Propagation of beams with a power-law dependence on the radius

O. A. Dyukareva
dukarevaola@gmail.com

Introduction

Optical traps [1] are widely used to capture, manipulate, and study molecules, atoms, and biological cells. For conventional light traps, when a microparticle is attracted to the region of maximum intensity, the destructive effect of heating on the trapped objects is one of the main problems. An alternative is to capture in the area with minimum intensity, in the so-called “light bottles” [2], which are an area of zero intensity surrounded by a high intensity area, which are light barriers.

Many works are devoted to the construction of a trap based on Airy beams formed by the cubic phase, since they have the property of abruptly autofocusing [3]. To create optical traps, it is logical to use beams with large intensity and phase gradients using diffusive optical elements or optical light modulators [4].

We consider beams with a power-law dependence on the radius, combined with a binary axicon [5], and with an additional apodization aperture, which provides a variation in the properties of self-focusing beams and the possibility of creating optical traps of different sizes and shapes.

Modelling

In this work, optical beams of the following form are considered:

\[ f(r) = c_0 \exp(-\text{i}k\alpha_1 (r - r_0)^3) \cos(\alpha_2 (r - r_0)), \]

where \( k = 2\pi/\lambda \) is the wave number for laser radiation with wavelength \( \lambda \), \( \alpha_1 \) is a positive real number less than one. The Fresnel transform is used to simulate the paraxial propagation of a beam in space. Input function can be represented as \( f(r, \omega) = A(\omega) \exp(\text{i}k\omega^m r), \)

where \( m \) is an integer, and has asymmetry (\( m = 0 \)), therefore the generated field will not depend on the angle:

\[ f_0(p, z) = \frac{k}{2} \exp(\text{i}kz) \exp\left(\frac{\text{i}kr^2}{2z}\right) \int_0^r A(r) \exp\left(\frac{\text{i}kr^2}{2z}\right) J_0\left(\frac{kr}{2z}\right) r dr. \]

The properties of lenses with quadratic and cubic dependencies on the radius with different apertures in the central part are illustrated. Using a binary axicon, optical traps of various sizes and lengths were built. It is shown that the power of the function also makes it possible to control the structure of optical traps.

References


Conclusion

The properties of lenses with quadratic and cubic dependencies on the radius with different apertures in the central part are illustrated. Using a binary axicon, optical traps of various sizes and lengths were built. It is shown that the power of the function also makes it possible to control the structure of optical traps.