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Optimized open-flow mixing: insights from microbubble streaming BHARGAV RALLABANDI[1], Department of Mechanical Science and Engineering, University of Illinois at Urbana-Champaign, CHENG WANG, Department of Mechanical and Aerospace Engineering, Missouri University of Science and Technology, LIN GUO, SASCHA HILGENFELDT, Department of Mechanical Science and Engineering, University of Illinois at Urbana-Champaign — Microbubble streaming has been developed into a robust and powerful flow actuation technique in microfluidics. Here, we study it as a paradigmatic system for microfluidic mixing under a continuous throughput of fluid (open-flow mixing), providing a systematic optimization of the device parameters in this practically important situation. Focusing on two-dimensional advective stirring (neglecting diffusion), we show through numerical simulation and analytical theory that mixing in steady streaming vortices becomes ineffective beyond a characteristic time scale, necessitating the introduction of unsteadiness. By duty cycling the streaming, such unsteadiness is introduced in a controlled fashion, leading to exponential refinement of the advection structures. The rate of refinement is then optimized for particular parameters of the time modulation, i.e. a particular combination of times for which the streaming is turned "on" and "off". The optimized protocol can be understood theoretically using the properties of the streaming vortices and the throughput Poiseuille flow. We can thus infer simple design principles for practical open flow micromixing applications, consistent with experiments.

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