khonina SN, Skidanov RV, Soifer VA, Turunen J. Diffraction of a conical wave and a Gaussian beam by a spiral phase plate. *Computer Optics* 2005; 28: 29-36.

[Access full text \(in Russian\)](#)

References

- [1] Prudnikov AP, Brychkov YuA, Marichev OI. Integrals and series. Volume 2: Special functions. Amsterdam: Gordon and Breach Science Publishers; 1998.
- [2] Alonzo CA, Rodrigo PJ, Gluckstad J. Helico-conical optical beams: a product of helical and conical phase fronts. *Opt Expr* 2005; 13(5): 1749-1760.
- [3] Cheong WG, Lee WM, Yuan X-C, Zhang L-S, Dholakia K, Wang H. Direct electron-beam writing of continuous spiral phase plates in negative resist with high power efficiency for optical manipulation. *Appl Phys Lett* 2004; 85(23): 5784-5786.
- [4] Furhapter S, Jesacher A, Bernet S, Ritsch-Marte M. Spiral phase contrast imaging in microscopy. *Opt Express* 2005; 13(3): 689-694.
- [5] Ganic D, Gan X, Gu M. Focusing of doughnut laser beams by a high numerical-aperture objective in free space. *Opt Express* 2003; 11(21): 2747-2752.
- [6] Khonina SN, Kotlyar VV, Shinkaryev MV, Soifer VA, Uspleniev GV. The rotor phase filter. *J Mod Opt* 1992; 39(5): 1147-1154. DOI: 10.1080/09500349214551151.
- [7] Khonina SN, Kotlyar VV, Skidanov RV, Soifer VA, Jefimos K, Simonen J, Turunen J. Rotation of microparticles with Bessel beams generated by diffractive elements. *J Mod Opt* 2004; 51(14): 2167-2184. DOI: 10.1080/09500340408232521.
- [8] Khonina SN, Kotlyar VV, Soifer VA, Shinkaryev MV, Uspleniev GV. Trochosocon. *Opt Commun* 1992; 91(3-4): 158-162. DOI: 10.1016/0030-4018(92)90430-Y.
- [9] Kotlyar VV, Almazov AA, Khonina SN, Soifer VA, Elfstrom H, Turunen J. Generation of phase singularity through diffracting a plane or Gaussian beam by a spiral phase plate. *J Opt Soc Am A* 2005; 22(5): 849-861. DOI: 10.1364/JOSAA.22.000849.
- [10] Lee WM, Ahluwalia BPS, Yuan X-C, Cheong WC, Dholakia K. Optical steering of high and low index microparticles by manipulating an off-axis optical vortex. *J Opt A Pure Appl Opt* 2005; 7: 1-6.
- [11] Niv A, Biener G, Kleiner V, Hasman E. Spiral phase elements obtained by use of discrete space-variant subwavelength gratings. *Opt Commun* 2005; 251: 306-314.
- [12] Oemrawsingh SSR, van Houwelingen JAW, Eliel ER, Woerdman JR, Vestegen EJK, Kloosterboer JG, Hooft GW. Production and characterization of spiral phase plates for optical wavelengths. *Appl Opt* 2004; 43(3): 688-694.
- [13] Paterson C, Smith R. Higher-order Bessel waves produced by axicon-type computer-generated holograms. *Opt Commun* 1996; 124: 123-130.
- [14] Saks ZS, Rozes D, Swatzlander GA. Holographic formation of optical-vortex filaments. *J Opt Soc Am B* 1998; 15: 2226-2234.
- [15] Sueda K, Miyaji G, Miyanaga N, Nakatsura M. Laguerre-Gaussian beam generated with a multilevel spiral phase plate for high intensity laser pulses. *Opt Expr* 2004; 12(15): 3548-3553.
- [16] Sundbeck S, Gruzberg I, Grier DG. Structure and scalling of helical modes of light. *Opt Lett* 2005; 30(5): 1-13.