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Measurement of the acoustic streaming pattern in a standing surface acoustic wave field

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1 Introduction

The application of standing surface acoustic waves (sSAW) has enabled the development of many flexible and easily scalable concepts for the fractionation of particle solutions in the field of microfluidic lab-on-a-chip devices. In this context, the acoustic radiation force (ARF) is often employed for the targeted manipulation of particle trajectories, whereas acoustically induced flows complicate efficient fractionation in many systems [Sehgal and Kirby (2017)]. Therefore, a characterization of the superimposed fluid motion is essential for the design of such devices. The present work focuses on a structural analysis of the acoustically excited flow, both in the center and in the outer regions of the standing wave field. For this, experimental flow measurements were conducted using astigmatism particle tracking velocimetry (APTV) [Cierpka et al. (2010)]. Through multiple approaches, we address the specific challenges for reliable velocity measurements in sSAW due to limited optical access, the influence of the ARF on particle motion, and regions of particle depletion caused by multiple pressure nodes along the channel width and height. Variations in frequency, channel geometry, and electrical power allow for conclusions to be drawn on the formation of a complex, three-dimensional vortex structure at the beginning and end of the sSAW.

2 Experimental microfluidic setup

The investigated microfluidic system (see Fig. 1) consists of a straight channel made of Polydimethylsiloxan (PDMS) with a rectangular cross-section (500 µm in width, heights between 85 µm and 480 µm) centrally located between two interdigital transducers (IDT) on a piezoelectric substrate consisting of $LiNbO_3$. Two coherent counter propagating surface acoustic waves (SAW) were excited that superimposed in the region of the microchannel to form a standing wave field within the carried fluid. To study the influence of the frequency, different pairs of IDTs with resonance frequencies ranging from 25.72 MHz to 194.8 MHz were used. A syringe pump (neMESYS, cetoni GmbH) was employed to provide a mixture of 80 % v/v de-ionized water and 20 % v/v glycerol at a constant flow rate. The glycerol was added to match the density between the fluid and suspended 1.14 µm polystyrene particles. In this way, not only sedimentation was reduced but also the influence of ARF due to a lower acoustic contrast factor. 3D3C flow measurements are performed by APTV in three distinct regions of interest (ROI) through the birefringent $LiNbO_3$, which requires the use of an additional polarization filter [Kiebert et al. (2017)].

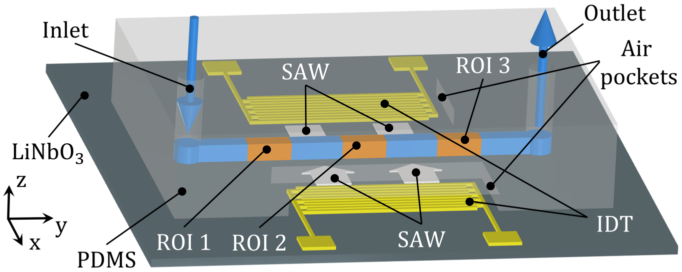

Figure 1: Schematic illustration of the microfluidic device with the observed regions at the beginning (ROI1), center (ROI2) and the end (ROI3) of the sSAW. The directions of SAW propagation are indicated by arrows.

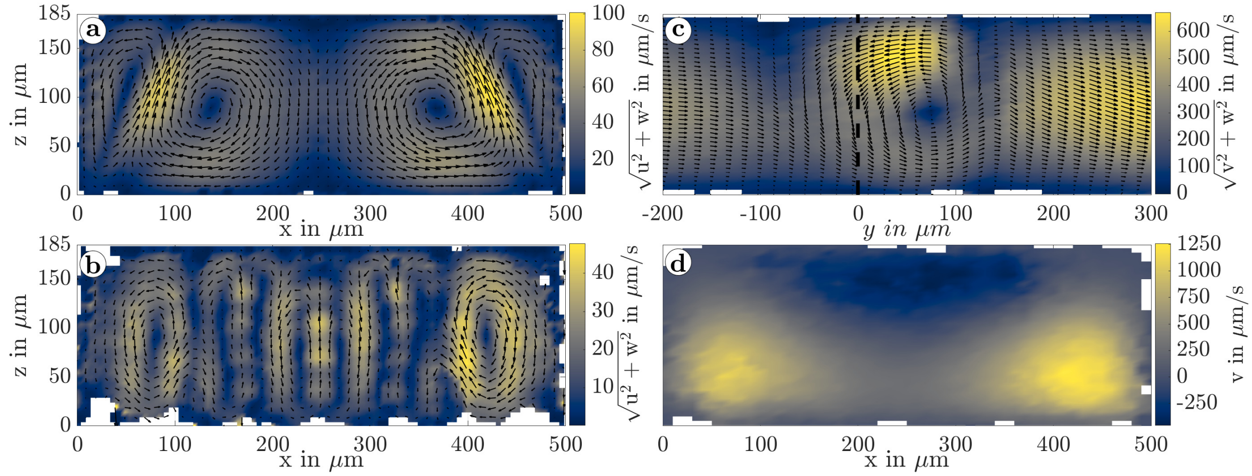

Figure 2: Experimentally determined particle motion transverse to the main flow in ROI2 for frequencies of 194.8 MHz (a) and 25.72 MHz (b). Flow field in sectional planes lengthwise (c, $x' = 250$ μm) and crosswise (d, $y' = 90.7$ μm) to the microchannel at the beginning (dashed line) of the sSAW.

3 Results

The flow field transverse to the imposed main flow at the center of the sSAW (ROI2) is depicted for frequencies of 194.8 MHz and 25.72 MHz in Fig. 2a and 2b, respectively. The irregularly distributed velocity vectors were interpolated onto a regular grid with a voxel size of $10 \times 800 \times 10$ μm^3. White areas indicate regions where no particles were detected. While two acoustically induced vortex pairs in Fig. 2a extend across the entire channel cross-section, periodic structures are visible in the center of the channel as the frequency decreases. With regard to the beginning of the sSAW (ROI1, Fig. 2c), a 3D vortex is visible, which has significant velocity components in the main flow direction. Combined with Fig. 2d, it is evident that recirculation occurs near the channel ceiling, while two separate maxima are formed at the lower corners.

4 Conclusion and outlook

In this study, the acoustically induced velocity field in the center and outer regions of the sSAW was revealed by 3D3C APTV measurements. More advanced investigations of the complex 3D vortices and results on the variation of frequency, channel geometry and electrical power will be presented at the conference.

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