Electronic Supplementary Information

An optofluidic prism tuned by two laminar flows

S. Xiong, A. Q. Liu,* L. K. Chin and Y. Yang

School of Electrical and Electronic Engineering, Nanyang Technological University, 50 Nanyang Avenue, Singapore 639798

* *Tel: +65 6790-4336; Fax: +65 6793-3318; E-mail: eaqliu@ntu.edu.sg*

Contents

Design of the triangular microchamber: Based on the simulation results, a smaller apex angle of the chamber allows a larger variation in the apex angle of the prism. However, recirculating flow caused by the triangular chamber shape with diverging and converging channel elements[33] occurs at the vertex of chamber for smaller chamber angle such as 50°. This induces the top of the optofluidic prism becomes much flatter and reduces the effective working length on the prism. In order to meet the balance between the two requirements, the chambers with apex angle of 70° and 90° were chosen in the experiments.

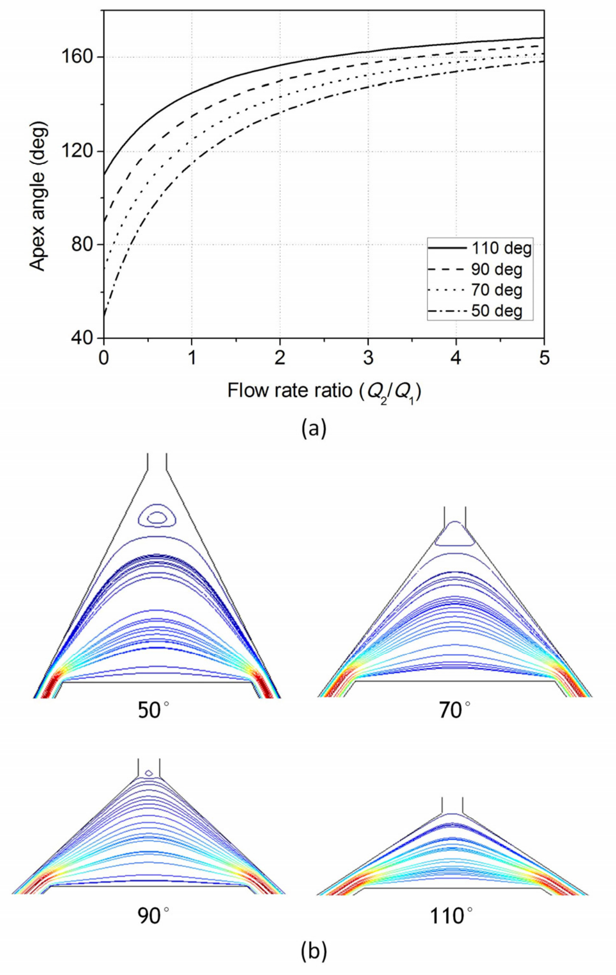

Fig. S1 (a) Relationship between the apex angle of the prism and the flow rate ratio, and (b) the simulation of the flow streams for chambers with different apex angles.

Experimental setup: Benzyl alcohol (n = 1.540, viscosity η = 5.47 mPa s at 25°C) and DI water (n = 1.332, viscosity η = 0.89 mPa s at 25°C) were used as the inner liquid. A mixture (viscosity $\eta \approx$ 8 mPa s at 25°C) of 80% ethylene glycol and 20% DI water with an effective refractive index matched to that of PDMS (n = 1.412) was used as outer liquid. The light deviation was observed using the combination of inner-outer liquids due to the sufficiently large contrast in refractive indices. Matching the refractive index of the cladding to that of PDMS reduced the scattering of light on the microchannel wall. The mixture of ethylene glycol and DI water containing 0.2 mM rhodamine 6G and 0.03 mM fluorescent red 646 was injected into the beam tracing chamber to visualize the optical path. The liquids were kept in 20-ml syringes, which were driven by the syringe pumps (NE-1000, New Era Pump System Inc.). The input light from an argon ion laser (Stellar-PRO, Modu-Laser) was coupled into the prism using a single-mode optical fiber (NA = 0.22). The image acquisition was performed using a microscope (Nikon Eclipse TE2000-E) and a CCD camera (Nikon DS-5M). The intensity of output light was detected by a spectrometer (HR4000, Ocean Optics Inc.).

Stability study of prism shape: In order to study the stability of the prism, the experiments were repeated for 10 times and 5 experimental data in 30-s interval were measured in each run. The standard deviation of apex angles of the prism was varied from 0.66° to 1.08°. However, when the inner flow was DI water, the standard deviation was varied from 1.11° to 1.95°. Therefore, the prism made from benzyl alcohol is more stable than that made from DI water. Such difference is caused by the Reynolds number mismatch between the inner and outer flow. For the case of a symmetric prism, the flow rate of outer flow was fixed at 10 μl/min with Reynolds number of 0.23. When the inner flow was benzyl alcohol, the Reynolds number ranged from 0.64 to 5.73 when the flow rate varied from 20 μl/min to 180 μl/min. On the other hand, when the inner flow was DI water, the Reynolds number ranged from 14.98 to 67.42 when the flow rate varied from 80 μl/min to 360 μl/min. Since the difference of Reynolds number between the outer mixture and inner DI water flow is much larger, the prism shape is more unstable for the prism constructed by DI water.

Beam width ratio: The beam width ratio of the symmetric prism can be expressed as

$$M = \frac{w_{out}}{w_{in}} = \left\{ \frac{\left[1-\left(\frac{n_2}{n_1}\right)^2 \sin^2 i_1\right]\left[1-\left(\frac{n_1}{n_2}\right)^2 \sin^2(\phi - i_3)\right]}{\left(1-\sin^2 i_1\right)\left[1-\sin^2(\phi - i_3)\right]} \right\}^{1/2} \quad \text{(S1)}$$

where w_{out} and w_{in} are the width of the beam exiting and entering the prism respectively, ϕ is the apex angle of the prism, n_1 and n_2 are the refractive index of the inner and outer fluid, respectively, i_1 is the incident angle of the unexpanded light beam on the prism, $i_3 = \arcsin\left(\frac{n_2}{n_1}\sin i_1\right)$. When the light beam is horizontally incident on the prism, i_1 is equal to $\frac{\phi}{2}$. The beam expansion factor is only affected by the apex angle and refractive index of the prism. In the experiments, the width of the beam entering the prism is 50 μm approximately. The width of the beam exiting the prism is changed from 13 to 50 μm with the tunable prism shape and refractive index.

Intensity measurement in parallel light scanning:

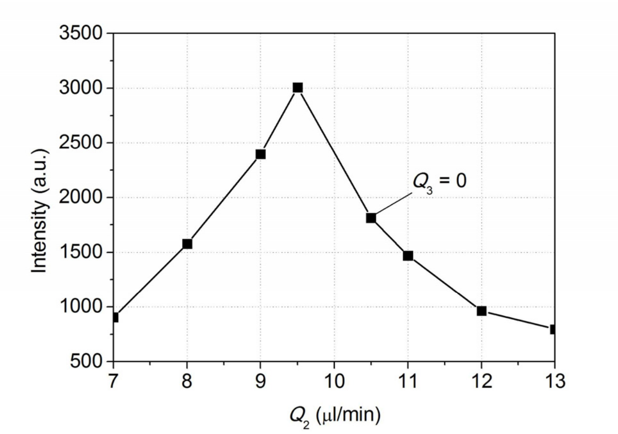

Fig. S2 The adjustment of the detected light intensity by tuning the output position.