Analysis of the Impact of Aberrational Distortions on the Intensity Pattern of Vortex Beams of Various Orders

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Introduction

Optical vortex beams are laser beams of a specific structure, the special properties of which have been actively studied for several decades [1]. The most important among their special properties is the presence of an orbital angular momentum, which is determined by the order of the vortex beam or the topological charge. Another distinguishing feature of vortex beams is also the presence of a vortex phase singularity, in which the phase is not defined and the amplitude is zero. Vortex beams are effectively used in various fields, such as optical information transmission [2], optical traps and manipulation [3], laser structuring, contrasting and edge extraction, and others.

Research

The optical vortex beam is given by the formula:

$$f(\rho,\varphi) = \exp(-\frac{\rho^2}{\sigma^2})\rho^{|l|}\exp(il\varphi), \qquad (1)$$

where l is the order of the vortex, and σ is the radius of the Gaussian beam.

The effect of various aberrations on a vortex beam can be modeled by multiplying formula (1) by an expression of the form $\exp(i\alpha Z_n^m(\rho,\varphi))$:

$$f(\rho,\varphi) = \exp\left(-\frac{\rho^2}{\sigma^2}\right)\rho^{|l|}\exp(il\varphi)\exp(i\alpha Z_n^m(\rho,\varphi))$$
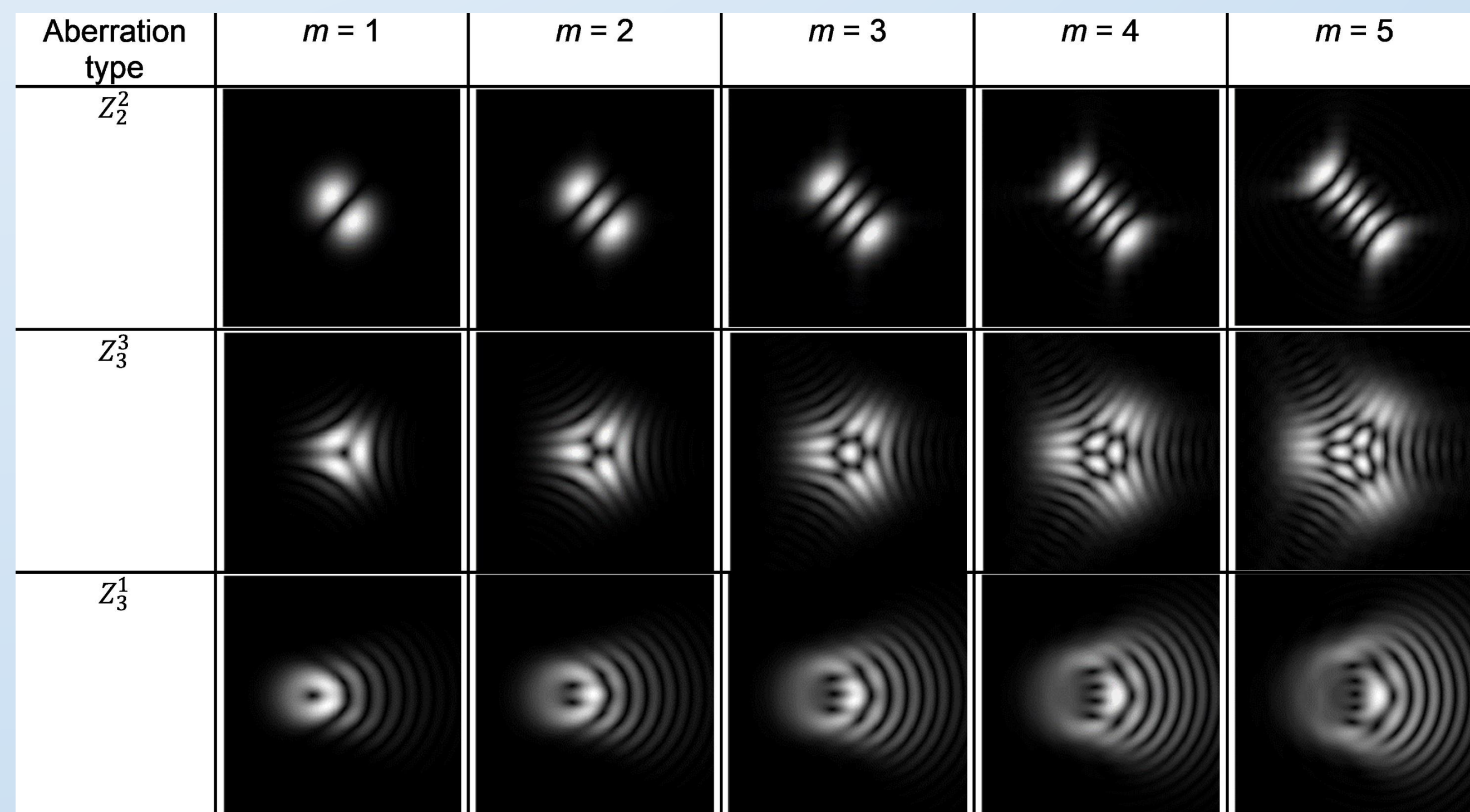
where α is the level of aberration.

Aberration type	m = 1	m = 2	m = 3	m = 4	m = 5
Z_2^2					
Z_3^3					
Z_3^1					

Fig. 1. The results of the impact of aberrations Z_2^2, Z_3^3 and Z_3^1 on vortex beams of order from 1 to 5

Aberration type	Topological charge m = 3	Topological charge m = −3
Z_2^2		
Z_3^3		
Z_3^1		
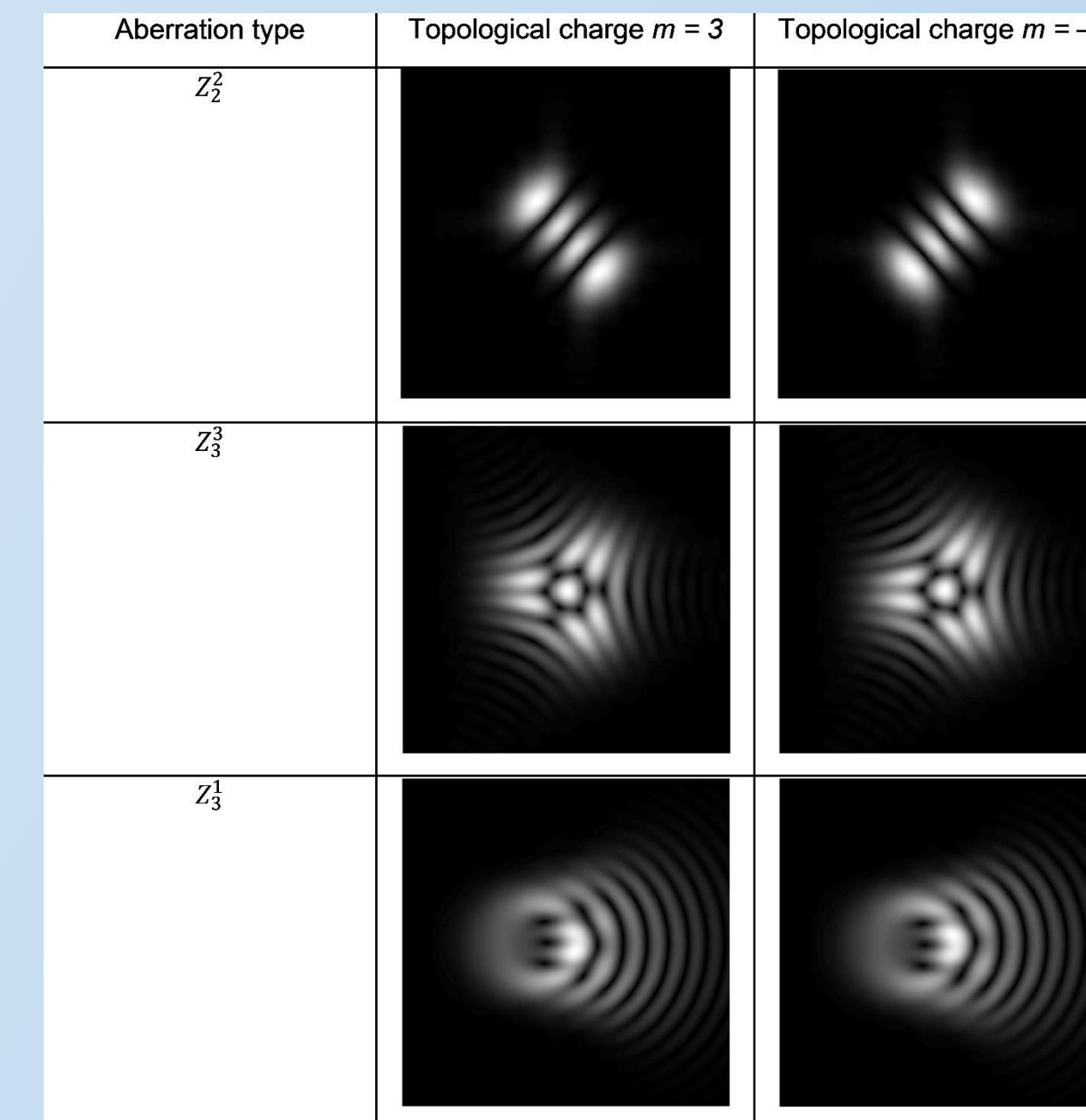
Fig. 2. Comparison of the intensity distribution for topological charges with different signs

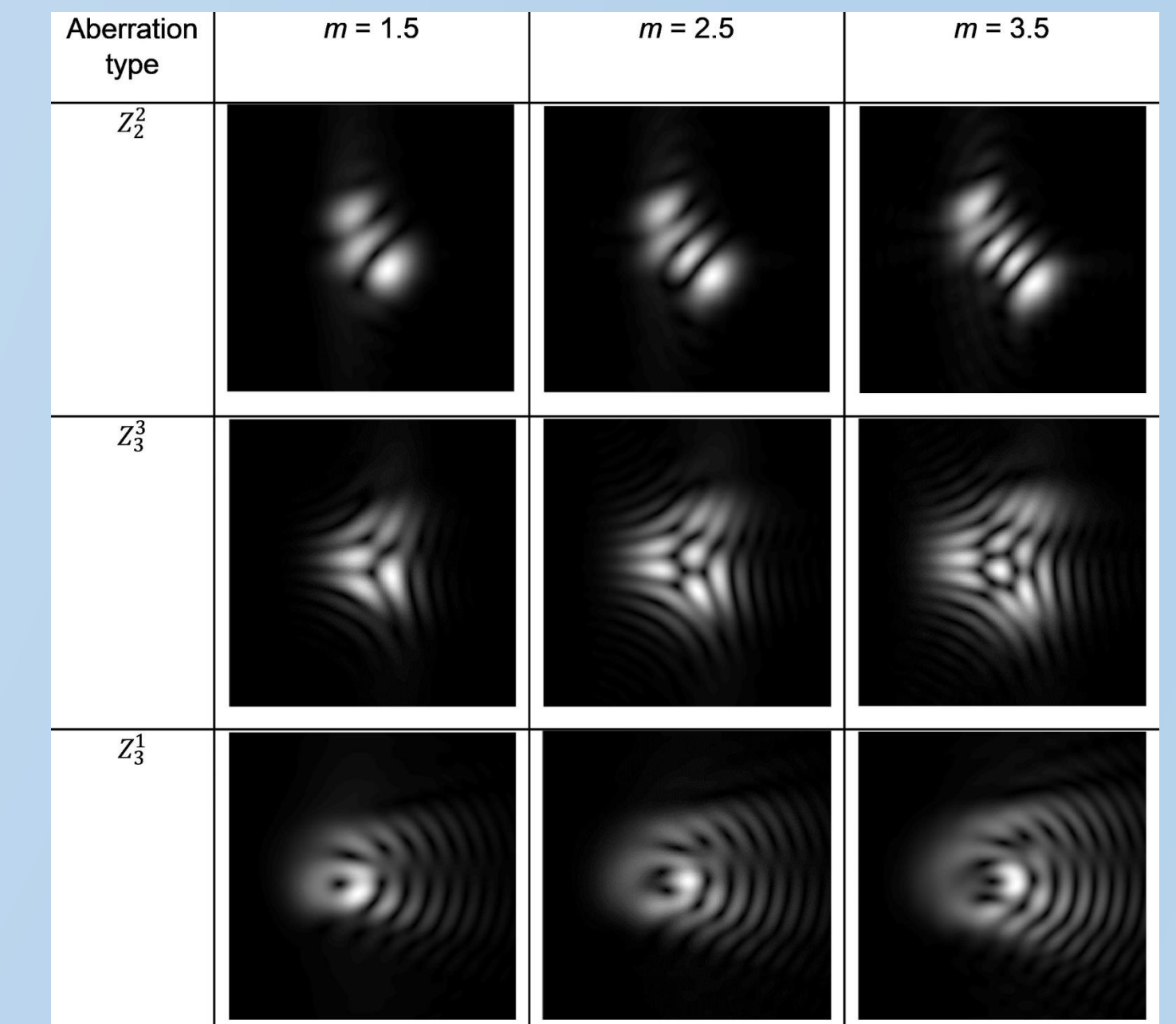| Aberration type	m = 1.5	m = 2.5	m = 3.5
Z_2^2			
Z_3^3			
Z_3^1			

Fig. 3. The results of the impact of aberrations Z_2^2, Z_3^3 and Z_3^1 on vortex beams of non-integer order m

Conclusion

Thus, it was shown in the work that the most useful in determining the order of a vortex beam are coma-type aberrations and astigmatism. If it is planned to measure only integer values of charges and their sign is important, it is better to use astigmatism. If the sign of the charge is not important, but there is a need to determine non-integer charges, it is better to use coma.

References

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