Supplementary Material (ESI) for Lab on a Chip

"Microfluidic Drifting" – Implementing Three-Dimensional Hydrodynamic Focusing with a Single-Layer Planar Microfluidic Device

Xiaole Mao,[ab] John Robert Waldeisen,[a] and Tony Jun Huang*[ab]

[a] *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*
[b] *Department of Bioengineering, The Pennsylvania State University, University Park, PA 16802, USA.*

1. Computational Fluid Dynamic (CFD) Simulation

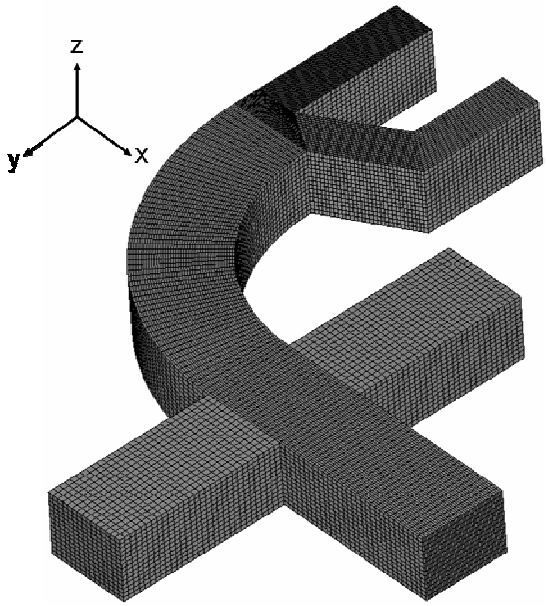

Fig. S1. Schematic of the computational grid.

The CFD simulation was conducted using a finite-volume based commercial package, CFD-ACE+ (ESI-CFD, Huntsville, AL). The built-in flow module and

chemistry module were used to simulate the flow and the fluorescent dye (fluorescein) distribution inside the three-dimensional (3D) focusing device. The computational grid (Fig. S1) was created using the ESI-GEOM tool of the ESI-CFD package. The grid has dimensions identical to the actual device except that only a portion of the device was modeled to reduce the computation load. The grid contains 123,000 computational cells to ensure sufficient grid density for the simulation.

2. Device Fabrication

Polydimethylsiloxane (PDMS) microchannels were fabricated using the standard soft lithography technique. The master mold for the soft lithography was made on a silicon wafer (TechGophers, Chino Hills, CA) by Deep Reactive Ion Etching (DRIE, Adixen, Hingham, MA). The positive photoresist Shipley 1827 (MicroChem, Newton, MA) was lithographically patterned on the silicon wafer to act as a mask for DRIE, and the etch depth was set at 75 μm. The final mold depth was measured using a profilometer (KLA-Tencor, San Jose, CA) to ensure that the desired depth had been achieved. The silicon mold was subsequently coated with 1H,1H,2H,2H-perfluorooctyl-trichlorosilane (Sigma Aldrich, St. Louis, MO) after DRIE, in order to reduce surface energy and hence the damage to the PDMS channel during the demolding process. This is a critical step because the surface smoothness of the PDMS channel sidewall is crucial for reducing scattering losses and ensuring the quality of side-view epifluorescence microscopy. Sylgard^{TM} 184 Silicone Elastomer Base and Sylgard^{TM} 184 Silicone Elastomer Curing Agent (Dow Corning, Midland, MI) were mixed at a 10:1 weight ratio, cast onto the silicon mold, and cured at 70 ºC for 2 hours. After the PDMS channel was hardened, it

was peeled from the mold. Inlets and outlets were drilled with a silicon carbide drill bit and the channel was subsequently sealed onto a glass slide. Polyethylene tubes (Becton Dickson, Franklin Lakes, NJ) were inserted into the inlets to connect the device to a syringe pump (KDS 210, KD scientific, Holliston, MA).

A 2 mm x 2 mm 90-degree prism (Edmund Optics, Barrington, NJ) was placed adjacent to the optical window to reflect the excitation light (wavelength = 488 nm) from the microscope lens into the microfluidic channel and the emission light (wavelength = 525nm) from the 3D focused flow downward into the microscope lens. Still images and a real-time video of the 3D focusing process were recorded using an inverted microscope (TE 2000U, Nikon, Melville, NY) and a CCD camera (CoolSNAP HQ2, Photometrics, Tucson, AZ).

3. Real-time Video of Switching between Static Flow and 3D Focusing (Flow Direction: Right to Left)

Video of Fig. 2c and Fig. 2d:

The video started with a static flow after a prior 3D focusing. The fluorescent dye (fluorescein) had uniformly diffused through the entire channel. The sample flow and sheath flows then resumed simultaneously at t = 1 sec. A “pulse” or a sudden increase in the width of the focused flow was recorded at t = 2 sec due to the compliance of the tubing and PDMS channel, but the flow was soon stabilized and a final 3D focused flow was achieved at approximately t = 4 sec. Two consecutive switching cycles were recorded to demonstrate the repeatability and robustness of the 3D hydrodynamic focusing technique.