International Conference on Advanced Optical Technologies
University of Erlangen-Nürnberg, March 13th – 15th 2019

Higher Order Aberrations of Alvarez Lenses

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An Alvarez lens pair is an optical system which contains two identical thin glass plates with small distance in between. The two surfaces which are facing each other have a cubic freeform profile [1]. When the two plates are centered on optical axis, the Alvarez lens pair can be viewed as simple double plane plate. When the two plates are shifted oppositely in x-direction, a defocus is generated. Correspondingly a dynamic focusing is achieved by the movement. Therefore as a benefit from this focal shift effect, the Alvarez lens pair can be applied as a compensator in several imaging applications. Unfortunately, the basic principle is only valid for one wavelength, on-axis collimated incoming light, small shifts, in the approximation of a small air gap and in low primary aberration order. Under real conditions, higher order aberrations are occurring [2,3]. With the help of generalized freeform surfaces instead of the simple cubic shapes, these drawbacks can be considerably reduced.

After analytically expanding the wavefront deformation of the Alvarez lens on axis [4], the 8th order aberrations are dominant for the residual aberrations. Therefore it is reasonable to extend the cubic freeform profile into general freeform profile to correct the induced higher order aberrations [5]. With this approach, it is a good opportunity to investigate the interplay of two freeform surfaces by understanding their functionality with respect to their relative positions.

In this talk, we investigate the influences of a finite air gap, the dynamic range, the sag amplitude as well as the size of the lateral shift on the performance of the system. The wavefront is represented by Zernike polynomials [6] and the behavior of Zernike coefficients (especially 4th and 6th orders) during the shift of the plates in x-direction is inspected. Then we will obtain the optimum freeform surface location in the Alvarez lens pair by comparing the performance after optimizing each surface with a general freeform surface while keeping other surfaces invariant. The result shows that the optimum locations are variant in the cases of different inner air thicknesses since the magnitude of induced aberrations are related to the air thickness. In the end, the applications of the Alvarez lens pair in real optical systems will also be discussed.

References

[1] L. W. Alveraz, *U.S. Patent.* **3,305,294** (1967)
[2] I. A. Palusinski, J. M. Sasian, J. E. Greivenkamp, *Applied optics*. **38(1)**, 86-90 (1999)
[3] A. Grewe, M. Hillenbrand, S. Sinzinger, *Applied optics*. **53(31)**, 7498-7506 (2014)
[4] C. Spiess, *Internship Report*. (FSU Jena, 2017)
[5] K. N. LaFortune, *United States. Department of Energy*. (2004)
[6] H. Gross, *Internal Report*. (FSU Jena, 2016)