Modeling the propagation of polygon beams

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Introduction

Beams with multiple intensity maximum that propagate along a curved trajectory have many interesting applications. In this work, we consider several phase masks, each of which allows us to obtain polygon beams with a different number of intensity peaks.

Modeling

The integral representation of regular polygonal beams can be written as:

$$E(x,y,z) = A\int_{-\infty}^{+\infty} d\xi \int_{-\infty}^{+\infty} d\eta \exp\left[ik\psi(\xi,\eta,x,y,z)\right]$$

When studying the works of other authors, several polynomials of a general form were identified. And one ot these polynomials is given by the following formula:

$$\varphi(\xi,\eta) = \xi^p + \eta^q - \xi^n \eta^m .$$

This polynomial makes it possible to obtain beams with four intensity peaks at specific values of the degrees p, q, n and m, as well as the value of the z index.

Figures 1 and 2 show the propagation of beams obtained using this polynomial at various parameters. As you can see, it allows you to obtain beams with different types of intensity peaks - point and tip structure

The next step was decided to use Zernike polynomials as a basis, since their diversity will allow to obtain many different results.

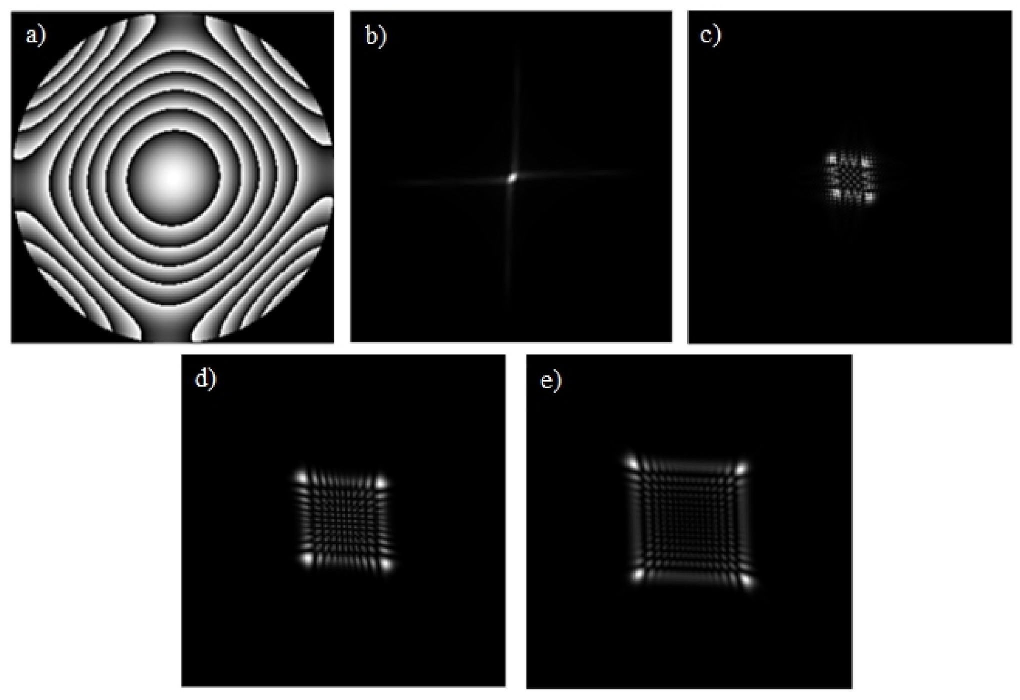

Fig. 1.Propagation in space of a polygonal beam with four intensity peaks at $z=4,\ p=1,\ q=1,\ n=2,\ m=2$. (a) – phase mask, (b-f) – distributions obtained at a distance from 1000 to 100000 mm.

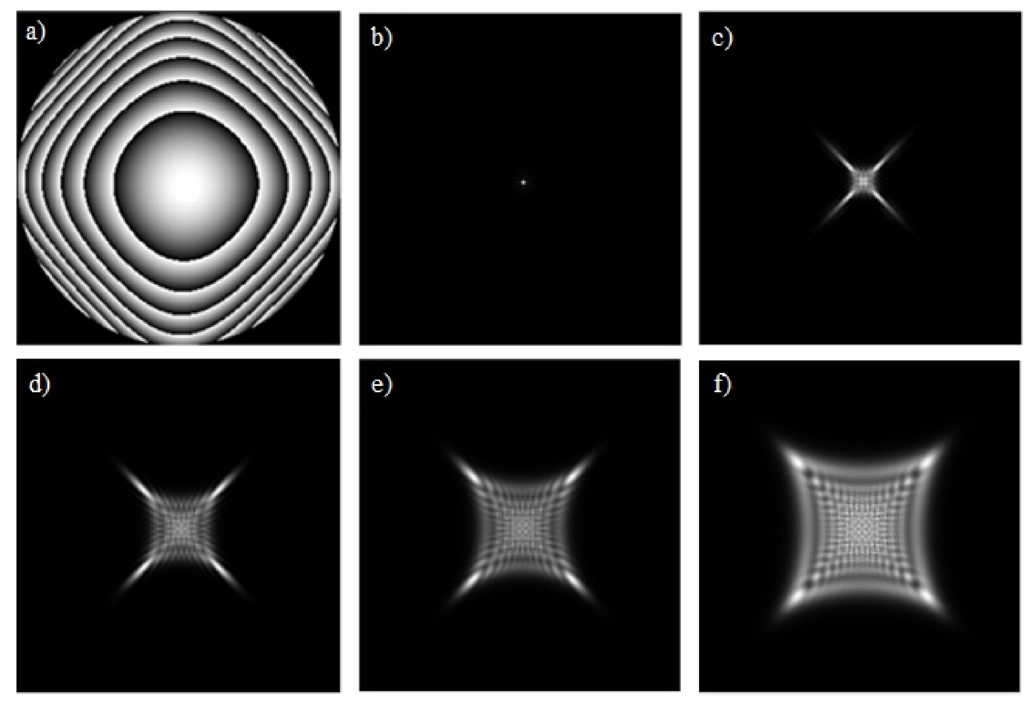

Fig. 2.Propagation in space of a polygonal beam with four intensity peak at $z=12,\ p=4,\ q=4,\ n=1,\ m=1$. (a) – phase mask, (b-e) – distributions obtained at a distance from 300 to 100000 mm.

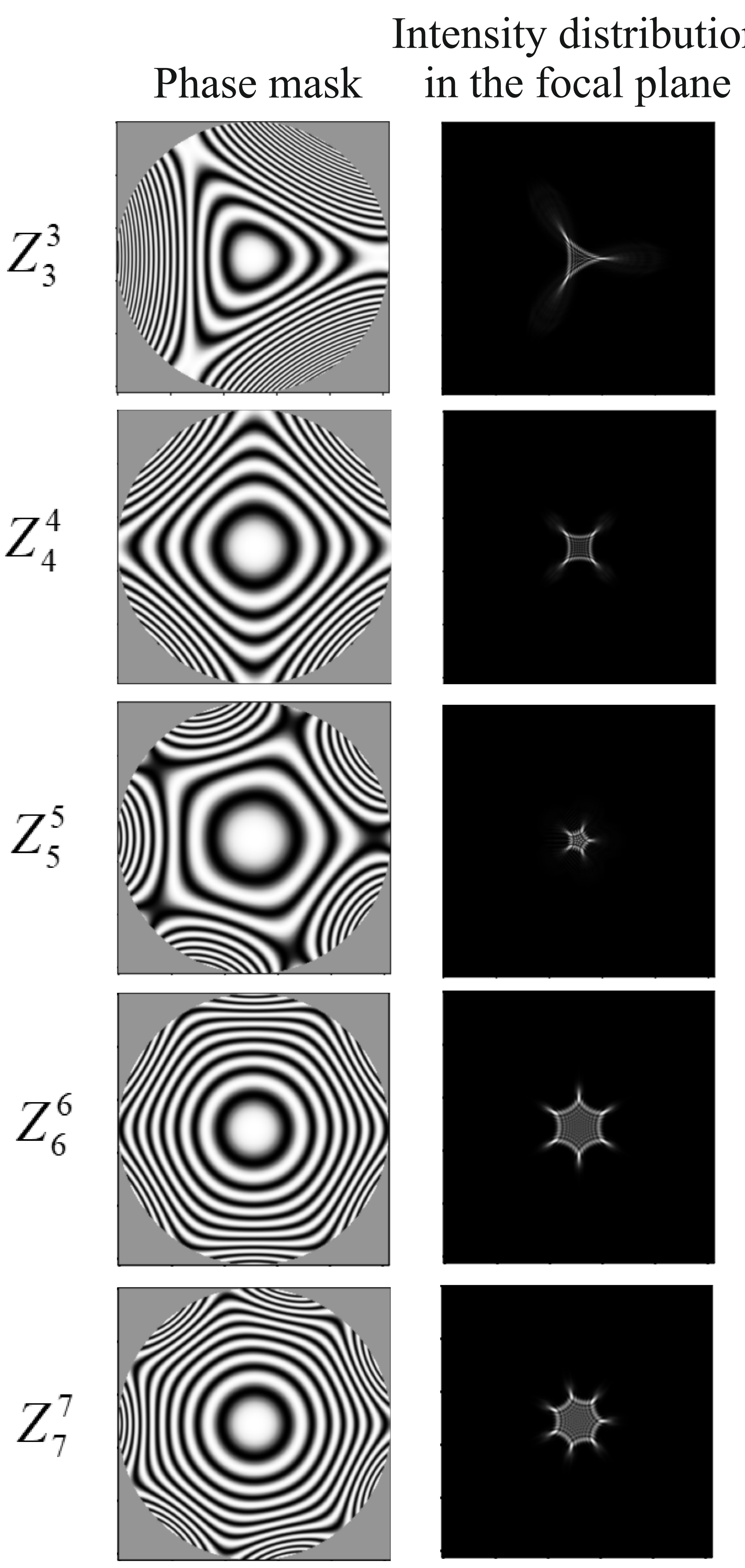

Fig. 3. Beams obtained using the Zernike polynomial.

For example:

$$Z_4^4 = \sqrt{10}(x^4 - 6x^2y^2 + y^4);$$

$$Z_5^3 = \sqrt{12}(5x^5 - 10x^3y^2 - 15xy^4 - 4x^3 + 12xy^2);$$

$$Z_6^2 = \sqrt{14}(15x^6 + 15x^4y^2 - 15x^2y^4 - 15y^6 - 20x^4 + 20y^4 + 6x^2 - 6y^2).$$

Figure 3 shows the phase masks and the results of modeling in the focal plane. Thus, the number of petals coincides with the order of the polynomial. But when it reaches six, the highs become less pronounced and more vague. And it isalso clear that only the central part is responsible for the shape of the final beam, since when moving further away from the center, the mask quickly becomes unreadable (Fig. 4-6).

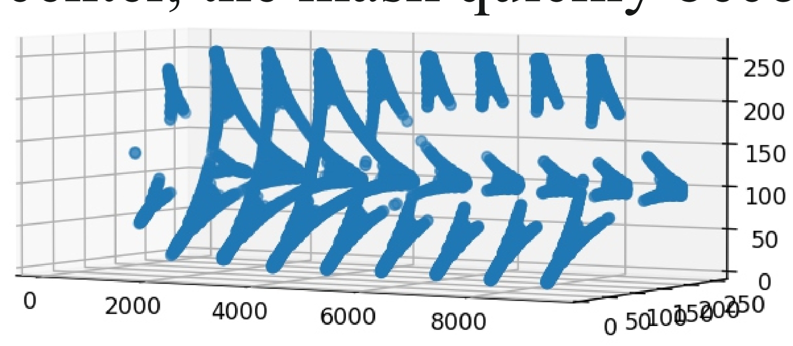

Fig. 4 Beam propagation with three maxima

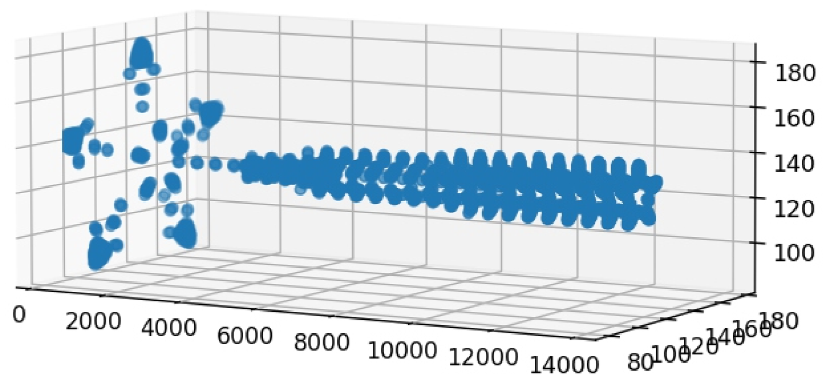

Fig. 5 Beam propagation with five maxima

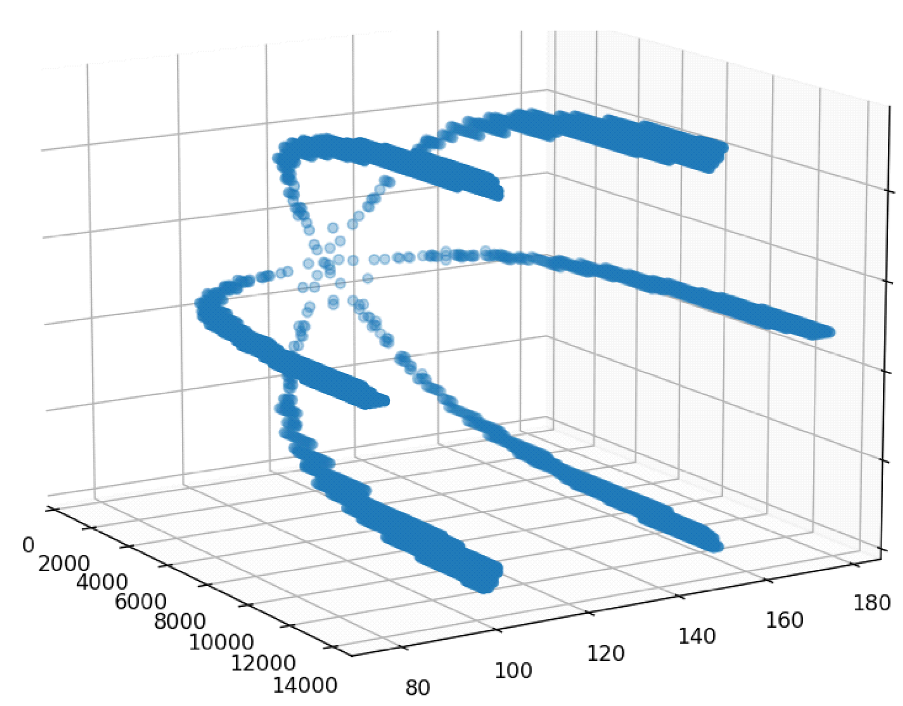

Fig. 6 Beam propagation with six maxima.

Conclusion

Several polygonal beams are considered, which make it possible to obtain a different number of intensity peaks moving along a curved trajectory. Experimental studies are necessary for a complete study of the properties. Based on the work carried out, it can be assumed that these beams can be used to expand the means of optical capture and manipulation of micro-objects.