Lab-on-a-Chip Application: Hydrodynamic Focusing using Integrated Modular Pumps, Valves, Connectors and Imaging

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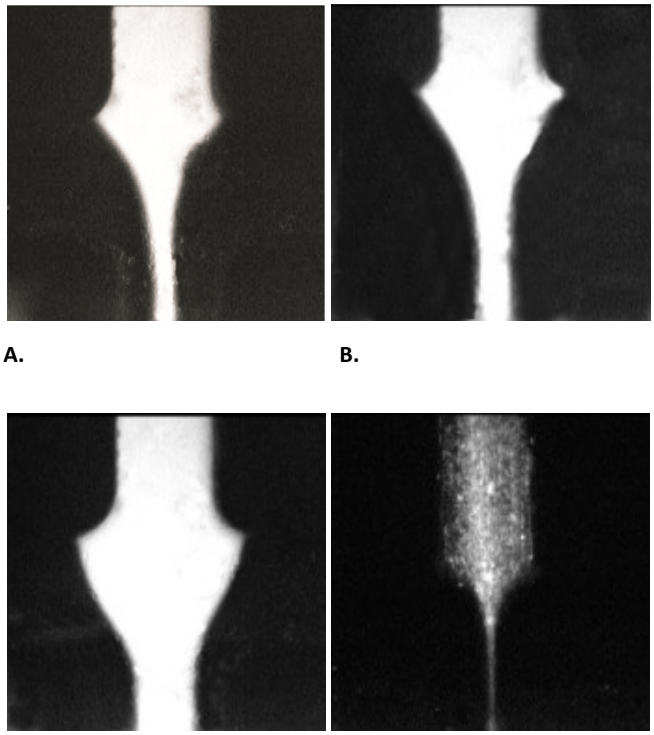
Hydrodynamic focusing capitalizes on the inherent advantages of the flow physics of a microfluidic system to overcome functional challenges encountered in microfluidic conditions such as mixing and the delivery of particles such as cells for counting. Hydrodynamic focusing requires reproducible flow rates, valving, and automated control of pumps and valves to direct the processes on chip, as well as process visualization including tools such as micro particle image velocimetry. LabSmith's unique combined technology of uProcess™ automated syringe pumps and valves, integrated breadboard (iBB), fluid reservoirs, CapTite microfluidic microconnectors™, and the SVM340 synchronized video microscope with uScope™ software meet the requirements to study and control hydrodynamic focusing on-a-chip for diverse applications.

Introduction

Two-dimensional hydrodynamic focusing occurs in microscopic flows when a center stream of fluid is confined to a region of a channel by at least two other streams. The streams each occupy a percentage of the channel dependent on the relative flow rates and viscosities of the three solution streams (Figure 1).[1] Hydrodynamic focusing is applied in diverse lab-on-a-chip application areas including flow cytometry (Figure 3),[2,3] droplet generation,[4] mixing[5] and reactors[6]. Because microfluidic dimensions produce conditions where the viscous effects of the fluid dominate, the Reynolds number (Re), the ratio of inertial to viscous forces, is very small. This results in a time-reversible and turbulent-free flow. These conditions present advantages and challenges depending on the desired result for the microfluidic geometry.[7] In general, without solutions such as hydrodynamic focusing, mixing rates are limited to the speed of diffusion.[4] The small streamlines generated between the two moving walls of fluid from the side arms create a particle sized tunnel suitable for flow cytometry.[2] These features have also been harnessed by using solutions of different viscosities for a range of applications, including surface patterning and reactors.[6]

Experimental Results



A. **B.**

C. **D.**

Figures 1. Snap shots of hydrodynamic focusing using the LabSmith setup. The main stream and side arm velocities were varied for A-D as described in Table 1. Cross-channel chip dimensions given in Figure 2. LabSmith equipment used for fluid circuit and imaging given in Figure 3.

Table 1. Key to Flow Rates Conditions for Figure 1A-D

Fig.	Side Arm Flow Rate (µm/min)	Center Stream Flow Rate (µm/min)	Center Stream Solution
A	5	1	Oregon Green (Life Technologies, Carlsbad,CA)
B	5	10	
C	5	20	
D	10	1	500 nm fluorescent-labeled polystyrene beads

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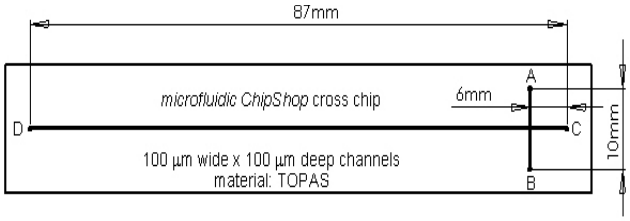

Figure 2. Dimensioned diagram of the microfluidic ChipShop Chip (Jena, Germany) used in hydrodynamic focusing experiments.

Hydrodynamic Focusing using Low Cost LabSmith Breadboard Solution

Hydrodynamic focusing experiments require precise and stable synchronization and control of multiple fluid streams. This level of control typically requires expensive, high-precision syringe pumps. We have devised a method of performing and recording the experiments using our modular, low-cost uProcess syringe pumps in tandem with our pressurized reservoirs and SVM340 synchronized video microscope (Figure 3).

LabSmith's SPS01 syringe pumps use a stepper motor to drive the flow. While this design allows for a compact product at one-tenth the price of pulse-free pumps, flow pulsations are inevitable. We use the CapTite™ Breadboard Reservoir to dampen these pulsations. The reservoir has three in-line capillary ports and can be used open (unpressurized) as a fluid reservoir or capped (pressurized) as a dampener. For these experiments the flow out of each syringe pump is routed through a capped reservoir filled ~75% full with the dispensing fluid. The result is well controlled, stable flow on a simple, modular platform at a fraction of the cost of the traditional approach (Figure 4).

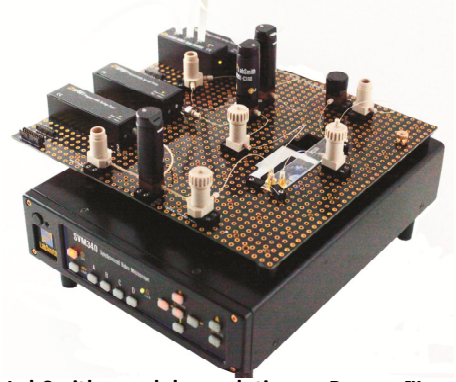

Figure 3. LabSmith modular solution. uProcess™ pumps and valves mounted on an integrated breadboard connected to a microfluidic chip with CapTite™ connectors mounted in place of a stage on the SVM340 synchronized video microscope.

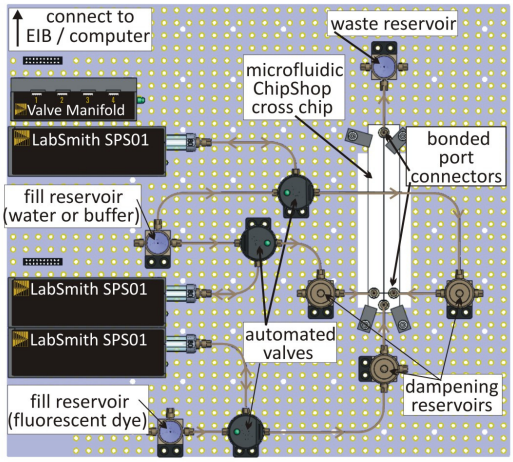

Figure 4. Labeled diagram of LabSmith hydrodynamic focusing breadboard layout.

The SVM340 inverted video microscope is designed so the epi-fluorescent optics module moves, not the stage. Therefore the prototype sits unperturbed as imaging experiments are performed. The SVM340 uScope™ software includes image recording features such as picture and video capture, buffering to prevent dropped frames, time lapse, frame averaging and delay. uScope™ software data probes can be applied in real time or on stored videos to collect data such as particle velocity (PIV Probes) and fluorescence intensity (Intensity Probes).

References

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