# The use of annular lenses in wide angle optical systems

**A.V. Pravdivtsev**

R & D Group “Constructive Cybernetics”, Moscow, Russia
**email:** avp@rdcn.ru

**Summary**

The report addresses questions of field congruence during optimization and technological aspects of annular lenses in the frontal part of wide angle optical systems. Changes in spot diagrams for overlapping fields in an optical system with continuous field of view are shown.

## Introduction

In an earlier report [1] the author discussed the concept of using annular lenses in wide angle “fish eye” optical systems (Fig. 1). The use of such lenses allows for a decrease in the weight of the systems while retaining the same optical quality. The author compared the typical solid lens to two annular lens variants: a) a lens with a gap in the field of view b) a lens with a continuous field of view. But the questions of technological effectiveness of such systems remain unaddressed.

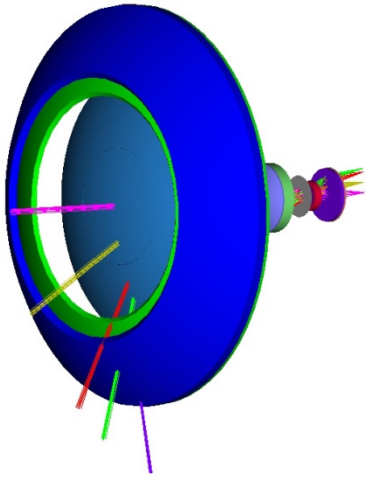

Fig. 1. Wide angle optical system with annular lenses.

The potential realizability of the approach was discussed for a system with the following characteristics [1]: field of view of 220°; focal plane array size of 36x36 mm; f-number is 1:4; working spectral range of 440-680 nm; front lens diameter of less than 240 mm.

## Discussion

Optical systems with annular lenses are lighter than classical solid systems. But the question of technological effectiveness is very important. To guarantee a continuous field of view in the discussed systems, the author used aspherical surfaces in frontal plastic annular components. Such surfaces result in more complicated systems.

We compared the requirements for manufacturing and positional tolerance for three optical systems: wide angle system with solid lenses, a system with annular lenses and a gap in the field of view, and a system with annular lenses and continuous field of view.

The technological effectiveness was analyzed by tolerance with Monte-Carlo method. A 20% increase in the RMS spot size was set as the criterion for good systems. The tolerance range was based on this criterion. Such approach additionally allows for the centroid ray height on the image surface to be dependent on the angular field as required.

As expected, the solid lens variant has the highest technological effectiveness. The system with discontinuous field is the second most effective. The aspherical surfaces in the variant with continuous field present difficulties in manufacturing due to the requirements in surface quality and positional tolerance.

The questions related to the shape of the point spread function (PSF) in the area of overlapping fields in the system with continuous field of view are quite interesting. The PSF shape for the inner and outer fields is different, so we discuss the variation of PSF in the area of overlapping fields. In this case the PSF is formed partly by inner fields and partly by outer fields. The ratio between the inner and outer parts depends on the value of angular field. The width of overlapped area in the discussed system is 2.4º. Fig. 2 shows the spot diagrams for the boundary fields and for two points in the overlapping area.

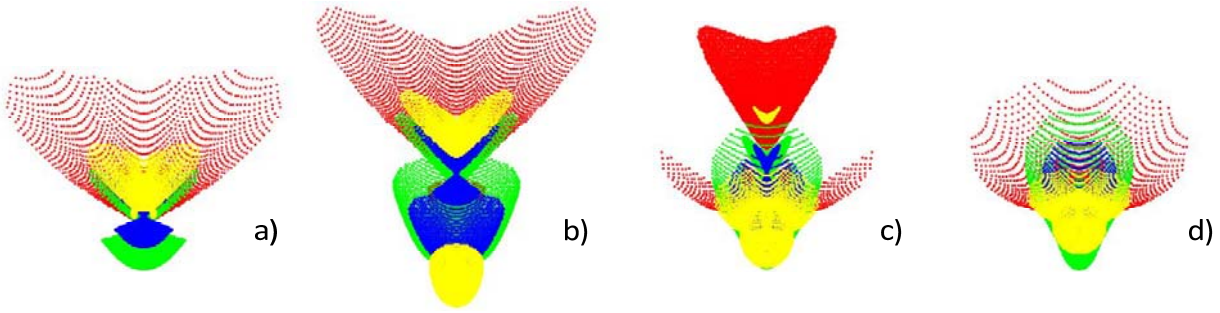


Fig. 2. Spot diagrams of a lens with continuous field. a), d) – inner and outer field, respectively, b) and c) – intermediate variants with different ratio of inner and outer fields.

One of the optimization goals was an equal RMS spot size over the field. In addition, for a continuous field we need the height of the chief ray for the edges of inner and outer fields to be equal. The analysis of intermediate variant shows that this requirement is not enough. Due to the lack of agreement in the fields at the intermediate points, the RMS spot size increased in the gap area. The reason is the difference in coordinates of the centroid ray for the same angular fields (Fig 2b and 2c shows the increasing RMS spot size).

## Conclusions

The article discusses the technological effectiveness of wide angle optical systems construction with annular lenses. The technological effectiveness was estimated by the range of tolerance for dimensions, position and surface quality of optical elements.

The changes in spot diagrams for the overlapping fields in the continuous field optical system are shown. The optical system with annular lenses and continuous field of view requires field concordance in the overlapping area. The centroid rays for inner and outer fields should have the same height on the image surface in the entire overlapping area. In addition this requirement should be realized in manufactured systems (with real tolerance values).

## References

[1] A. V. Pravdivtsev, Ring lenses in wide angle optical systems, 9-th International Conference on Optics-photonics Design & Fabrication , Technical digest. Japan Society of Applied Physics, 2014, pp. 159-160. ISBN: 978-4-86348-399-6.