PENNSTATE

BioMEMS@PSU

Center for Optical Technologies

Optical Diagnostics for use in Microfluidic Devices

Sung Yang[1], Huinan Liang[1] and Jeffrey D. Zahn[1, 2,*]

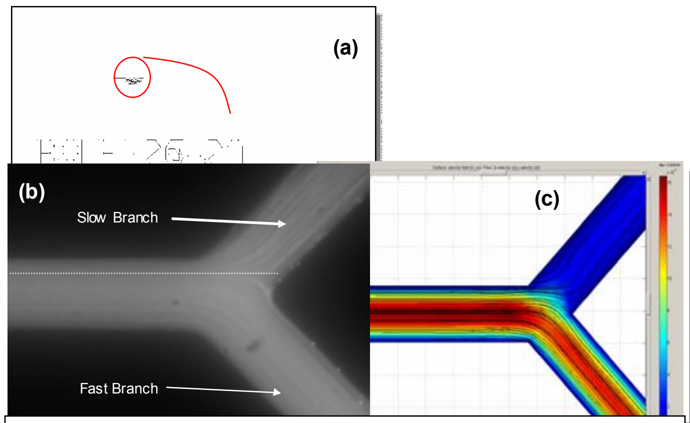
1) Department of Bioengineering 2) Materials Research Institute

The Pennsylvania State University 224 Hallowell Building University Park, PA 16802 , *email: jdz10@psu.edu

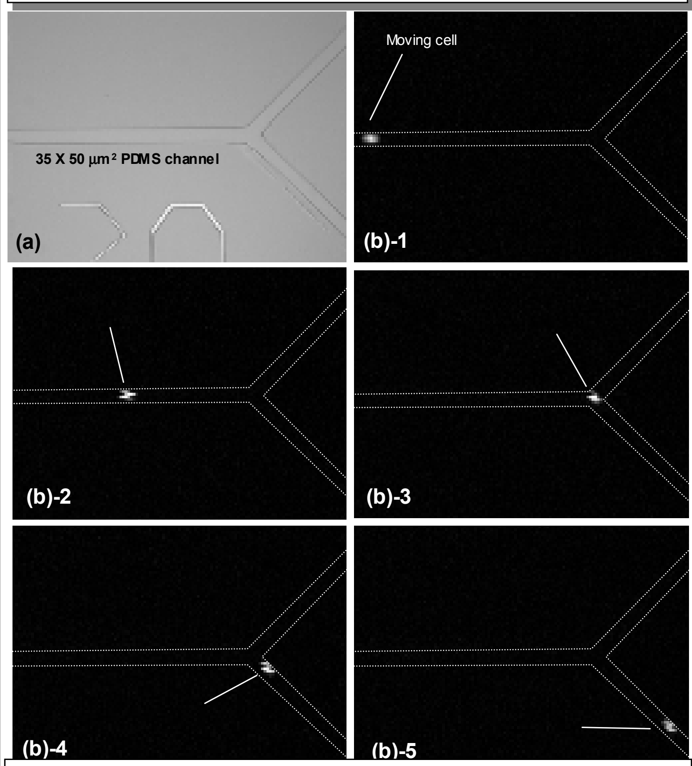
Particle Separation in Microfluidic Channels using Flow Rate Control

Sung Yang, Jeffery D. Zahn

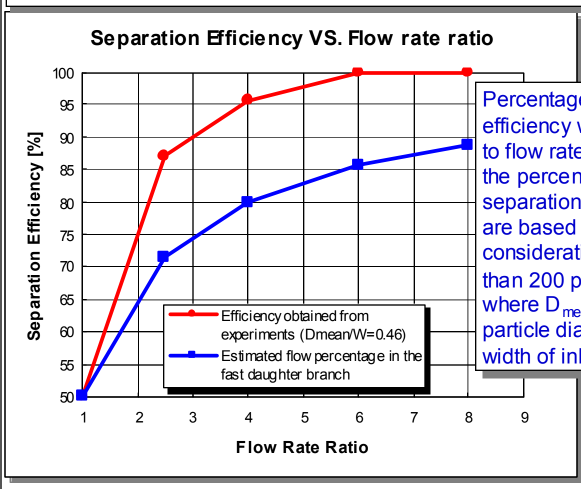
In many miniaturized total analysis systems, sample preparation still remains a critical challenge. Most biological cell analyses require the ability to either remove cells from a biological fluid, such as the removal of blood cells from plasma, or to concentrate the cells for downstream processing. In this study, microfluidic channels are designed to enhance particle separation based on the Zweifach-Fung effect (Fung et. al., 1973). In the microcirculation, when erythrocytes flow through a bifurcating region of the capillary blood vessel, they have tendency to travel into the daughter vessel which has the faster flow rate resulting almost zero cells traveling to the slower flow rate channel. The critical flow rate ratio between the daughter branches for this separation is on the order of 2.5:1 when the cell-to-vessel diameter ratio is of the order of 1.



(a). A schematic drawing of a particle separation device based on the Zweifach-Fung effect. (b). Streakline image at the bifurcating region of channels. Flow rate ratio = 4:1, Particle-diameter: 1 μm. The white dashed line shows the stagnation streakline.(c) CFD simulation result for 4:1 flow rate ratio showing streamlines.



(a) A bright filed image of separation channel and (b) a series of fluorescent images of Calcein AM dye stained "biological cell" heading for lower resistance channel. The white dashed line is a guide for eye showing channel dimension. D/W=0.23, flow rate ratio = 4:1, where D: cell diameter, W: width of inlet channel. The separation efficiency was 98.9 %.



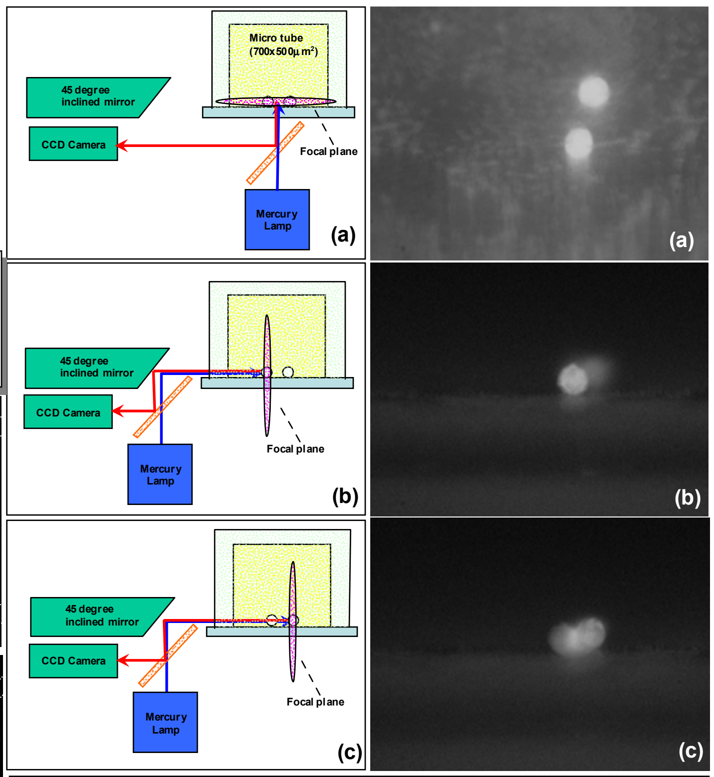
Percentage separation efficiency with respect to flow rate ratios, All the percentage separation efficiencies are based on the consideration of more than 200 particles. where D_{mean}: mean particle diameter, W: width of inlet channel.

Side View imaging for Three Dimensional Microflow Profile Reconstruction

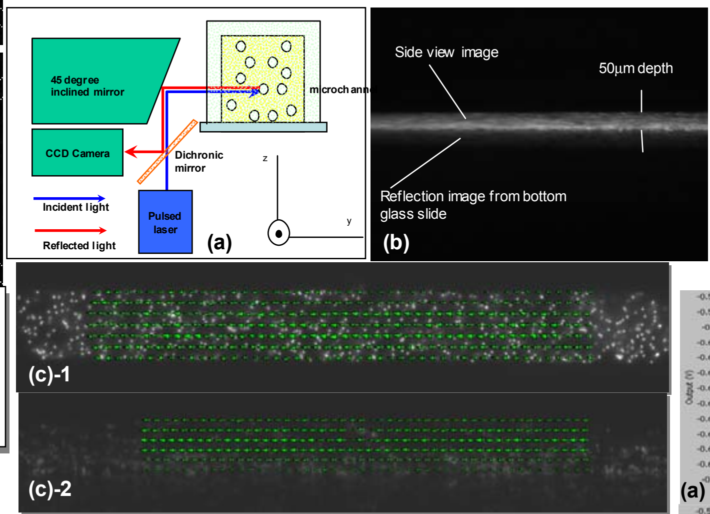
Sung Yang, Jeffery D. Zahn

Particle Image Velocimetry (PIV) is a quantitative field measurement technique that has greatly improved researchers' ability to visualize and analyze flow structure. For PIV techniques, the flow is seeded with tracer particles that follow the fluid flow, images are recorded on a sensor and velocity profiles are determined using cross correlation analysis. Due to the planar nature of microfluidic devices and the needs for implementation of a microPIV laser light source through a microscope, most MicroPIV flow profiles are limited by the depth of focus of the microscope objectives and are planar representation of a three dimensional flow profile throughout the depth of the device, where any depth (z axis) directed velocity profiles must be inferred.

In most microfluidic channels, fluids flow within the device plane, with a parabolic flow profile in the z direction. However, there are specific instances where data on a z directed profile is needed, such as during instability mixing and determining flow profiles when a sample has a non-uniform channel depth. In a recent development, a side-view flow chamber was devised to study cell deformation and adhesion to various adhesion surfaces in a microcapillary. This design allowed not only the measurement of the effects of flow on cell-surface adhesion strength, but also the visualization of cell deformation and the cell-substrate contact interface in shear flow. This technique is adapted for use with μPIV for full three dimensional flow profile reconstruction.



Experimental setup and fluorescent images showing (a) top and (b-c) side view images of particles (16μm) with respect to focal planes



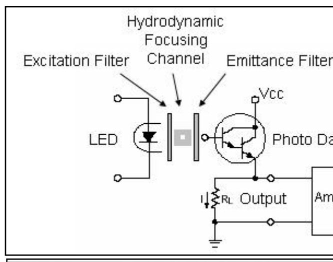
(a). A schematic side-view microPIV system. A 45 degree inclined mirror is coated with Au(200nm)/Cr(50nm). (b). Side view streakline image of a microchannel having 35μmx50μm dimension. (c) Velocity vector profiles of a microchannel (35X50μm²) under flow conditions obtained by top view (c-1) and side view (c-2) microPIV system showing parabolic velocity profiles.

Fluorescence Based Assays in a Programmable Microfluidic Cytometer

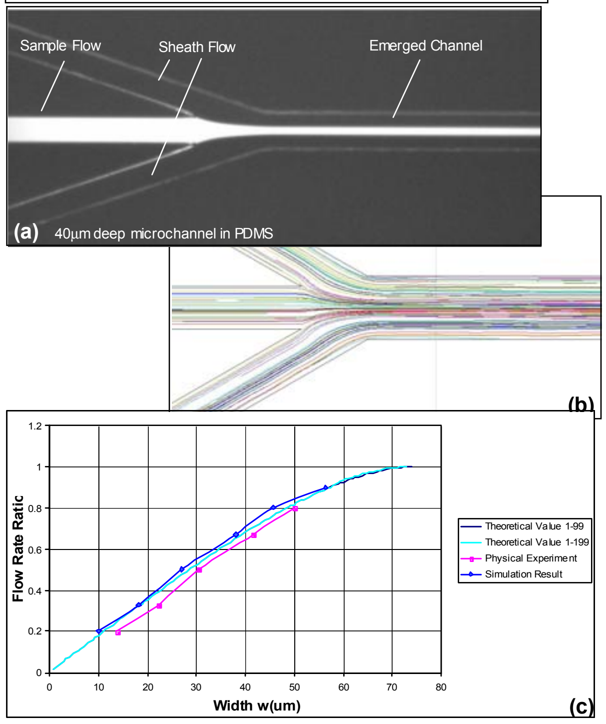
Huinan Liang, Jeffery D. Zahn

A major research thrust in the microfluidics field is the development of autonomous platforms for cellular analysis. At present, the pharmaceutical industry uses complicated automated robotic systems and cell based assays to test potential therapeutic compounds. Since these systems typically screen hundreds of thousands of compounds to develop a single commercial drug, there are currently major research efforts to miniaturize these automated platforms. The scope of this work is to develop a multidisciplinary approach to investigate highly-parallel, high-throughput drug screening using fluorescence-based cellular assays in a programmable, parallel, microfluidic cytometer (PPMC).

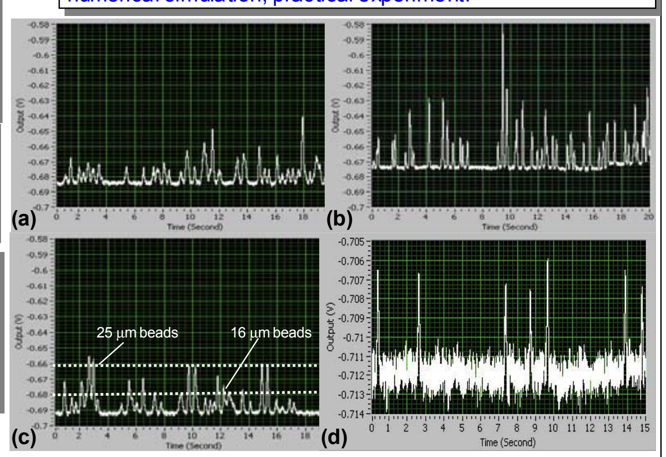
The whole system is composed of a hydrodynamic focusing flow channel which is commonly used in micro-cytometer systems, and optical components including; a blue LED, photodarlington and optical filters. To precisely control the flow rate of the system, a systematic investigation of the hydrodynamic focusing flow is performed including: numerical simulation, theoretical analysis and practical physical experiment. Fluorescent bead and Calcein AM dye stained cell detection are demonstrated in microtube and hydrodynamic focusing flow channel respectively.



Schematic of System Setup. The data acquisition and post processing are handled by LabVIEW Program with a DAQ card.



(a) Hydrodynamic focusing flow pattern at sample flow rate of 5μl/minute and flow rate ratio of sample flow rate to total flow rate in emerged channel equal to 1/5. (b) CFD simulation of flow pattern at same parameter. (c) Analysis result of hydrodynamic focusing flow with theoretical analysis, numerical simulation, practical experiment.



(a). 16μm (b). 25μm (c). 16μm&25μm mixture fluorescent beads are detected in a square microtube whose internal diameter is 100μm at a flow rate of 5μl/minute. The white lines delineate the approximate cutoff between the two populations. (d) Calcein AM dye stained cells are detected in a sheathing flow at a sample flow rate of 1μl/minute and a flow rate ratio of 1/5.