

Tunable Two-Dimensional Liquid Gradient Refractive Index (L-GRIN) Lens for Variable Light Focusing

Hua Huang,^{ab} Xiaole Mao,^{bc} Sz-Chin Steven Lin,^b Yiping Huang,^a and Tony Jun Huang^{*bc}

^a ASIC and System State Key Lab, Department of Microelectronics, Fudan University, Shanghai, 200433, P.R.China

^b Department of Engineering Science and Mechanics, The Pennsylvania State University, University Park, PA 16802, USA. Fax: 814-865-9974; Tel: 814-863-4209; E-mail: junhuang@psu.edu

^c Department of Bioengineering, The Pennsylvania State University, University Park, PA 16802, USA.

1. Device Fabrication Procedure

The 2D L-GRIN lens was fabricated through the following procedure:

- a. The pattern of the fluidic chamber was designed using AutoCAD software.
- b. The pattern was transferred onto a photo-mask using a high-resolution laser writer, DWL66 (Heidelberg Instruments).
- c. The mould for soft-lithography (thickness = 155 μm) was fabricated on a silicon wafer by Deep Reactive Ion Etching (DRIE).
- d. The silicon mold was processed with 1H,1H,2H,2H-perfluorooctyl-trichlorosilane vapor (Sigma Aldrich) for reducing the surface adhesion to PDMS.
- e. The PDMS device was made with SylgardTM 184 silicone elastomer base and curing agent (Dow Corning), which were mixed in a 10:1 weight ratio. The mixture was casted onto the silicon mould and cured at 65 °C for 1 h.
- f. Inlets and outlets were made by drilling, and polyethylene tubings (Becton Dickson) were inserted for the connection to syringe pumps (KDS 210, KD scientific).
- g. In this experiment, the device includes a glass substrate sandwiched by two PDMS layers (a lens chamber and a dye chamber). The alignment of the two PDMS layers on opposite sides of the glass substrate was performed manually under a microscope.

2. 2D HS Curve fitting for CFD Simulated Results

For the ray-tracing simulation, a 2D HS curve fitting was performed on the CFD-simulated 2D refractive index profile. Fig. 1a shows an example of the refractive index profile obtained with CFD (CaCl₂ solution flow rate = 8.0 $\mu\text{l}/\text{min}$, DI water flow rate = 8.0 $\mu\text{l}/\text{min}$). The 2D HS curve-fitted result is shown in Fig. 1b. Fig. 1c is the refractive index difference between the CFD-simulated result and 2D HS curve fitting model. Fig. 1c suggests that the CFD simulated

refractive index profile can be well-fitted to a 2D HS profile.

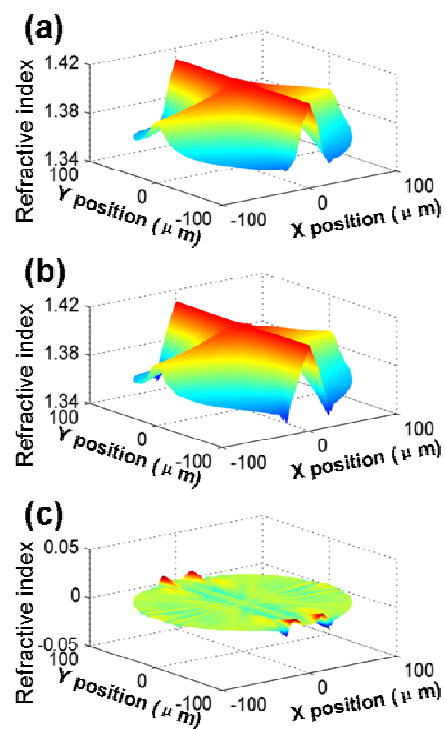


Fig. 1 2D HS Curve fitting for CFD Simulated Results. (a) The refractive index profile obtained with CFD (CaCl_2 solution flow rate = $8.0 \mu\text{l}/\text{min}$, DI water flow rate = $8.0 \mu\text{l}/\text{min}$). (b) 2D HS curve fitted refractive index profile. (c) The difference between (a) and (b)