

Three-dimensional intensity distribution of beams under double phase quantization in an asymmetric lens

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Olga Dyukareva
Samara National Research University
dukarevaola@gmail.com

MATHEMATICAL MODEL

The free space beams propagation in the paraxial region can be calculated using the Fresnel transform:

$$F(u, v, z) = -\frac{ik}{2\pi z} \exp(ikz) \iint_{-\infty}^{\infty} g(x, y) \exp\left(\frac{ik}{2z}((x-u)^2 + (y-v)^2)\right) dx dy, \sqrt{(x-u)^2 + (y-v)^2} \ll z,$$

where $k = 2\pi/\lambda$ is the wavenumber, λ is the radiation wavelength, $g(x, y)$ is the input field; $g(x, y) = 0$ outside of input pupil with radius R .

To shift the lens focus from the optical axis, we supplement it with an optical wedge of the form $\exp(ik\alpha y)$, then the input field can be described by the expression:

$$g(r) = e^{-ik\left(\frac{r^2}{2f} - \alpha y\right)}.$$

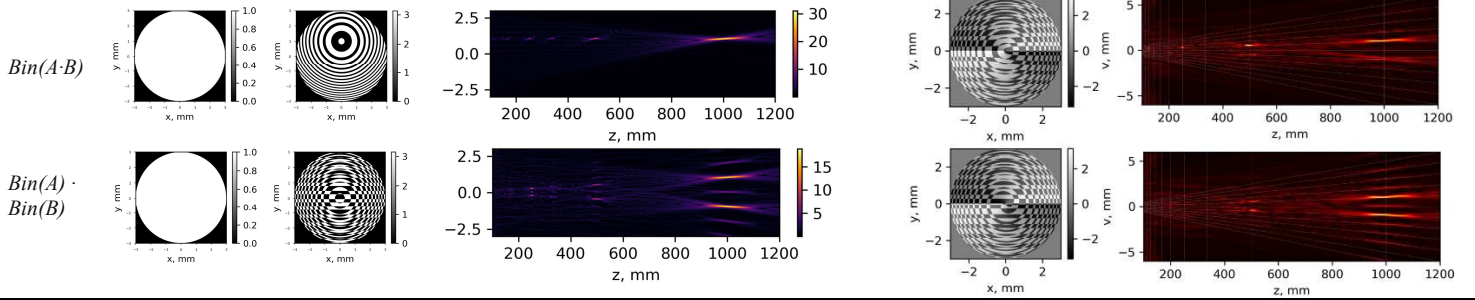
Quantization is performed at a certain level γ :

$$g_\gamma(r) = \exp\left(\frac{i\pi\left(1 + \text{sign}(\arg(g(r)) + \pi - 2\pi\gamma)\right)}{2}\right).$$

In this work, by cascade quantization (or cascade binarization, in the particular case) we shall mean the sequential dependent application of a quantization operator to individual parts of the phase of the complex transmission function of an optical element of the form $\text{Bin}_1[\text{Bin}_2[A]*B]$.

ASYMMETRIC LENS WITH INDEPENDENT BINARIZATION

- In the horizontal direction, there are no orders corresponding to the lens's γ , and in the vertical direction, none corresponding to the wedge—independently.

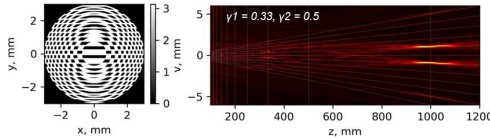


CASCADED QUANTIZATION

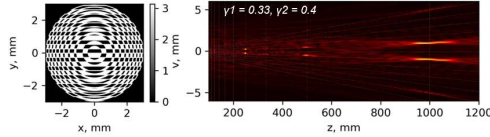
$$g_1(r) = B\gamma_1 \left\{ B\gamma_2 \left\{ \exp\left[-ik\frac{r^2}{2f}\right] \right\} \exp[ik\alpha y] \right\},$$

$$g_2(r) = B\gamma_1 \left\{ B\gamma_2 \left\{ \exp[ik\alpha y] \right\} \exp\left[-ik\frac{r^2}{2f}\right] \right\}.$$

- a stable transverse order structure is observed;

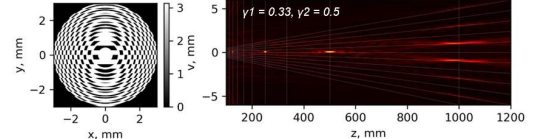


- feature: predominance of first-order components at all quantization levels;

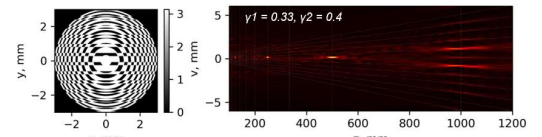


- the order dependence on the axis is not preserved.

- $\gamma=0.5$: symmetrical transverse odd wedge orders in every second odd order of the lens;



- else: wedge orders are formed only in odd (first, third, etc.) orders of the lens;



- in even orders, a zero maximum is formed.

CONCLUSIONS

A combination of a quantized lens and a quantized wedge makes it possible to simultaneously obtain transverse and longitudinal multiplication of the number of diffraction maxima. In this case, the main transverse energy is concentrated in the first symmetric orders, and as the input plane is approached, the maximum intensity of the orders does not decrease, but the energy is distributed over a smaller area. Quantized elements can be effectively used in problems of detecting multiplexed beams in dense optical information transmission.

ACKNOWLEDGMENTS

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