Formation of a set of axial optical bottles due to annular screening of the binary axicon

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A simple method of forming a set of optical flasks arranged sequentially one after the other on the optical axis, which are formed by blocking the binary diffraction axicon with an annular screen, is considered.

The binary axicon is given in the following form: $\tau_{bax}(r) = \exp\left[i\arg(\cos(k\alpha r))\right]$

To shield the element, the aperture is used, which can be written as follows: $\tau_{ring} = \begin{cases} 0, & r_0 < r < r_0 + \Delta \\ 1, & else \end{cases}$

Then, when combining the two formulas presented above, the final formula of the element in question takes the following in: $\tau_{rbax} = \tau_{ring} \exp[i\arg(\cos(k\alpha r))]$

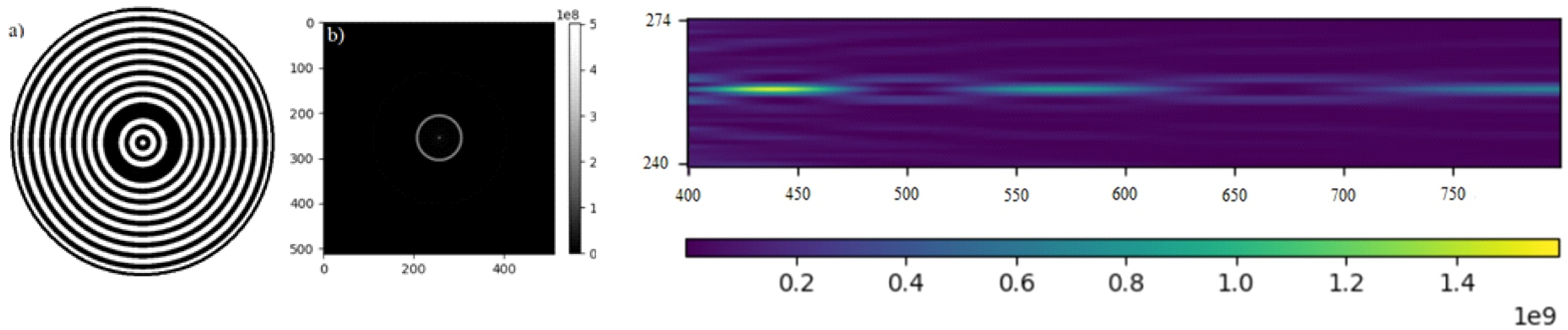

Fig. 1. Phase mask of a binary axicon with third ring blocking (a), intensity distribution in the focal plane (the scale has been doubled) (b), and the longitudinal distribution of the beam intensity at a distance of 400–800 mm

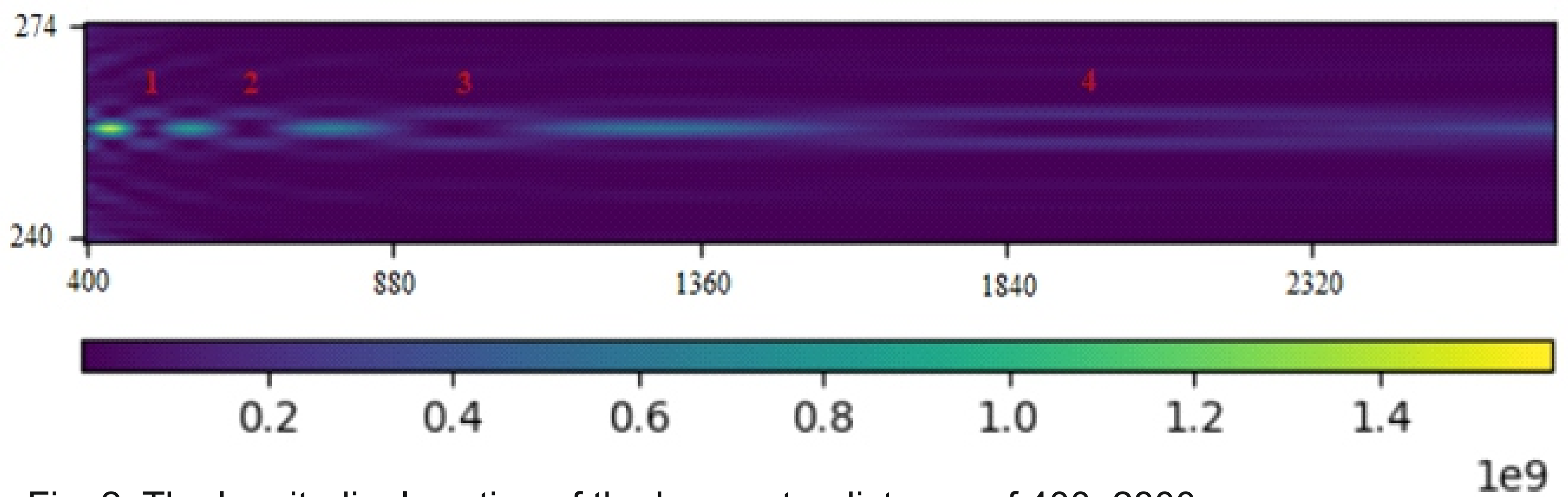

Fig. 2. The longitudinal section of the beam at a distance of 400–2800 mm

It is known that the axicon forms an axial light segment. If an annular screen is applied to the axicon, this will block the radiation at the corresponding point of the optical axis. As a result, a shadow region will be formed in this place, surrounded by light walls (due to diffraction effects), which is an optical trap.

The multiplicity of traps can be explained by the fact that the axicon in question is binary, that is, it actually consists of a combination of two axicons. In addition, the overlay of the ring screen also divides the element into two areas - internal and external. Accordingly, when light propagates from different areas of the optical element, interference occurs, which leads to the formation of not one, but several traps. At longer distances (z > 3000 mm), traps are no longer formed.

A more visual representation of the properties of the formed beamcan be obtained by three-dimensional visualization of its propagation.

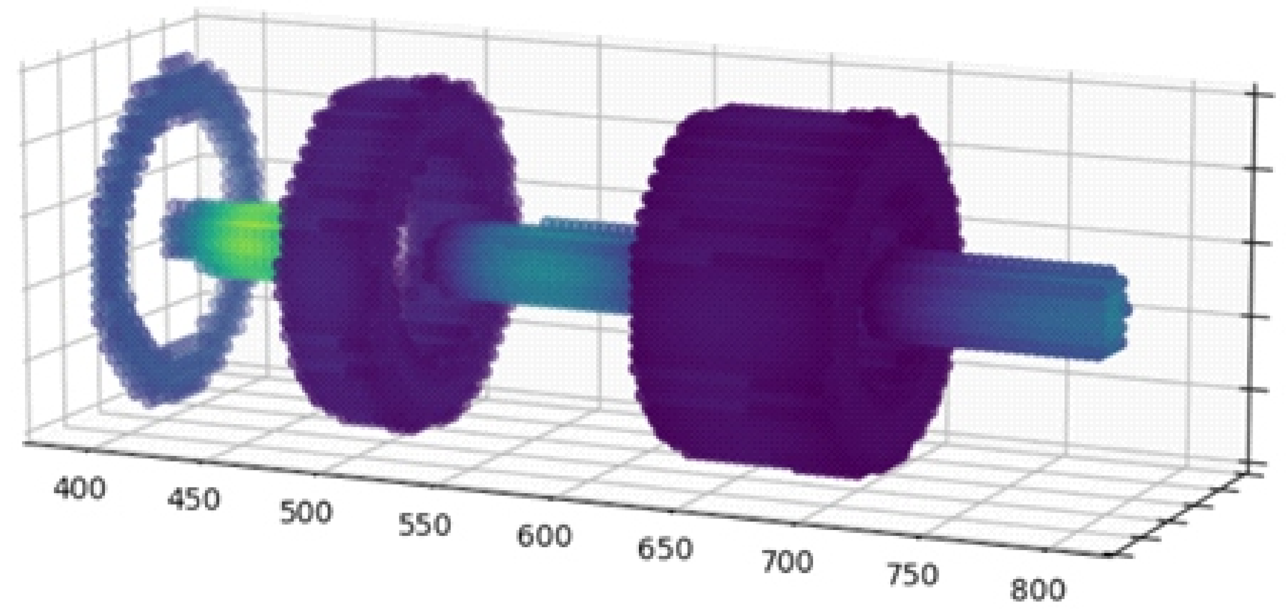

Fig. 3. 3D visualization of beam intensity in space at a distance of 400–800 mm

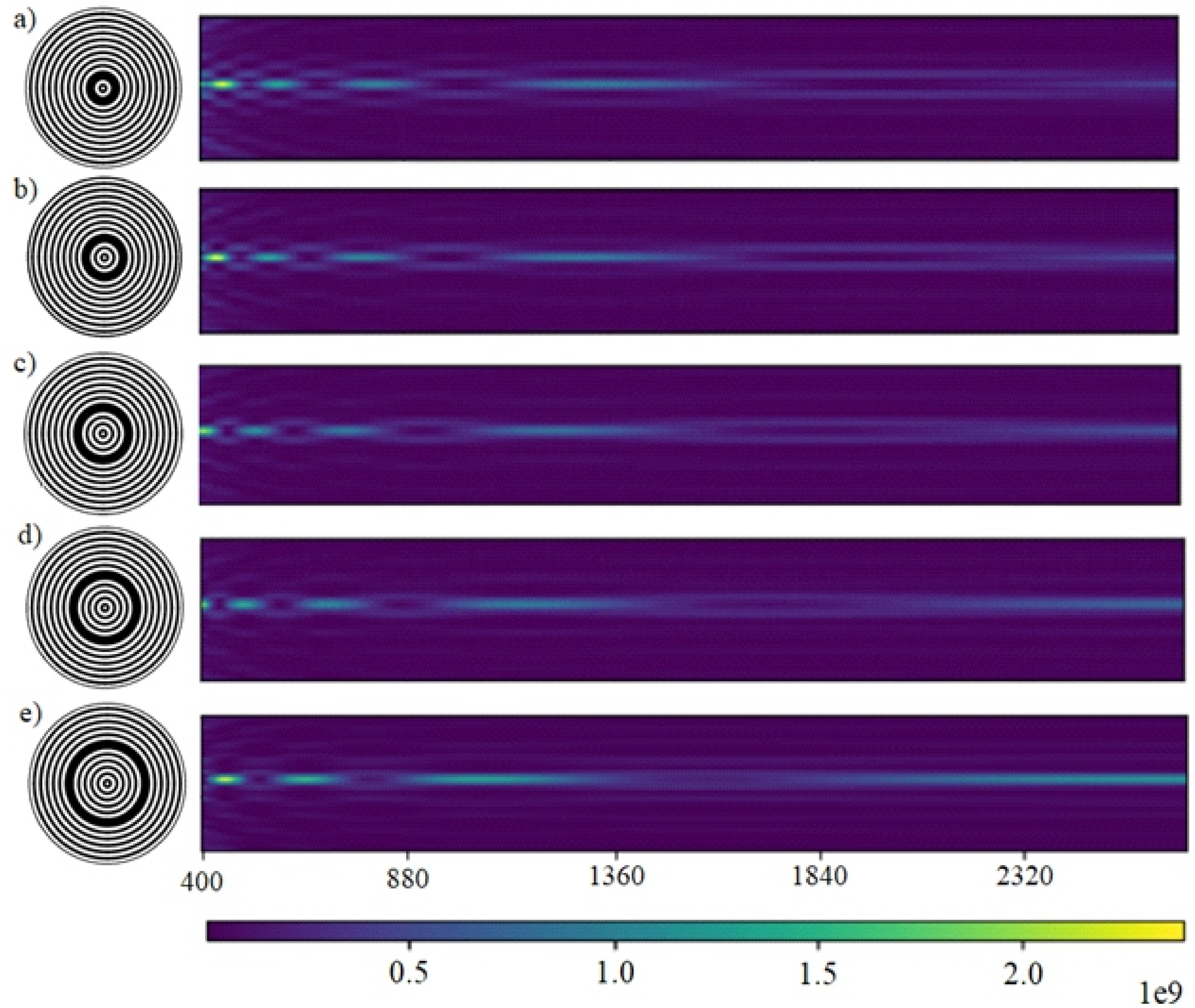

Fig. 4. Phase masks and longitudinal beam intensity distributions at 400–2800 mm, for the case of blocking the second (a), third (b), fourth (c), fifth (d) and sixth (e) rings.

CONCLUSION

Based on numerical simulation, the possibility of forming and controlling a set of optical bottles located on the optical axis by screening the binary diffraction axicon with an annular screen is shown. The dependence of the location of the bottles on the number of the overlapping ring is investigated. Such beams can find their application in manipulating and capturing micro- and nano-objects.