Exact solution of flow fraction-based hydrodynamic focusing in rectangular microchannels

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The flow focusing provides the effective means of controlling the passage of reagents or bio-samples through the microchannels of microfluidic devices. It has been demonstrated in a wide variety of applications, including flow cytometers for cell/particle counting, DNA stretching, microflow switching, droplet generator, and micro-particle production. A precise prediction of the fractioned boundary width of the focused stream is necessary to design the optimal channel for hydrodynamic focusing. We take into account the 3-dimensional flow profile at the rectangular cross-section and then derive the exact solution of flow ratio between each incoming or outgoing stream. Especially, our derived model can predict the effect of fluid slippage at hydrophobic surfaces of channel wall by applying Navier's slip boundary condition. We consider the flow fraction behavior with variations of the channel aspect ratio (i.e., ratio of height to width) for each limit case and compare with the 2-dimensional approximate solution. Our model performs a theoretical analysis of flow control in microfluidic devices to support particle counting and sorting applications.