Modeling the formation of contour laser beams

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***Abstract*—The paper presents modeling results of the formation of polymorphic contour beams. The influence of various parameters on the curves properties investigated.**

***Keywords*— Super Formula, Whittaker integral, Fourier transform, polymorphic contour beams.**

1. INTRODUCTION

Laser radiation has found wide application in various fields of science and technology, for example, this technology has found its application for cooling atoms, manipulating particles, and processing materials [1-4]. The possibility of designing optical elements that allow controlling the optical flow opens up promising new prospects for the use of laser radiation [5-9].

There are situations when there is a need to concentrate radiation in narrow contour areas. To solve this problem, polymorphic contour bundles can be used [5, 10], as well as diffraction optical elements focusing into specified 2D and 3D curves [11-20].

A simple and convenient solution for the formation of arbitrary curves is the composition in one optical element of several elements focusing into some primitive distributions (points, lines, rings, spirals) [13, 21-23]. Compositions of diffraction-free beams can also be used to form given distributions [24-27]. Since the spatial spectrum of diffraction-free beams is defined on a narrow ring and the propagation operator of such beams can be reduced to a one-dimensional integral [11, 24, 28, 29], then the solution of the problem becomes even faster.

The expected applications of polymorphic contour beams include single-pulse laser lithography, laser surface microtreatment, and photo production of structures for fabrics of engineering frames or other complex structures, transportation of particles along programmed trajectories.

This paper presents modeling results of the formation of polymorphic contour beams. The influence of various parameters on the curves properties investigated.

2. THEORETICAL FOUNDATIONS

At the first stage, we will set the curve that we want to get in the focal plane.

To set and draw a certain specified curve, a developed program uses an expression known as the Super Formula (SF) that Johan Gielis propose in 2003 [30], while studying biological and other natural forms. The SF depends on parameters a, b, n_1, n_2, n_3, m :

$$R(t) = p(t)\left[\left|\frac{1}{a}\cos\left(\frac{m}{4}t\right)\right|^{n_2} + \left|\frac{1}{b}\sin\left(\frac{m}{4}t\right)\right|^{n_3}\right]^{-\frac{1}{n_1}}, \quad (1)$$

where m is an integer number, parameters a, b, n_1, n_2, n_3, m determine the periodic part of the curve, the function $p(t)$ is the function that is responsible for the asymmetric part, t is the polar angle.

For $p(t) = p_0$ and $q = (a, b, n_1, n_2, n_3, m)$, where $t \in [0, 2\pi]$, it turns out a circle with a radius $R(t) = p_0$, while the other value q allow you to create a large set of closed polygons of various symmetries.

This paper proposes a simple method for generating a complex field based on a previously defined curve function (1). The expression has following form [5]:

$$E(x, y) = \int_0^T g(t)\exp\left[-i\frac{k}{f_0}R(t)(x\cos t + y\sin t)\right]dt, \quad (2)$$

where the parameter T defines the maximum value of the azimuth angle t, $k = \dfrac{2\pi}{\lambda}$, λ is the radiation wavelength, f_0 is the focal length of the lens, $R(t)$ and $g(t)$ are parametric functions describing the shape of the curve and the distribution on the curve, respectively.

To model curve formation we use the Fourier transformation:

$$F(u, v) = \iint_\Omega E(x, y)\exp\left[i\left(\frac{2\pi}{\lambda f_0}\right)(xu + yv)\right]dxdy, \quad (3)$$

where $\Omega : x^2 + y^2 \le R_0$, R_0 is the maximum of field size.

3. MODELING

Based on SF (1), we will simulate the formation of a curve.

Fig. 1 shows examples of constructing curves using various parameters.

Based on Whittaker integral (2), we will calculate the input field of the beam.

Fig. 2 demonstrates examples of calculated amplitudes and phases of the input fields for different curves.

The fig. 2 shows what the parameters of the amplitude and phase of the input field should be in order to obtain a certain curve.

The fig. 3 shows results of simulation the propagation of the input fields bounded by aperture $R_0 = 3$ through the lens by Fourier transform (3).

Fig. 4 demonstrates a comparison of the results obtained with the expected ones.

The comparison shows that the expected curves has been formed, but intensity of the output field is uneven. Probably, this effect is related to the limitation of the parameter R_0. Then, we investigate the effect of this parameter.

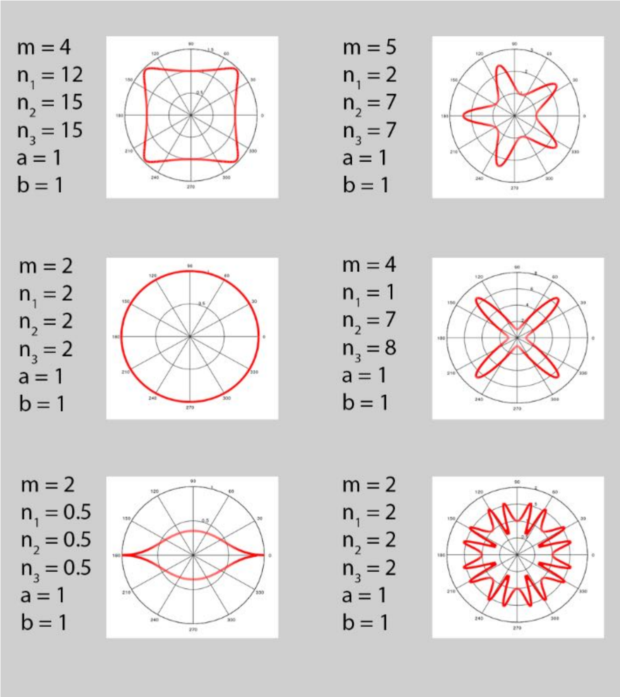

Fig. 1. Results of constructing of various curves

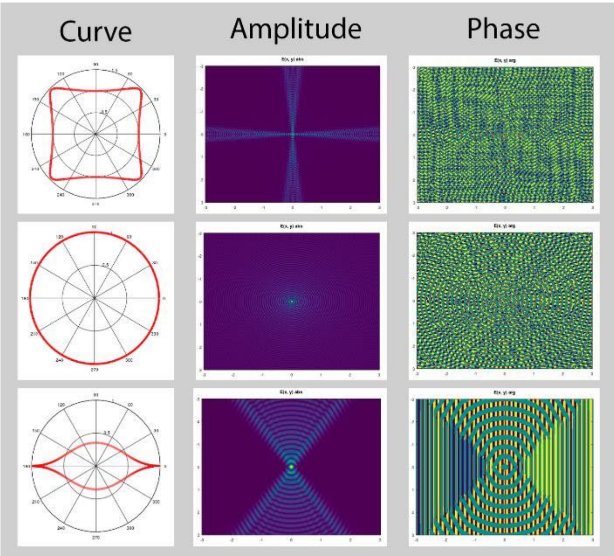

Fig. 2. Construction of the amplitudes and phases of the input fields

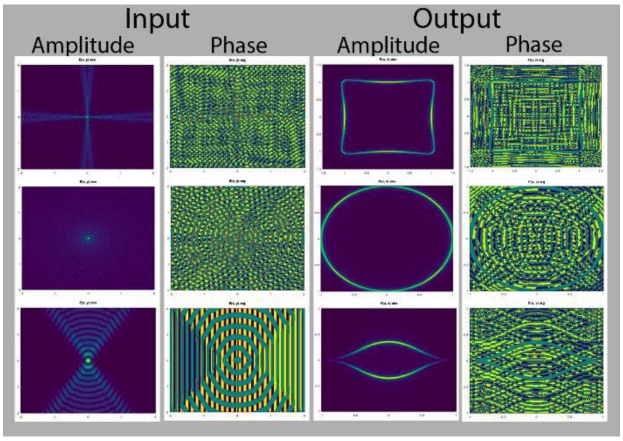

Fig. 3. Construction of the output fields for the bounded input fields

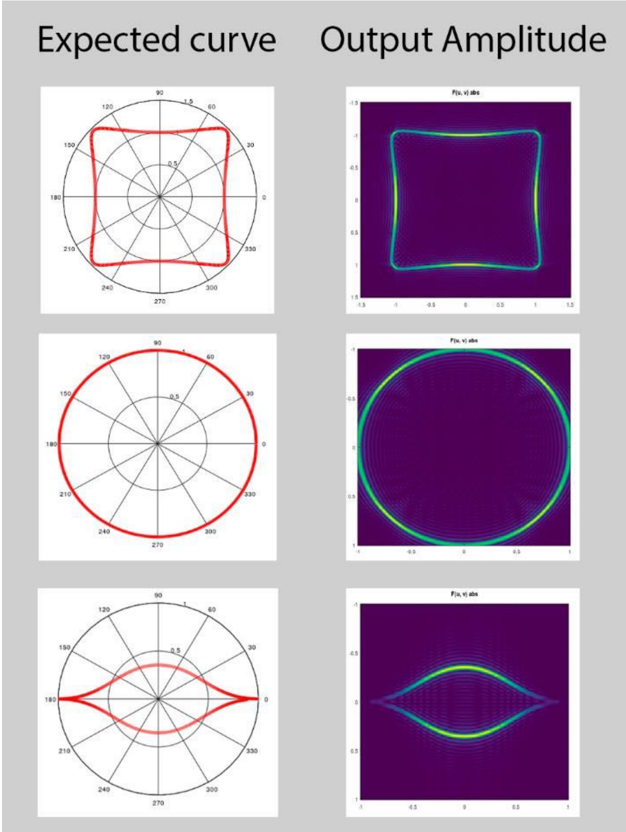

Fig. 4. Comparison expected curve and output field amplitude

4. INVESTIGATION

We investigate the effect of the input field size R_0 on the output field, especially on the amplitude.

The fig. 5 shows results of the investigation.

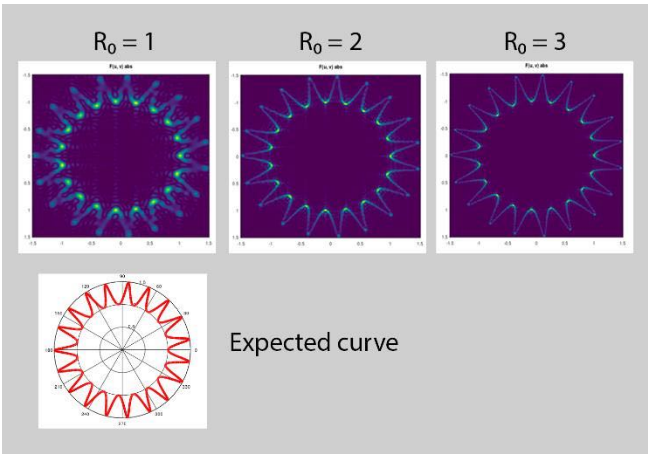

Fig. 5. Comparison expected curve and output field amplitude

Based on the conducted research, it is concluded that the larger the size of the input field, the more accurate the output curve will be.

5. CONCLUSION

In this paper, considered and demonstrated approach to model the formation of polymorphic beams by using Super Formula, Whittaker integral and Fourier transformation. Investigations showed that the larger the size of the input field, the more accurate the output curve will be.

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