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Laser-based fabrication chain enabling high quality mini aspheres

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Abstract. In recent years, 3D machining in glass for micro-components has seen a notable boost, notably with the development of a novel optical fabrication chain. This approach uses lasers for shaping and polishing, enabling the creation of complex mini-optics efficiently. The process begins with selective laser-induced etching (SLE) to define the optics' outer shape and surface figure. Subsequent polishing, using a "one-shot laser polishing" technique, removes imperfections and reduces roughness in a single step, achieving optical-grade smoothness. This fabrication chain is applicable to mini-aspheres as well, enhancing their production efficiency. Additionally, it allows for wafer-level production, where multiple mini-optics are interconnected on a single glass substrate.

1 Introduction

Traditional lens manufacturing involves mechanical grinding and polishing, which can lead to tool wear, waste generation, and limitations in producing complex geometries. To address these challenges, David B. et al [1] introduced a novel laser-based method for manufacturing glass lenses. This method uses lasers for both shaping and finishing the lenses, eliminating the need for physical contact and the associated drawbacks. The laser-based approach offers several advantages like elimination of tool wear and waste, production of complex geometries and efficient production of multiple lenses.

The laser method, as detailed in [1], has been demonstrated on a biconvex aspheric. This lens can be used for fiber collimators. This versatile technique holds immense potential for revolutionizing the manufacturing of mini optics, offering a path towards more efficient, flexible, and environmentally sustainable lens production.

2 Infrastructure for production and analysis

Materials: Double side polished Fused silica substrates with a diameter of 100 mm and a thickness of 1 mm were used.

SLE system: The shape of the aspheres was created with the SLE Lightfab 3D Printer by using a wavelength of 1030 nm, a pulse repletion rate of 750 kHz, a pulse duration of 1 ps and focusing objective with a magnification of 20x. The etching was carried out in a KOH bath with 8 mol/l concentration and 80°C.

Laser polishing system: A CO_2 laser system with a wavelength of 10.6 µm and a power of 100 W was used for polishing. The laser beam was defocused on the wafer, where the asphere lenses are placed using a scanning galvanometer system. The beam diameter was set to 10 mm at $1/e^2$. The wafer was placed on a heating plate with a maximum heating temperature of 600 °C.

Laser polishing strategy: All aspheres were polished according to the one-shot strategy. This means that the defocused laser beam is operated in continuous wave mode and is not scanned. The wafer is exposed to the CO_2 laser light until polishing takes place.

Measurement System: The ashperes generated were measured with the stitching white light interferomerter (WLI) S Neox from Sensofar. The evaluation and comparison with design data was carried out with the MountainsMap software.

3 Target shape of the asphere

The asphere created here is shown in the following technical drawing Fig. 1. The initial situation is a biconvex lens, whereby the left surface is an asphere and the right side is a sphere. The diameter of the asphere is 1.6 mm. Such aspheres are used for example in fiber collimators.

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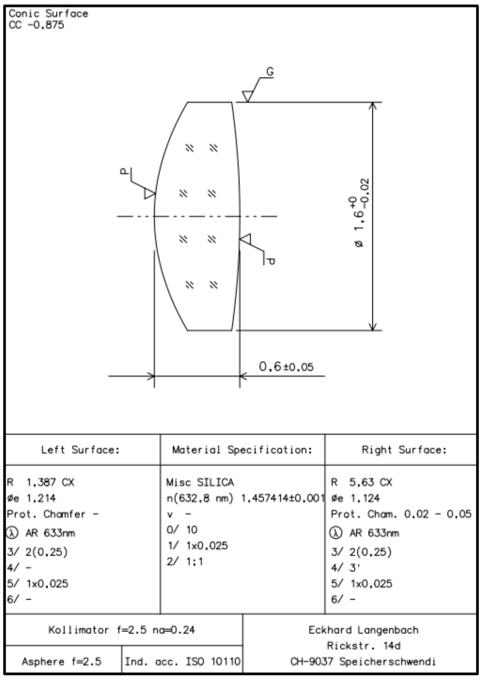


Fig. 1. Technical drawing of the Aspheres, which are produced with the SLE and LP process.

4 Results

In this paper the right surface of the lens is presented. For better visualisation, Figure 2 shows a wafer with its 112 aspheres.

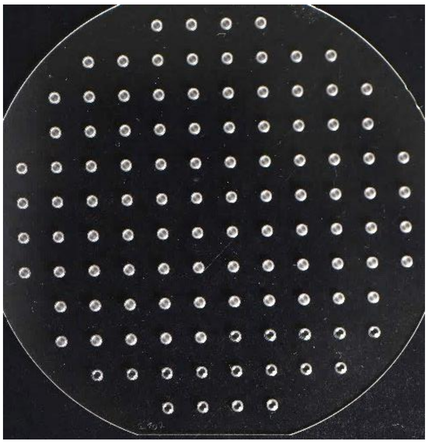


Fig. 2.: Overview of the wafer produced with their 112 aspheres.

The SLE process results in a roughness value Sq of 400 nm and a shape deviation PV of 2 µm. The polishing process can reduce the lens to an Sq value of 2 nm, which is within the tolerance. The shape deviation is still outside the tolerance with an PV value of 2 µm. In order to get a better idea of the evaluation, the analysis of the lens after laser polishing is explained in more detail below.

As the lens is rotationally symmetrical, a WLI measurement in ePSI mode is carried out in the X-direction. A 50x DI objective is used to scan from left to right and the images are then merged. The merged WLI measurement can be seen in the Figure 3. This is a measurement of the right surface of the asphere.

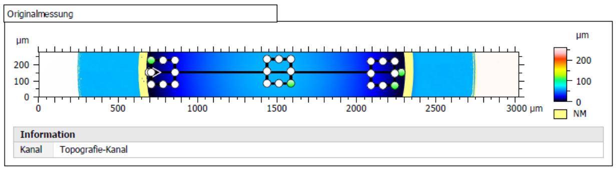


Fig. 3.: Overview of the merged WLI measurement of the right surface of the mini-asphere

A profile section is then taken from this measurement, see black line in the WLI measurement Figure 3. This profile section passes through the highest point of the convex surface. This profile section is removed from the target function. The form deviation results from this difference. The original profile section, the target function and the form deviation are shown in Figure 4. There is a PV value of approx. 2 µm. The shape is generated by the SLE process and must therefore already be correct after the SLE process. The generation of the shape accuracy can be optimised by the writing strategy of the SLE system.

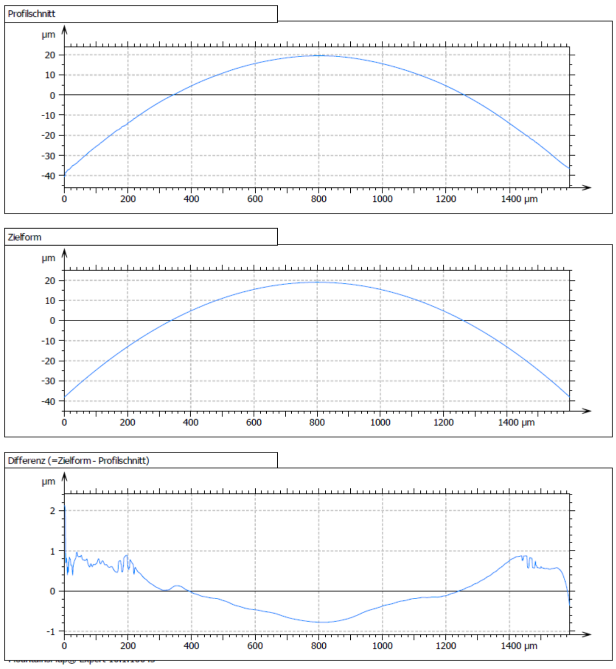
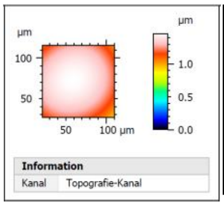


Fig. 4. Profile one is the original profile section, profile two is the target function and profile three is the difference between the target function and the original measurement.

The roughness values are analysed by taking an area of 150 x 150 µm^2 from the WLI measurement. Figure 5. shows the area taken from the centre of the lens. Before analysing the roughness Sq, this area is filtered with a short-pass filter of 2.5 µm and a long-pass filter of 80 µm. The result is a roughness value of 1.24 nm.



ISO 25178 - Rauheit (S-L)		
S-Filter (λs): Gauß, 2.5 µm, 1/2 Cut-off		
F-Operation: Keine		
L-Filter (λc): Gauß, 0.08 mm, 1/2 Cut-off		
Höhen-Parameter		
Sq	1.24e-03	µm

Fig. 5. Evaluation of the roughness of the asphere after laser polishing

The roughness values at the edge of the lens are around 20 nm. This can be optimised by beamforming or scanning strategies in order to achieve a homogeneous roughness value.

5 Conclusion

These results show the great potential of the laser process chain consisting of selective laser etching and laser polishing. Further intensive research is being carried out in this area to improve figure erros and the roughness at higher slopes. Final aim is to provide a flexible process chain to produce aspherical mini-optics with complex mechanics.

References

[1] D. Bischof, S. Lämmler, H. Moser, M. Forrer, O. Faehnle. Novel laser-based manufacturing chain for wafer-level mini-optics. 11th European Seminar on Precision Optics Manufacturing. Teisnach, Germany. April 23th - April 24th 2024