A Three-Dimensional Hydrodynamic Focusing Manifold

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Abstract:

A manifold was developed to focus a fluid stream into the central volume of a square microchannel. The manifold was designed for operation in rectangular microchannels and can be readily constructed with photolithography. A set of channel junctions of cleverly designed geometry was employed to confine an input stream on all sides by sheath fluid and position the input stream at the center of the microchannel. The fluid distributions were observed downstream of the manifold with confocal microscopy and were observed to match the simulations.

Research Summary:

Fluid focusing manifolds have been developed to operate within microchannels for several applications including flow cytometry, diffusion mixing, and microfiber synthesis. Hydrodynamic focusing is currently the more commonly employed method of fluid-focusing within microchannels and is achieved by applying a pressure differential across the inputs and output(s) of a manifold junction. Hydrodynamic focusing within microchannels operated at low Reynold’s Number leverages the property of laminar flow, allowing the impinging of fluid streams into one another to be choreographed by informed manifold design.

Here, we report the design and characterization of a simple hydrodynamic focusing manifold for which the central design requirement was that the input stream be maneuvered into the geometric center of the channel. A secondary design consideration was fabrication simplicity. In particular, our manifold was designed for construction from two patterned surfaces of polydimethylsiloxane (PDMS) manifold housing. In addition, the number of fluid inputs was minimized in order to simplify packaging and run-time operation.

Manifolds satisfying the design considerations were simulated using ANSYS Computational Fluid Dynamics Modeling Software. Several variations were defined as a 3D FLOTTRAN-142 element. The feature height for both layers was chosen to be 125 µm, and the width of the input and output channel was chosen to be 125 µm so that the input and output channel have square cross-section. The simulation is a two-species transport solution obtained by loading the central input with a species of molecular weight 480 (fluorescein) and by loading the sheath inputs with a species of molecular weight 330 in water (rhodamine). The geometry was solved with 60-global iterations of the preconjugated residual method over the manifold volume, which was meshed with an element edge length of 5 µm.

The manifold of this geometry was fabricated in the Cornell NanoScale Facility using standard soft lithography techniques and was observed to function as predicted using food coloring indicator dye and an optical microscope.

Confocal microscopy was used to experimentally image the cross-section of the output of the manifold. Fluorescein dye was pumped into the input for focusing, and rhodamine dye was pumped into the sheath fluid inputs (Figure 1). The experimental result is shown side-by-side with the simulated concentration distribution of fluorescein (Figure 2). The manifold is shown to operate as predicted and could become useful in a microfabricated flow cytometer, a diffusion micromixer, or a microfiber gellation/polymerization system.
**Figure 1:** Schematic of confocal microscopy imaging experiment. Sheath fluid labeled with rhodamine and sample fluid labeled with fluorescein are pumped into the flow-cell, and the output is imaged with a confocal microscope to obtain the concentration distributions across a cross-section of the channel.

**Figure 2:** 3D Fluid Focusing. A fluorescein-labeled stream is cylindrically focused by rhodamine-labeled sheath fluid. The channel dimension is 125 µm height by 125 µm width. Left: Simulation based on the Finite Element Method. Right: Experimental measurement with confocal microscopy.