Micro mixing and transport within a micro T-mixer at high frequency

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Mixers are fundamental components of integrated microfluidic systems. Micro mixers have been demonstrated as effective in a variety of applications such as flow cytometry, micro reactors, protein crystallization and DNA hybridization. Control over mixing processes on a chip is becoming as necessary as controlling the flow rate or direction of fluid flow. Many different approaches have therefore been developed to enhance mixing within the framework of microfluidic systems. Time periodic flows have long been known to enhance mixing, a concept which has been exploited by a variety of micro mixer designs including the pulsed flow T-mixer which has been explored in both numerical simulations and experiments [1, 2].

We present data examining mixing in a pulsatile micro T-mixer over a range of frequencies spanning 1 - 100 Hz. Previous experimental studies although limited in frequency range have pointed to enhanced mixing at increasing Strouhal number (St). An impedance pump downstream of the mixing section is therefore used to provide high frequency pulsatile flow providing St in excess of 30. An impedance pump uses constructive interference of pressure waves interacting along a compressible section of the pump to generate a pulsatile flow output at a specific waveform, frequency, offset and duty cycle [3]. The characteristic length of the mixing channel is 133 μm. The mean flow rate from either of the inlet channels is 250 nL/min resulting in a Re = 0.06.

Flows were visualized using phase averaged micro particle image velocimetry (μPIV) as well as laser induced fluorescence (LIF). Phase averaged flow data allows the observation of flow patterns which emerge during a period of flow oscillation. LIF data is used to provide a quantitative measure of mixing efficiency within the mixing channel. Lagrangian Coherent Structures (LCS) are used to analyze the flow field data to identify transport boundaries within the flow. LCS are defined as the local maxima of the Finite-Time Lyapunov Exponent (FTLE) fields [4]. In general, such systems with time dependent periodic forcing display emergent patterns which influence the transport of particles within the flow. Given a time periodic forcing imposed on the micro T-mixer we are able to identify how transport boundaries within the flow evolve under different frequency conditions. Exploiting these patterns within the phase space of the flow we are able to identify frequencies which are beneficial to mixing.

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