



Acoustophoretic control of microparticles using a multi-wavelength surface acoustic wave device

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Abstract: Standing surface acoustic waves (SSAWs) are widely used in microfluidic devices to manipulate various cells and micro/nano-objects. The physical interplay between electromechanical fields of the piezoelectric substrate and acoustofluidic effects including fluid-solid interactions are exploited for achieving particle focusing and separation. The common implementation of SSAWs in microfluidics is via single-pitch interdigital transducers (IDTs) with a single excitation frequency. Recently, dual-pitch IDTs have been suggested that allow for generating two different SSAWs in the same region of action. This idea has great potential for versatile applications and leads to more complex functionality of more compact versions of existing designs. In this work, we go one step further and investigate numerically the possibility of a multi-frequency SSAW device with multi-pitch IDTs.

Keywords: numerical simulation, acoustofluidic, microtechnology, SAW

INTRODUCTION

The manipulation of particles is a critical requirement for lab-on-a-chip (LoC) technologies in the fields of biosensors and environmental sensors (Destgeer and Hyung, 2015). In the last two decades, various manipulation strategies of microparticles have been developed, including electrokinetic, hydrodynamic, optical, magneto- and acoustophoretic methods (Hsu et al., 2019). Each method has its own strengths and weaknesses that make them suitable for a particular application. However, the acoustofluidics-based approaches possess some distinct advantages over competing technologies. Acoustofluidic methods are capable of manipulating cells/particles based on relative density and compressibility and are not limited by the electrical, magnetic, and optical properties of the target particles. In addition, excellent cell viability, non-contact and label-free manipulation make acoustofluidic approaches a promising platform for future LoC-technologies. Particularly acoustofluidic methods based on standing surface acoustic waves (SSAWs) have the ability to easily integrate with other microfluidic technologies, see for example (Gupta et al., 1995). While there are countless reports on examples of LoC in microtechnology, very few configurations make it to market. The efficiency and reproducibility of available devices need to be improved, which can be achieved by optimization and innovative designs. This approach will contribute to the development and exploitation of the potential of LoC to become a real product. Here, numerical simulation plays a crucial role not only by providing a physical understanding of the complex interplay between acoustofluidic and fluid-particle interaction, but also by improving and optimising the design before its fabrication and testing.

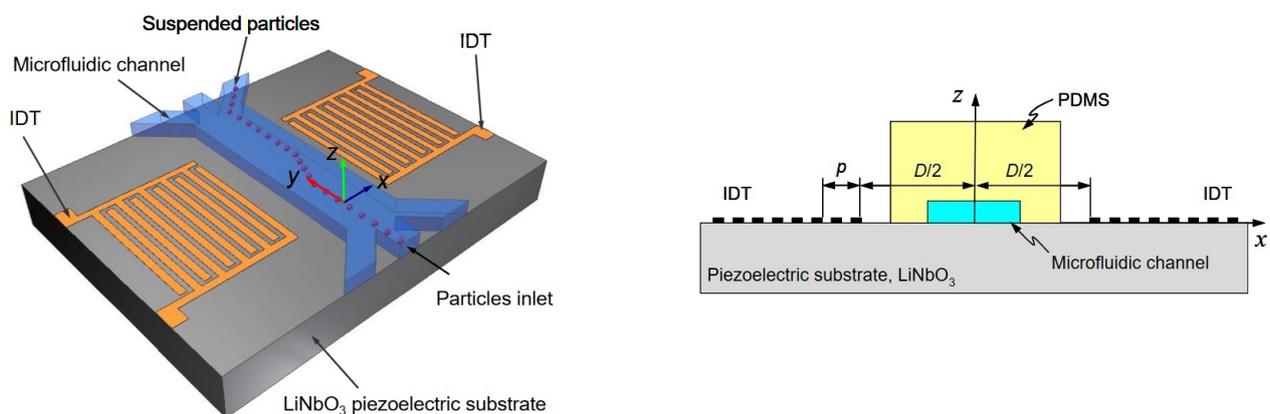


Figure 1 – Schematic sketch (left) and cross-section (right) of a SSAW-based acoustofluidic device with IDTs used for the numerical simulations. Pictures are taken from (Namnabat et al. 2019).

RESULTS

The mainstream solution for generating SSAWs is employing interdigital transducers (IDTs) with a uniform distance between the oppositely actuated fingers – single-pitch IDTs. A typical configuration of such a setup is shown in Fig. 1 for a constant pitch p . Recently, dual-pitch IDTs have been suggested (Hsu et al., 2019) that allow for generating two different SSAWs in the same region of action. This idea has great potential for versatile applications and leads to more complex functionality in more compact versions of existing designs. In this work, we go one step further and investigate numerically the possibility of a multi-frequency SSAW device with multi-pitch IDTs. We perform numerical calculations in COMSOL Multiphysics of two- and three-dimensional configurations as in Fig. 1 with single and multiple pitch values in a single design. Starting with a single pitch and dual-pitch values p_1 and p_2 as shown in Fig. 2, we compare our results with existing literature (Hsu et al., 2019) in order to verify the calculation process in terms of physical parameters, numerical accuracy and mesh quality. Then we extend our design to multiple pitch values p_1 , p_2 and p_3 .

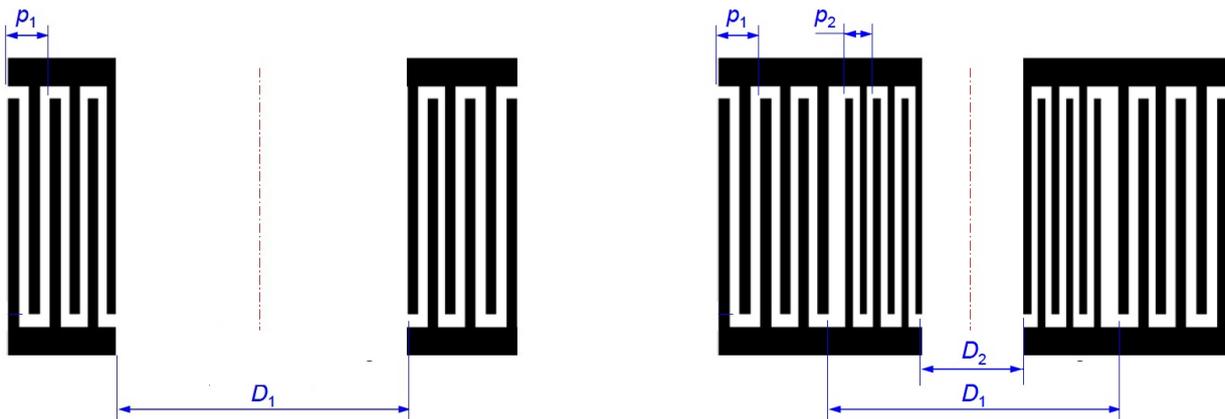


Figure 2 – Schematic sketch of IDTs with single-pitch (left) and dual-pitch (right) based on (Hsu et al. 2019).

The systematic comparison and tuning of designs show that clearly the newly gained capability of IDTs with a very compact design. When the driving frequency which is applied to the IDTs is changed from the value corresponding to the pitch p_1 to the value corresponding to pitch p_2 or p_3 , the pressure node generated by SSAW is moved noticeably and predictably perpendicular to the flow direction. Numerical simulations revealed the variations of the acoustic pressure fields induced by the SSAWs and their influences on particle motion. This switchable target area allows for efficient and contact-free handling of particles. The design is especially suitable for multi-channel microfluidic transport devices. The results of this work aim to trigger and facilitate innovative designs in order to accomplish real-life and reproducibly measuring LoC.

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