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Control of a Bulk Acoustic Wave micro-channel through frequency shifting and its application to cell reconcentration

Ludovic Bellebon^{1,2}, Deborah François², Mauricio Hoyos¹ and Jean-Luc Aider¹

¹PMMH Laboratory, ESPCI Paris - PSL, Paris, France

E-mail: ludovic.bellebon@espci.fr

²Aenitis Technologies, Paris, France

Introduction

Tuning the acoustic frequency of a Bulk Acoustic Wave (BAW) resonator is the first step before using any acoustofluidics setup, precisely because the Acoustic Radiation Force (ARF) is supposed to be maximum if the resonance condition ($\lambda_{ac} = 2.h$, with h the height of the cavity and λ_{ac} the acoustic wavelength) is satisfied. If this condition is theoretically simple, it is much more difficult to find the right acoustic frequency when dealing with an actual experimental setup where multiple imperfect boundary conditions have to be dealt with, from the transducer to the reflector and through the transmitter and fluid layer. Many studies have been devoted to this issue, searching for a possible simple method to find the optimal frequency based on electric measurements, admittance or impedance measurements [1-3].

In this study we are interested in using the acoustic frequency as a way to control some of the main characteristics of an acoustofluidics cavity or micro-channel. Indeed, it was shown by Dron & Aider [4] that it is possible to move the axial position of the levitation plane z_{foc} along the entire height of a micro-channel just by shifting the acoustic frequency over a wide range of acoustic frequency centered on the optimal frequency of the transducer (from 1.6 to 2.8 MHz). In this experimental work we go further and show that this phenomenon is robust and can be used to control the position of acoustic focusing as well as the axial acoustic focusing velocity of particles. Finally this approach is applied successfully to various biological cells for cell-reconcentration applications.

Height and axial velocity depending the frequency

Using microscopy, we measured the evolution of the axial position of the levitation plane as a function of the

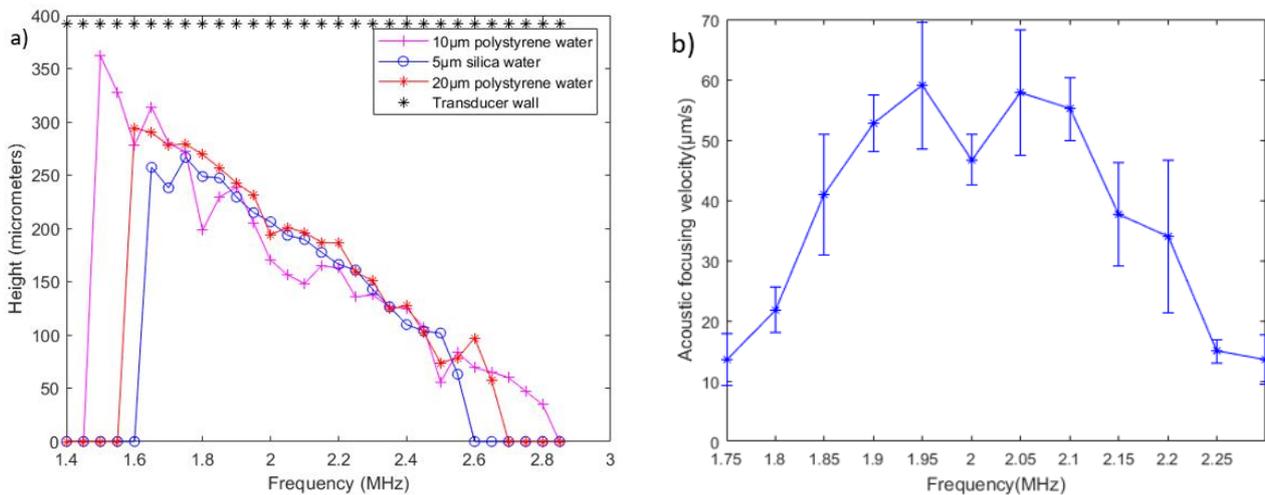


Figure 1: a) Position of 10µm, 20µm polystyrene and 5µm silica particles in micro-channel depending the frequency. Transducer is placed on the upper part of the channel. As we increase the frequency, particles are moving to the opposite wall of the transducer. b) Evolution of the focusing velocity of 5µm silica particles. Two peaks around the resonant frequency are observed while the velocity decreases as we are getting away from it.

acoustic frequency for different types and sizes of particles (10µm and 20µm polystyrene particles and 5µm silica). The channel height is $h = 400\mu\text{m}$, which corresponds to an optimal resonant frequency $F_{ac} = 1.9\text{MHz}$. As shown on Fig. 1, the axial location of the levitation plane can be moved nearly over the full height of the

channel, depending on the type of particles, over a wide range of acoustic frequencies, from 1.4MHz to 2.8MHz. The first observation is that z_{foc} decreases as the frequency increases. For low frequencies, the levitation plane is close to the transmitter wall and as we increase the frequency, it moves toward the opposite wall of the transducer. It is important to notice that the levitation planes are stable, i.e. the particles can be kept in levitation for each position.

To go further, it is important to measure the axial focusing velocity v_{foc} as a function of the acoustic frequency, in order to assess the yield of the system, as it is directly correlated to the magnitude of the ARF. We measure v_{foc} using the defocusing technique as presented in [5]. Two peaks of maximal velocities are observed around the resonant frequency (Fig. 1b). This velocity decreases for higher or lower frequencies; nevertheless the velocity is close to its maximum value over a relatively broad range of frequency (0.2MHz).

Knowing the frequency dependency of these two parameters it is possible to use it to optimize either separation or reconcentration processes.

Application to cell reconcentration

In order to validate these results in an actual acoustofluidics reconcentration setup, we apply this approach to various cells, illustrated here on Non Parenchymal Cells (NPC). We vary f_{ac} from 1.9MHz to 2.5MHz for a given flow rate of 1.5mL/min and a given voltage of 20V. Samples are collected in three different outlets of the micro-channel: one outlet is close to the transmitter wall, another collect the fluid at the mid-height of the channel while the third collect samples close to the reflector wall (opposite outlet). The result is shown on Fig. 2. We succeed to collect most of the cells in different outlets depending on the frequency. Most of the cells were collected in the adjacent outlet for 1.9MHz, in the central outlet for 2.1MHz and in the opposite outlet for 2.5MHz, in agreement with the frequency evolution shown in Fig. 1.

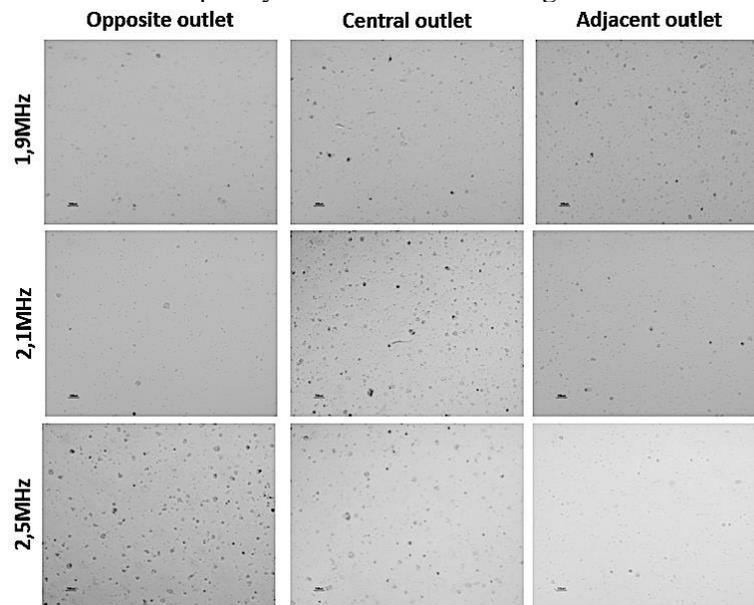


Figure 2: Pictures of samples of NPC cells in the different outlets after their passage in the BAW micro-channel for a given flow rate (1.5mL/min) and voltage (20V). Depending on the acoustic frequency the concentration of cells is increased in the adjacent outlet (1.9 MHz), central outlet (2.1 MHz) or opposite outlet (2.5 MHz).

Conclusion

In this experimental study, we demonstrate that it is possible to control some of the main properties of a broadband bulk acoustic wave micro-channel just through the proper choice of the acoustic frequency. We show that it is possible to control the axial position of the acoustic levitation plane as well as the focusing velocities of particles by tuning the acoustic frequency and we apply it successfully to a reconcentration process of NPC cells.

References

- [1] J. Dual, et al., *Lab on a Chip* 12.5 (2012): 852-862.
- [2] B. Hammarström, et al., " *Lab on a Chip* 14.5 (2014): 1005-1013.
- [3] V. Vitali, et al. *Nature Scientific Reports* 9, 19081 (2019).
- [4] O. Dron & J.-L. Aider. *Ultrasonics* 12, 4617-4627 (2013).
- [5] O. Dron & J.-L. Aider. *European Physics Letters* 97.4: 44011 (2012).