Additive Manufacturing – Design and Fabrication of a Fisheye Lens

A. Suckow, F. M. Shariff, A. Heinrich

Center for Optical Technologies, Aalen University

mailto:Andreas.Heinrich@hs-aalen.de

A simple monochromatic fisheye lens including different optical and mechanical parts is produced by means of an additive manufacturing process. After polishing the lens surfaces a surface roughness RMS of about 12 nm was found. Through the single lenses a frequency between 6 and 32 line pairs per mm can be observed.

1 Introduction

Nowadays, the additive manufacturing technology is used in many applications such as in medical industry, lighting application and print-optical technology for illumination.

The purpose of this article is to show the possibility of the production of a complete optical system based on the additive manufacturing technology. The complete optical system includes the optical and the mechanical parts that are the mountings of the lenses.

2 Design

Using the optical design software Zemax a simple monochromatic fisheye lens consisting out of four lenses has been designed and printed with the Keyence Agilista 3100.

The fisheye lens is designed as retrofocus lens that is the inversion of the telephoto design. Thus, the systems focal length is smaller than the back focal length of the system [1]. The fisheye lens consists of a group of converging lenses on the front side followed by a group of diverging lenses on the rear side to focus the beam into the detector.

For the realization of a lens system with a large field angle two strongly curved negative lenses at the front side are used. The properties of the fisheye lens are shown in table 1.

Field angle	126°
System length	73.9 mm
Focal lenght	5.5 mm
F-number	2.54

Tab. 1 *System Parameters*

In addition to the optical components, the system contains mechanical components which are the mountings for the lenses. These components (designed with the software Creo Parametric) are attached to the individual lenses. They make the lenses stackable without any other mechanical components. This allows to work with each of the lenses or to polish them separately. Fig. 1 shows the whole stackable system consisting out of optical and mechanical parts. Additionally an aperture (Fig. 1 / black part) was introduced to reduce unwanted scattering effects.

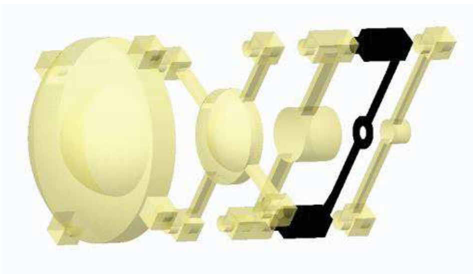

Fig. 1 *Optical and mechanical components of the fisheye lens.*

3 Fabrication

For the production of the fisheye lens all components were printed in one run. The minimum layer thickness of the printing machine that works based on the Mulit-Jet Modeling method (MJM) is 15 microns [2]. To reduce the time for the manufacturing process and to get the best surface quality it is helpful to have a look at the orientation of the lenses, as one can get different surface characteristics if model and support material are in contact with each other or not. The yellow marked area in Fig. 2 indicates the area where the printed part has to be supported by the support material. For this project the lenses were printed horizontally as demonstrated on the left in Fig. 2. So the surface on the top side didn't need support material which made it shinier and less rough than the surface on the bottom side that needed support material. A more detailed description on the fabrication and rework process of additive manufactured optics are given in [3].

DGaO Proceedings 2016 - http://www.dgao-proceedings.de - ISSN: 1614-8436 - urn:nbn:de:0287-2016-A012-0
submitted: 23.Jul.2016 - published: 10.Aug.2016

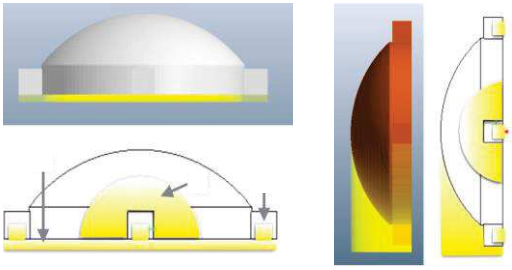

Fig. 2 *Orientation of the lenses on the printing bed.*

Fig. 3 shows one of the lenses directly after the printing process, the top side of the lens on the left and the bottom side on the right. The surface of the bottom side is more rough and unstructured than the surface of the top because it was surrounded with support material for the printing process as shown in Fig. 2 (left). The surface that is printed without support material is shinier and has a layered structure. To obtain sufficient optical quality of the lens surfaces a rework process for each surface is necessary.

Fig. 3 *Surface quality of one lens directly after the printing process.*

4 Rework

The lenses were polished using the negative polishing technique on a standard polishing machine. Therefore, for each lens a corresponding polishing head was constructed with the opposite negative radius of the lens curvature. After polishing the surfaces with sandpaper (grit size 2500) the polishing process is performed by applying polyurethane polishing pads and for different polishing steps different suspension agents. These were first aluminum oxide with different grain sizes (20 microns – 6 microns) and at the end cerium oxide with a grain size of 1 micron. The stacked lens system with the polished lenses is shown in Fig. 4.

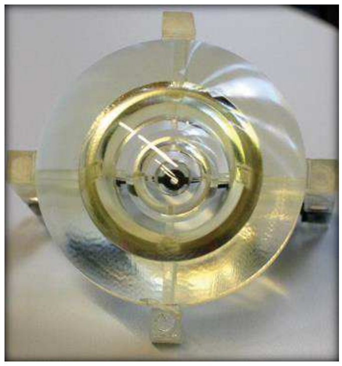

Fig. 4 *Stacked fish eye lens with polished lens surfaces.*

5 Surface Roughness

Reworking the printed optics with this polishing method leads to a surface roughness RMS of about 12 nm and a Peak to Valley roughness of about 1.1 microns. The non-polished 3D printed elements have a Peak to Valley roughness of about 8.6 microns.

6 Optical Experiments

The experiments for the verification of the optical performance of the fisheye lens were conducted based on spatial frequency measurements. For this, a sine pattern with different frequencies and different contrast, the Sine M-6 pattern (Fig. 5, left), was used.

Fig. 5 (right) shows how line pairs with a spatial frequency of 6 line pairs per mm (red marked part on the pattern) appear through one of the lenses (lens no. 3). With the different lenses a different number of line pairs per mm, from 6 to 32, can be observed.

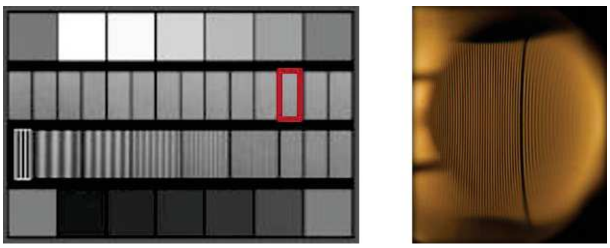

Fig. 5 *Sine M-6 pattern with different frequencies and image of 6 line pairs per mm through lens no. 3.*

References

[1] J. E. Greivenkamp: *Field Guide to Geometrical Optics*, (*SPIE Press* 2004)

[2] U. Berger, A. Hartmann, D. Schmid: *Additive Fertigungsverfahren. Rapid Prototyping, Rapid Tooling, Rapid Manufacturing*, (Verlag Europa-Lehrmittel 2013)

[3] A. Heinrich et al*: Additive manufacturing of optical components,* (Advanced optical Technologies, 5(4) 2016)

DGaO Proceedings 2016 - http://www.dgao-proceedings.de - ISSN: 1614-8436 - urn:nbn:de:0287-2016-A012-0
submitted: 23.Jul.2016 - published: 10.Aug.2016