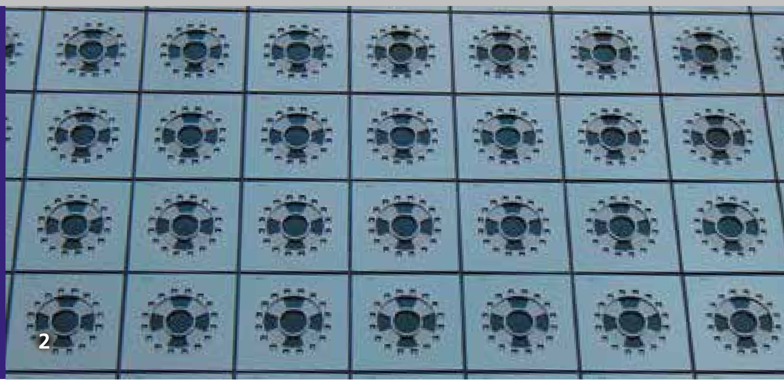
FRAUNHOFER INSTITUTE FOR PHOTONIC MICROSYSTEMS IPMS



1 Tunable micro-lens device with an integrated polymer actuator.
2 Micro-fluidic chamber chips on a silicon wafer.

TUNABLE MICRO-LENS WITH AN INTEGRATED POLYMER ACTUATOR

Conventional optical imaging systems and cameras with autofocus and zooming options require the physical positioning of a movable lens element to focus an image of an object onto an image sensor or to change the overall magnification of the system. This is usually realized by means of a bulky mechanical positioning system. The large physical dimension of a focusing and zooming system makes it difficult to place such optical functions onto miniature imaging systems such as cell phone cameras.

In order to improve the functionalities, increase the efficiency and decrease the costs of a zoom objective, an autofocus option or other adjustable optical element for miniature imaging systems, alternative solutions have been adopted, including lenses of continuously varying focal length.

The Fraunhofer IPMS developed a miniaturized tunable lens system with a compact and flexible design (fig. 1). A continuous variation of focal length is obtained by controlling the deflection of an integrated polymer actuator with an applied electrical field.

Design – Fabrication – Operation

A tunable micro-lens concept has been developed for wafer-level fabrication (fig. 2). The device consists of two micro-fluidic chambers, sealed by an elastic membrane made of an elastomer, which are bonded together and filled with two different fluids. The elastomeric membrane defines the lens boundary, i.e. its inner part, and it has attached to it, i.e. on its outer part, a bending micro-actuator of radial shape. The actuator, based on a special electrostrictive polymer of very large strain characteristics, is designed to pump a liquid against the lens membrane. By this measure, a lens ef-

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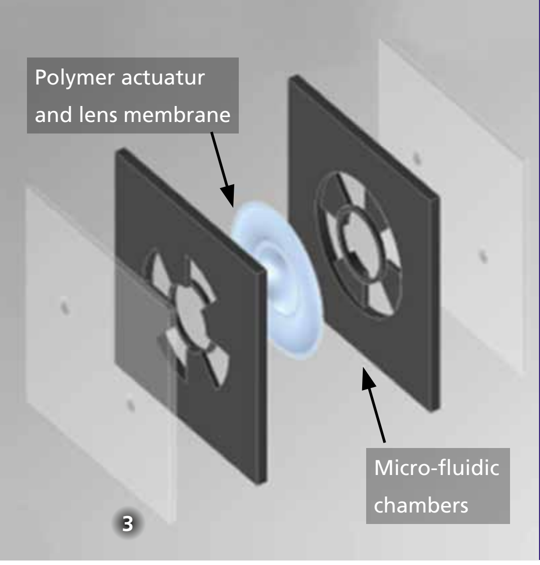

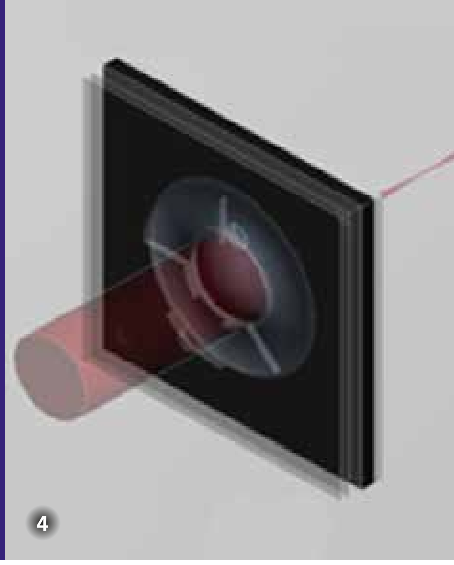

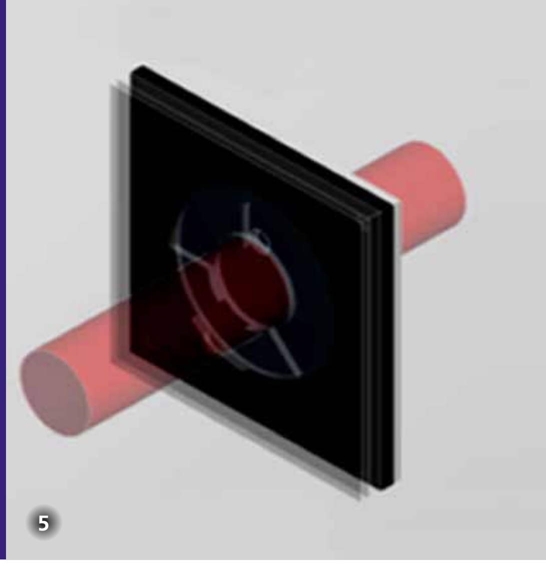

fect can controllably be increased depending on the deformation of the membrane. Fig. 3 presents schematically the different parts of the micro-lens device and figs. 4 and 5 illustrate its principle of operation.

The two micro-fluidic chambers ensure a compact and robust micro-lens design and provide the option of utilizing fluids of different refractive indices. Hence, the focal length of the optical micro-lens can be more flexibly and reliably adjusted.

The manufacturing steps for the micro-lens chip include processes such as actuator fabrication with a layer-by-layer method, micro-fluidic chamber structuring by silicon wafer bulk micro-machining and glass wafer processing. The device assembly is realized by wafer bonding.

The tunable micro-lens fabricated in this way and filled with oils can ensure an optical power variation of more than 15 dpt. This is warranted by an actuator deflection of more than 100 µm.

Advantages

The fluidic variable focal length optical lens concept allows on the one hand for a miniaturized lens system with a compact, robust and flexible design and, on the other hand, allows for an easy and/or robust usage, handling and manufacturing.

With a 3 mm optical aperture and a small footprint of 10 × 10 mm² the tunable micro-lens could be integrated in a zoom objective or autofocus system for a camera in a cell phone.

In addition, the Fraunhofer IPMS tunable micro-lenses could find usage in many other application fields such as medical and industrial imaging, optical systems for laser beam manipulation and lab-on-a-chip applications for cell manipulation and detection.

By utilizing wafer-level fabrication methods multiple devices can be fabricated in parallel on one wafer allowing for more flexibility in design and cost-effective production.

Specifications

- Lens aperture: 3 mm
- Optical power variation: 15 dpt
- Dimension: 10 × 10 mm²
- Convex or concave design
- Transmission > 94 % (400 - 700 nm)

Key features

- Continuously voltage adjustable focus
- Wide tuning range
- Wafer level technology
- Easy system integration
- Scalable, flexible design
- Includes integrated polymer actuators of large deflection
- No mechanical parts

Applications

- Autofocus
- Optical zoom objective
- Cell phone cameras
- Medical imaging cameras
- Miniature industrial cameras
- Beam manipulation
- Lab-on-a-chip

3 *3D exploded view of the tunable micro-lens.*
4 *Principle of operation at finite focus, i.e. actuated / E on-state.*
5 *Principle of operation at infinite focus, i.e. non-actuated / E off-state.*
(E denotes the electrical field applied on the actuator)