APPENDIX

Bessel beams, formed by superposition of a set of plane waves that undergo the same phase shift over a spatial propagation, with the wave vectors propagating on a cone (Fig. A1), are localized beams with transverse patterns that remain stationary along the propagation distance The electric field component of a Bessel beam can be represented as[7]

$$E(r, \phi, z) = A_0 \exp(ik_z z)\, J_\mathrm{n}(k_\mathrm{r} r) \exp(\pm im\phi)$$

where J_n is an nth-order Bessel function of the first kind, A_0 is the amplitude of the electric component of the electromagnetic wave, k_z is the longitudinal wave vector, k_r is the radial wave vector, and r, ϕ and z are the radial, azimuthal and longitudinal components, respectively. This equation may be reduced by $|J_\mathrm{n}|$ as when generated by an axicon or similar. The phase carries the important properties, from which the spiral vortex set by order m may also be omitted.

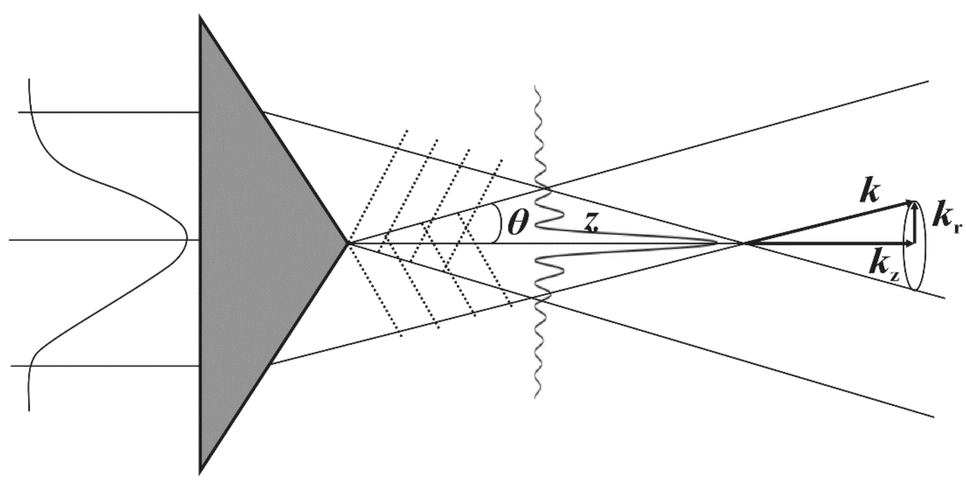

Figure A1. Spatial spectrum of a Bessel beam generated using an axicon with wave vectors of plane waves on the surface of a cone. θ, Opening angle of cone; k, wave vector; k_r, radial component of k; k_z, longitudinal component of k. (Modified from reference[6])

The transportation of energy from rings of the Bessel beam prevents the central lobe from spreading as well as contributing to the beam reconstruction beyond an obstruction,[7, 11, 24] i.e., if an obstructing object is placed in the center of the beam, the energy from the rings is transported to the center of the beam and the initial profile is reformed after a further distance z_{min} given by[7]

$$z_{\mathrm{min}} \approx \frac{ak}{2k_{\mathrm{z}}}$$

where a is the width of the obstruction measured from the beam center and k is the wave number whose magnitude is given by

$$k = \sqrt{k_{\mathrm{z}}^2 + k_{\mathrm{r}}^2}$$