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Experimental analysis of particle trapping and separation in microcavities

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Microfluidic devices are critical tools across various fields, such as biomedical diagnostics, drug delivery, and chemical analysis, due to their ability to manipulate small volumes of fluids and particles with high precision. Despite their potential, the precise hydrodynamic control of particle behavior remains a significant challenge, primarily due to unpredictable flow patterns and limited particle manipulation capabilities. This study addresses these challenges by investigating the flow topology and particle behavior within microcavities, aiming to enhance the understanding and control of microscale particle dynamics.

In this research, a micro particle image velocimetry system (µPIV) and a high-speed camera are utilized to experimentally analyze particle behavior in microchannels with cavities. Experiments are performed in a series of square and semicircular microcavities. Particle separation by size, dynamics of entry into the cavity, trapping in the recirculation zone, as well as behavior in the recirculation zone—including particle trajectories, velocity distribution in the orbit around the recirculation zone, and trapping efficiency—are analyzed depending on particle size, cavity geometry, and flow parameters. Three sizes of particles, namely 10, 20, and 30 µm, are used.

Key findings reveal distinct patterns in particle trapping and recirculation dynamics, providing insights into the relationship between particle size, cavity design, and flow conditions. These results deepen the fundamental understanding of particle recirculation behavior and offer practical guidance for designing vortex-based microfluidic systems. This research lays the groundwork for future studies exploring optimized microcavity designs for enhanced particle control, with potential applications in biomedical and chemical processing fields.

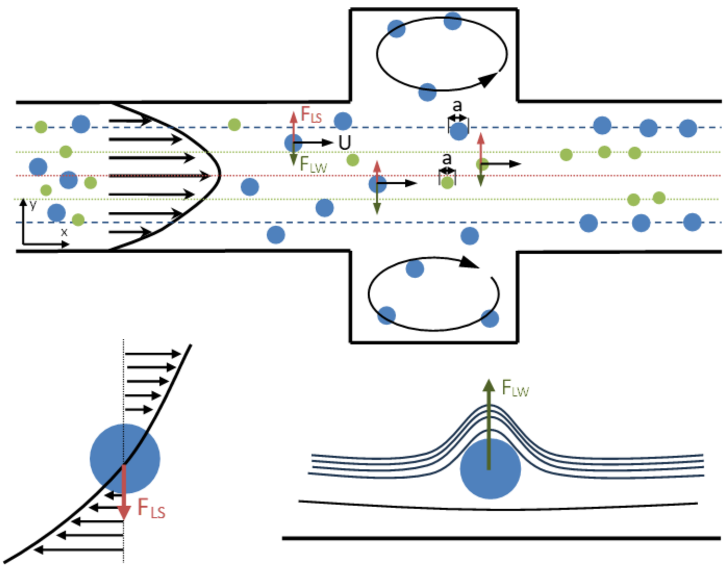

Figure 1: Schematic diagram of inertial lift forces acting on microparticles in the flow

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