Discretely Tunable Optofluidic Compound Microlenses

Peng Fei,[a] Zi He,[a] Chunhong Zheng,[a] Tao Chen,[a] Yongfan Men,[a] and Yanyi Huang *[a,b]

[a] *College of Engineering, and Biodynamic Optical Imaging Center (BIOPIC), Peking University, Beijing 100871, China. Email: yanyi@pku.edu.cn*
[b] *State Key Laboratory for Mesoscopic Physics, Peking University, Beijing 100871, China.*

Supplementary Figures

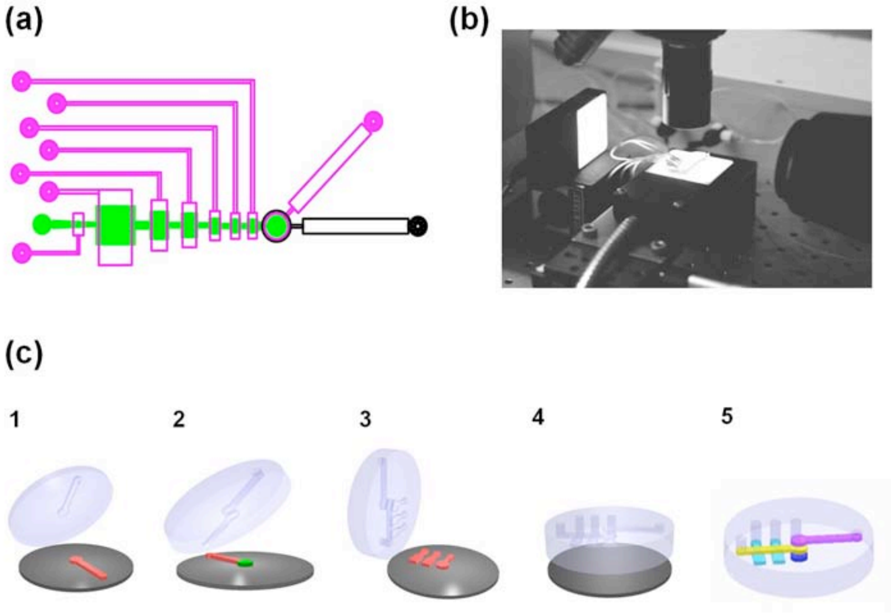

Fig.S1 Fabrication of compound microlenses chip and experimental setup. (a) Design layout of the chip. Black layer is the top lens layer, green layer is the middle fluid/lens layer and purple layer is the bottom control/lens layer. (b) Imaging and observation setup. The chip is placed on a slab light source. An upright microscope mounted with a monochrome CCD is used to observe the imaging property of compound microlenses, meanwhile, another microscope with CCD is used to monitor the deformation process from the side. (c) The fabrication of a microlens device. 1. Cast the top layer; 2. Cast the middle layer and align the top and middle layers; 3. Cast the bottom layer and align the three layers; 4. Bond the three layers of PDMS onto a flat PDMS plate to form the closed chip; 5. The whole structure of microlens chip.

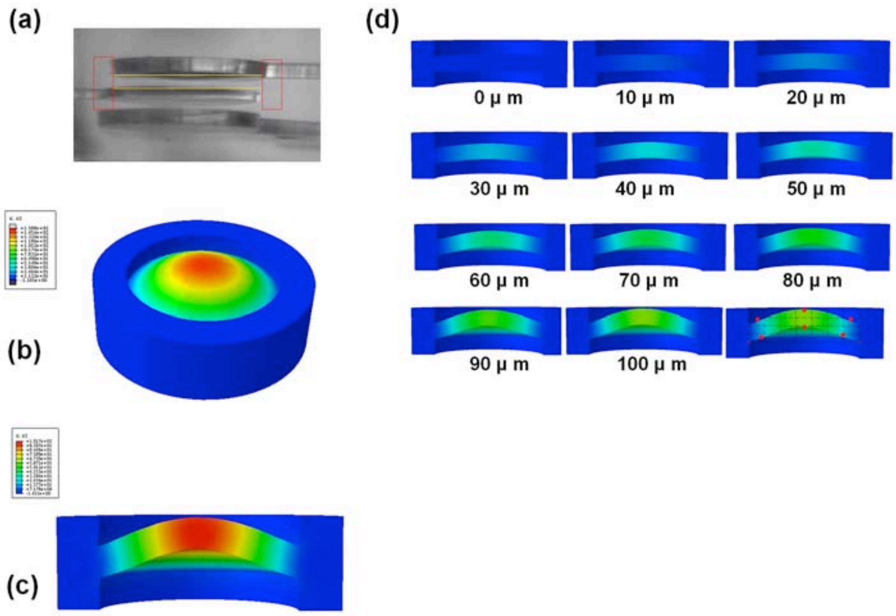

Fig.S2 Mechanical simulation for amending the optical simulation. (a) Side-view microphotograph of a real 3-layer microlens device with 700 μm diameter and 100 μm depth. The yellow lines indicate the active surfaces, while the red lines indicate the confined surfaces. (b) A 3D model built from the real structure. The PDMS membrane in the model is set to stand an upward hydraulic pressure P = 0.1 MPa till it reaches its maximum deformation. The tensile modulus E and Poisson ratio u of 184-PDMS are also defined (E = 1.8 MPa, u = 0.4).Vertical displacement distribution of PDMS membrane is shown as the result. (c) Cross section view of the 3-D model. Vertical displacement distribution is shown as the result. (d) 10 isotonic displacement statuses are picked out from 0-100μm based on the displacement of the central point A. With the coordinates of specified points, inner and outer curvature radiuses in each status are calculated.

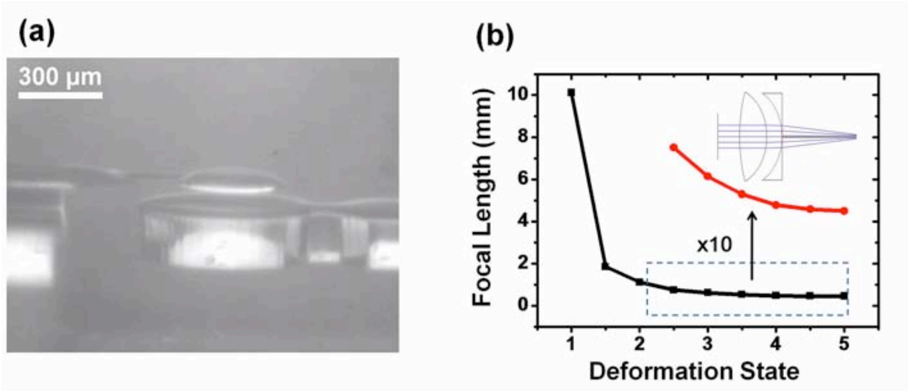

Fig.S3 A 2-layer compound microlenses with smaller focal length can also be fabricated. (a) Side-view microphotograph of a 2-layer microlens with 300μm aperture diameter. (b) Simulated focal length of the device. The minimum focal length of this chip can be as low as 400μm.

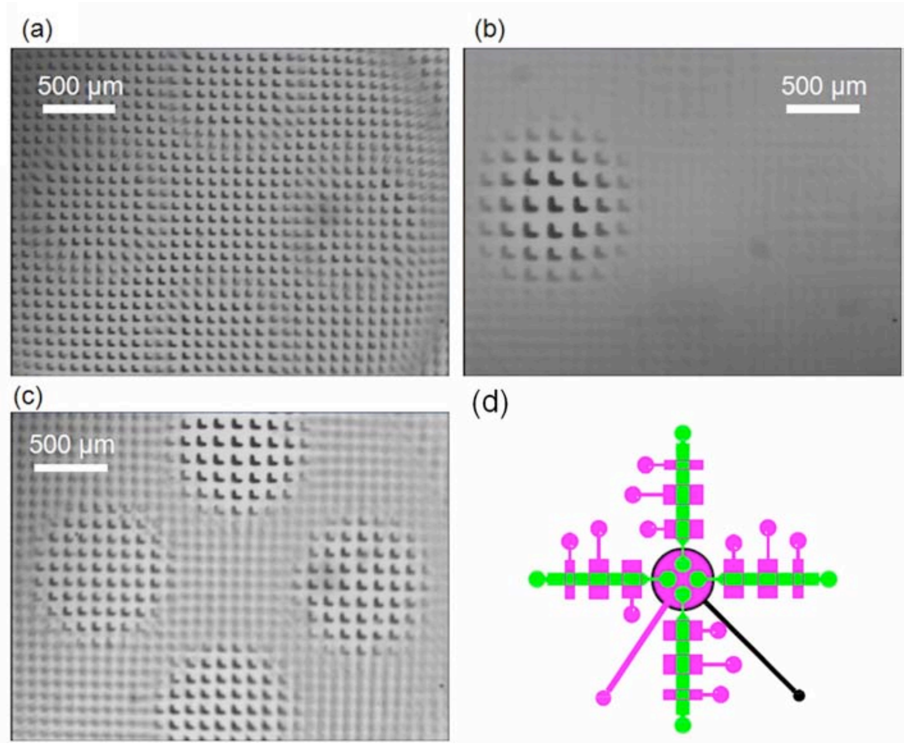

Fig.S4 Lens array including four multi-layer lens groups is fabricated to extend the potential in application. Every lens group has 4 independently tunable levels (a) Picture of lens array in original status. (b) Picture of lens array with only one lens group in work status. The working lens is in level 4. (c) Picture of lens array with all lens groups in work status. They are all in level 2. (d) Schematic layout of the lens-array chip.

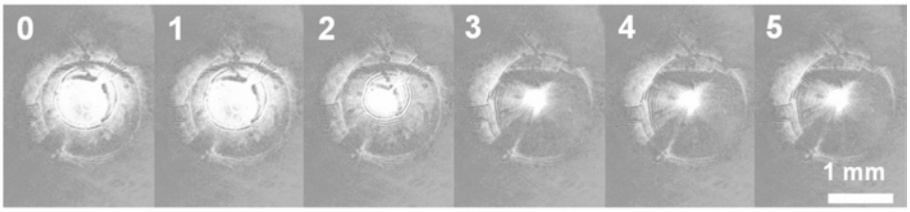

Fig.S5 Light focusing ability test. Transmitted images were taken via a CMOS camera (Gsou, Model No.T10, China) placed behind the microlenses. While we actuated the valves, we took the images of a collimated laser beam (473 nm), which propagated through a microlens with an aperture diameter = 500 μm. First, we fixed the distance (1 mm) between the microlens and the camera's CMOS sensor. When the convergence angle of the transmitted beam was increased via the microlens, the size of the spot on the sensor was reduced. This continued until the beam was focused to a point.