DOI: 10.61782/fa.2025.0532

FORUM ACUSTICUM EURONOISE 2025

LOW ORDER LATERAL MODES OF PLATE TRANSDUCERS AS BASIS FOR EFFECTIVE AND REPRODUCIBLE ACOUSTOFLUIDIC DEVICES

Andreas Fuchsluger[1*] **Annalisa De Pastina**[2] **Bernhard Jakoby**[1]
[1] Institute for Microelectronics and Microsensors, Johannes Kepler University Linz, Austria
[2] Microsystems, Silicon Austria Labs, Villach, Austria

ABSTRACT

Acoustofluidics is a contactless and thus gentle method for handling objects from the sub-micrometer to the millimeter length scale. Making use of the radiation force, small objects can be aligned at the pressure nodes or antinodes of a stationary acoustic field generated inside microfluidic structures. Besides the intensity and frequency of the acoustic field, the acoustic force on an object purely relies on its mechanical properties, and therefore, no special requirements or treatments are necessary. We designed and built numerically optimized acoustofluidic devices consisting of microfluidic silicon-glass chips actuated by attached piezoelectric plate transducers. The specialty in our design is the utilization of a low order lateral width mode of the plate transducer, which stands in contrast to the usually used thickness mode. A glycerol layer between the transducer and the chip ensures weak coupling of the lateral mode, meaning that the resonance frequency of the transducer is barely altered when attached to the chip. Together with low patch-to-patch variation of the used components, this altogether leads to very reliable and reproducible operating devices. We will demonstrate the performance of our concept by manipulating objects in millimeter-sized structures and in the milliseconds-timeframe, reaching acoustic energy densities close to $3000\,\mathrm{J/m^3}$.

Keywords: *Acoustofluidics, Acoustopheresis, Ultrasound, Lateral Modes, Particle Focusing*

****Corresponding author***: *andreas.fuchsluger@jku.at.*

1. INTRODUCTION

Small particles suspended in a fluid and exposed to a standing acoustic plane wave experience a force that, depending on the mechanical properties of the involved materials, will either drive them toward the pressure nodes or antinodes of the acoustic field, where the particles accumulate. This force is known as the acoustic radiation force [1]

$$F_{\text{rad}} = 3V\,\Phi\,E_{\text{ac}}\,k\sin(2kx), \tag{1}$$

which depends on the particle volume V, the acoustic contrast factor Φ, and on the acoustic energy density E_{ac} and the wave-number k of the standing pressure-wave $p_0\cos(kx)$ oriented along the x-direction with the pressure amplitude p_0. The acoustic contrast factor Φ characterizes the influence of the mechanical properties of both the fluid and the particle. Its sign determines the direction of the force. The particles used in our experiment have a density similar to that of the surrounding fluid but lower compressibility, resulting in a positive Φ. Consequently, F_{rad} directs the particles toward the pressure nodes of the wave.

2. THE DEVICE

The core elements of our device are formed by the microfluidic silicon-glass chip and the piezoelectric plate transducer for ultrasonic actuation shown in Fig. 1. The chip is mounted into our custom-made chip holder [2], where the transducer is clamped towards the bottom of the chip using a thin layer of glycerol in between as an acoustic coupling medium.

The chip geometry is numerically optimized for particle focusing in the center of the channel relying on the second-order lateral extensional width mode of the plate

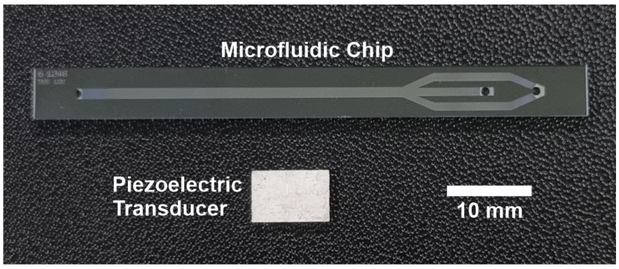

Figure 1. The core elements of the device are formed by a microfluidic chip made out of silicon and glass, and a piezoelectric plate transducer that is attached to the bottom of the chip for ultrasonic actuation.

transducer. Minimizing the focusing time and improving the setup is ongoing work [3,4]. As a final goal, using the trifurcation at the end of the channel, the system should operate as an effective flow-through separator using the lateral mode of the transducer instead of the usually employed thickness modes, e.g., as implemented in [5].

The lateral mode of the transducer, which is fundamental to our actuation, exhibits only a weak coupling with the microfluidic chip. Consequently, the lateral resonance of the transducer remains nearly unchanged when the transducer is attached to the microfluidic chip. Conversely, the thickness mode demonstrates strong coupling, resulting in significant alteration of the behavior at resonance [4].

3. RESULTS

With an actuation voltage of approximately $70\,\mathrm{V_{pp}}$, we cleared the outer region of a 1240-$\mu\mathrm{m}$ wide channel of 20-$\mu\mathrm{m}$ polystyrene (PS) particles, focusing them at its center within $16\,\mathrm{ms}$. By measuring the focusing time and using the method from [6], which is based on equating the acoustic radiation force to the drag force experienced by a particle when moving through the fluid, we obtained an acoustic energy density of $E_{\mathrm{ac}} = 2770\,\mathrm{J/m^3}$.

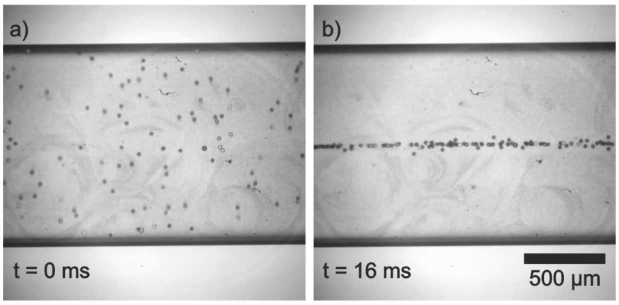

Figure 2. Particle focusing in a 1240-$\mu\mathrm{m}$ wide channel within 16 milliseconds, corresponding to an acoustic energy density of $E_{\mathrm{ac}} = 2770\,\mathrm{J/m^3}$. The actuation frequency and the actuation voltage are $547\,\mathrm{kHz}$ and approximately $70\,\mathrm{V_{pp}}$, respectively.

4. REFERENCES

[1] H. Bruus, “Acoustofluidics 7: The acoustic radiation force on small particles,” *Lab Chip*, vol. 12, pp. 1014–1021, 2012.

[2] A. Fuchsluger, A. De Pastina, R. Ecker, T. Mitteramskogler, T. Voglhuber-Brunnmaier, N. Andrianov, N. Cselyuszka, and B. Jakoby, “Acoustofluidic particle trapping in a structured microchannel using lateral transducer modes,” *IEEE Sensors Journal*, vol. 24, no. 24, pp. 40274–40285, 2024.

[3] A. Fuchsluger, A. De Pastina, N. Cselyuszka, N. Andrianov, A. Roshanghias, T. Mitteramskogler, R. Ecker, T. Voglhuber-Brunnmaier, M. Moridi, and B. Jakoby, “Utilizing lateral plate transducer modes for high quality acoustofluidics in silicon-based chips,” in *2022 IEEE Sensors*, pp. 1–4, 2022.

[4] A. Fuchsluger, A. De Pastina, T. Mitteramskogler, R. Ecker, T. Voglhuber-Brunnmaier, N. Andrianov, A. Shatalov, N. Cselyuszka, M. Moridi, and B. Jakoby, “Ultra-fast acoustofluidic particle focusing using lateral modes of a plate transducer,” in *2023 22nd International Conference on Solid-State Sensors, Actuators and Microsystems (Transducers)*, pp. 1333–1336, 2023.

[5] F. Petersson, A. Nilsson, C. Holm, H. Jönsson, and T. Laurell, “Separation of lipids from blood utilizing ultrasonic standing waves in microfluidic channels,” *Analyst*, vol. 129, pp. 938–943, 2004.

[6] R. Barnkob, P. Augustsson, T. Laurell, and H. Bruus, “Measuring the local pressure amplitude in microchannel acoustophoresis,” *Lab Chip*, vol. 10, pp. 563–570, 2010.