Measurement of the 3D particle velocity and temperature distribution induced by surface acoustic waves using V3V-Flex volumetric PIV and PLIF

J. König1, C. Kykal2, F. Kiebert1, A. Boomsma3, H. Schmidt1
1: IFW Dresden, SAWLab Saxony, P.O. 270116, 01171 Dresden, Germany
2: TSI GmbH, Neuköllner Str. 4, 52058 Aachen, Germany
3: Fluid Mechanics Research Instruments, TSI Incorporated, Shoreview, MN, USA

* Correspondent author: j.koenig@ifw-dresden.de

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HIGHLIGHTS

- The V3V-Flex system allows for measuring particle positions with very low uncertainty of 4.3 µm for the in-plane components and 36 µm for the out-of-plane component, within a measurement volume of (70 x 56 x 22) mm³.
- Acoustic streaming dominates the particle velocity for a traveling acoustic pressure wave of 42.9 MHz. The acoustic radiation force can be neglected for particles less than 21 µm in diameter.
- Based on PLIF measurements, a temperature increase up to 0.85 K was found at a low electrical power level (Pₑ = 7 mW), that locally coincides with the fluid flow induced by the acoustic streaming.

ABSTRACT

Surface acoustic waves (SAWs) allow for tailored fluid and particle manipulation based on the acoustic streaming and the acoustic radiation force, using high-frequency ultrasonic waves of up to 5 GHz. However, detailed knowledge about the influence of those high-frequency waves is still missing in the literature, regarding not only both types of forces, but also the temperature effects induced in the fluid. For the first time, volumetric velocimetry and temperature measurements of the fluid flow induced by surface acoustic waves are presented, using a novel combination of a V3V-Flex system from TSI Inc. and planar laser induced fluorescence (PLIF). Based on tomographic aperture encoded particle tracking velocimetry (TAPTv), the V3V-Flex system enabled the measurement of the acoustically-induced particle velocity with high spatial resolution of 0.06 mm³, in a simplified experimental setup consisting of a large glass cuvette filled with water and a SAW-device operated at a frequency of 42.9 MHz. It is shown that, in this case, the acoustic radiation force can be neglected for particles up to 21 µm in diameter. The three-dimensional fluid flow is characterized by two velocity jets that deeply penetrate into the water with a velocity in the range of a few mm/s. Even though a very low electrical power level (Pₑ = 7 mW) is used, a local temperature increase of the water, up to 0.85 K, within the measurement volume was determined. The temperature increase locally coincides with the velocity jets, which confirms that acoustic energy absorption and acoustic streaming occur at the same time.

Fig. 1 (left) 3D velocity measurement and (right) corresponding temperature field at the central xy-plane.