INHOMOGENEOUS LIQUID MEDIUM FOR BIOCHEMICAL SENSING

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This paper reports a new design of tunable thermal gradient index (GRIN) lens using the thermal diffusion between one liquid [1], and its application in dynamic trap of single living HEK 293 cell. This system consists of the GRIN lens part and the cell trapping part. The former includes a trapezoid and a rhombus region to form a GRIN lens. The optical properties can be modulated by flow rates and liquid temperature. The latter is isolated to the GRIN lens by a very thin PDMS wall for dynamic cell trap. The cells flowing in this region will be trapped and analyzed by the synergy of optical forces and drag forces. Unlike other counterparts using concentration diffusion [2] and thermal diffusion [3], this thermal GRIN lens is formed by thermal diffusion between only one liquid, and the RI along radial direction fits to a parabolic variation, and its enhanced performance shows more flexibility of controlling single living cell as compared to the solid optical tweezers.

The working principle of the flat liquid GRIN lens and its application in cell control is shown in Fig. 1. In the GRIN lens part, the trapezoid region in upper layer consists of three flow streams, and the central flow stream has a relatively lower temperature as compared to the side flow streams. The GRIN lens will be formed in lower layer by introducing the compensation streams. The enhanced performance makes the dynamic cell trap possible in the cell trapping part.

The simulated and measured RI profiles are given by Fig. 2. The widths of inlets (claddings, core and compensations) are all 50 μm. The base widths of the trapezoid channel are 150 μm and 100 μm, respectively and its height is 500 μm. The size of the rhombus is 500 × 300 μm^2 (only 100 × 300 μm^2 for GRIN lens). The temperatures of injected benzyl alcohol are 100 ℃ (claddings and compensations, corresponding RI 1.50) and 0 ℃ (core, corresponding RI 1.55). The *Pe* number is 230. It can be seen that the experiment well match the simulation, and shows a standard RI profile of GRIN lens.

Fig. 4 shows the tunable focusing effects of our GRIN lens with the change of flow rates. The temperature of all injected liquids is remained unchanged in all light experiments. When the *Pe* is in the range from 100 to 250, the GRIN lens has a better performance. However, when the *Pe* is too larger such as 450, the GRIN lens cannot be formed, and the light is focused to a region.

Based on the focus in Fig. 4, the single living HEK 293 cell can be trapped in a range of 280 μm. In cell trapping experiments, the GRIN lens works in 1064 nm and the input power is 180 mW. Fig. 5 and 6 show the dynamic cell trap with the change of *Pe* and the change of sample flow rates, respectively.

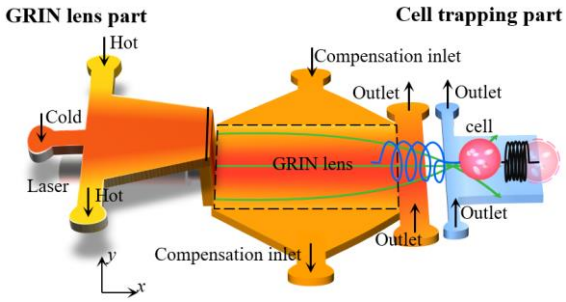

Fig. 1 The principle of the liquid thermal GRIN lens and cell trapping. Five streams of one liquid with different temperatures flows in GRIN lens part and forms a flat GRIN lens. The focusing properties are modulated by flow rates. Based on the focusing effect, single cell is trapped in flowing conditions in cell trapping part.

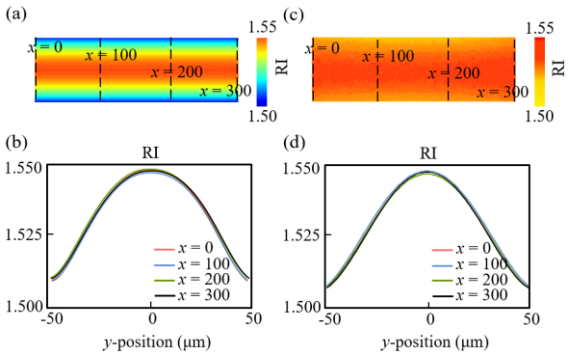

Fig. 2 Simulation ((a) and (b)) and experiment ((c) and (d)) of RI profile in GRIN lens when Pe = 230.

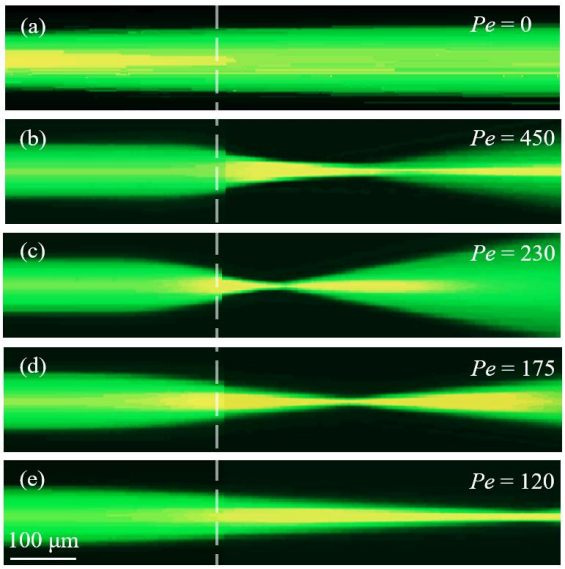

Fig. 3 Experimental light focusing with different Pe. (a) Pe = 0, (b) Pe = 450, (c) Pe = 230, (d) Pe = 175 and (e) Pe = 120.

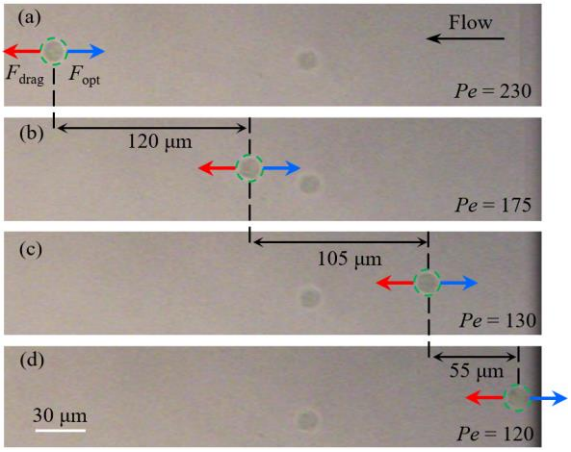

Fig. 4 Tunable single cell trapping with different Pe when the sample velocity is 90 μm/s.

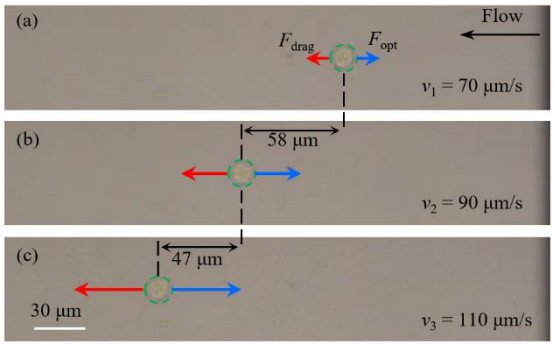

Fig. 5 Tunable single cell trapping with different sample velocity when the Pe = 175.

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