# 3D printed diffractive lens systems allow for micro-optics smaller than 500 nm

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Complex optics in small devices – by using several diffractive optical elements this is now possible. The optical elements are printed in one piece using a 3D printer, so there is no need to assemble small parts.

- Low print volumes = short printing time
- New standards in imaging performance for micro-optics
- High numerical aperture & large image angle
- Suitable for the smallest technical applications thanks to lightweight design


## Fields of application

This system makes it possible to manufacture micro-optics of unprecedented size, with structures smaller than 500 nm. This approach enables the fabrication of particularly small and powerful optics like for endoscopes, smartphones or drones.

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**Service**
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## Background

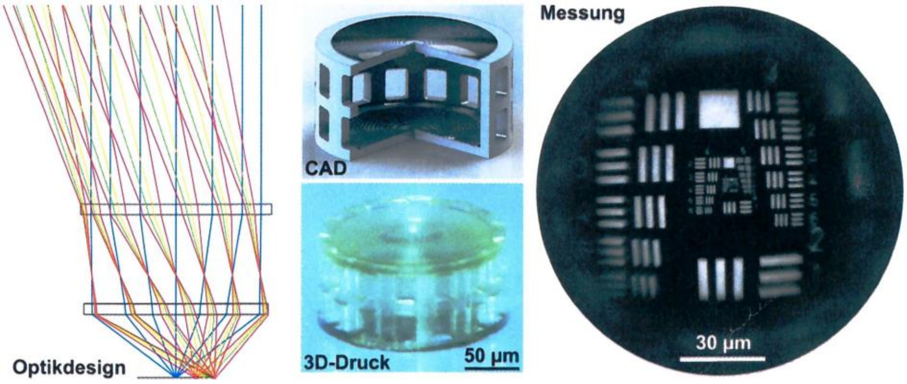
Complex optics in small devices, such as endoscopes or smartphones, are usually made up of individually manufactured lenses. These so-called assembled optics rarely achieve high numerical apertures and their size and functionality often do not meet today's requirements.
The 3D printed diffractive lens system developed at the University of Stuttgart, as part of a project funded by the Baden-Württemberg Stiftung gGmbH, makes it possible to manufacture micro-optics of unprecedented size, with structures smaller than 500 nm.

## Problem

When using conventional, refractive lens systems, minimum size and maximum numerical aperture are competing with each other. The minimum lens diameter of about 300 µm is currently the lower limit, which is due to the necessary refractive power and the technical production capabilities. Although wafer-based systems offer smaller dimensions, it is difficult to produce free-form lenses on wafers.

## Solution

The inventive lens system, consisting of several individual lenses, can be produced additively in a single process step, using femtosecond 2-photon lithography. As a result, no time is wasted on merging the individual elements. By using diffractive elements, the volume to be printed becomes much smaller and thus the time required for printing is considerably reduced. By cleverly combining several miniaturized, diffractive elements into one micro-optic, image errors can be corrected more extensively than ever before. This is a great advantage, especially for high field angles and high numerical apertures. Due to the high resolution of the manufacturing process of approx. 200 nm, images with high line densities and a high aspect ratio can be realised. This is particularly relevant for high-frequency patterns, like the one that can be found in the USAF test pattern. In addition, structural optimization helps to further improve diffraction efficiency. The flexibility of the process is another major advantage of this new approach.




Left: an exemplary optical design. Center: CAD design and real, printed lens system. Right: view on USAF-1951 test pattern [University of Stuttgart].

### Publication and links

Simon Thiele, Christof Pruss, Alois M. Herkommer, and Harald Giessen, "3D printed stacked diffractive microlenses," Opt. Express 27, 35621-35630 (2019), [doi.org/10.1364/OE.27.035621](https://doi.org/10.1364/OE.27.035621)