# Simulation Optimization Of Acoustophoresis In Microfluidics: Modelling And Performance Parameters

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## Abstract

Acoustophoresis is a promising technology for the downstream processing of microalgae biorefineries(Zhang et al., 2025). By generating acoustic radiation forces and acoustic streaming, it enables precise manipulation of particles within an acoustic standing field of a microfluidic chip(Novotny, Lenshof, & Laurell, 2022). This technique has great potential for microalgae cell harvesting and intracellular component (proteins, lipids, etc.) separation, though current research in this specific application remains limited(Kieffer et al., 2025). Thus, a 2D acoustic microfluidic model was designed to simulate the acoustic pressure distribution, velocity field, particle trajectories and forces acting on particles (2 µm & 7 µm).
The model comprises a square Polymethyl Methacrylate (PMMA) substrate and a 0.35 mm wide water-filled microchannel with trident-shaped inlets and outlets, which could be fabricated by 3D printing or laser cutting. Two PZT-26 piezoelectric transducers are symmetrically positioned 0.64 mm from either side of the microchannel. The acoustic field is created by coupling Solid Mechanics and Electrostatics physics, with actuation achieved via an oscillating voltage (12V) applied across the transducers.
Perfectly Matched Layers (PMLs) are implemented to absorb outgoing acoustic waves and minimize reflections. The acoustic field is modelled using Pressure Acoustics, Frequency Domain (acpr) physics, the fluid dynamics is modelled by Laminar Flow (spf) physics, while Particle Tracing for Fluid Flow is employed to simulate the trajectories of particles with varying material properties (density and diameter).
A comprehensive simulation study was conducted to investigate particle behaviour and system performance in the acoustofluidic device. The acoustic pressure distribution and particle trajectories in the channel were obtained, enabling selective separation through designated outlets. By simulating particles with different diameters and material properties, the separation across various outlets could be evaluated. The simulated particle trajectories demonstrated that 7 µm and 2 µm polystyrene beads were effectively separated into distinct outlets based on size-dependent acoustic radiation forces. Furthermore, the Gor'kov potential field was computed and visualized to identify potential regions for particle trapping, particularly the negative acoustic contrast particles. Simulations showed that 2 µm Polydimethylsiloxane beads were preferentially trapped at the positions of minimal Gor'kov potential. Additionally, acoustic streaming effects along the channel height were investigated using an additional model representing the front view (cross-sectional view) of the original system, incorporating 0.4 µm and 3 µm polystyrene beads. Under the reality conditions, streaming had minimal influence on particle behaviour. However, when the peak-to-peak voltage was increased or the transducer-to-channel distance was reduced, enhanced acoustic streaming induced vortex movement of 0.4 µm beads and contributed to focusing of 3 µm beads. Most notably, parametric studies on actuation frequency, transducer-to-channel distance, inlet flow rate, and peak-to-peak voltage highlighted the strong dependence of particle motion on system parameters, providing critical guidance for performance optimization under different operating conditions. These results could be used to determine the geometry and frequency of acoustofluidic chips for separation processes.

## Reference

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## Figures used in the abstract

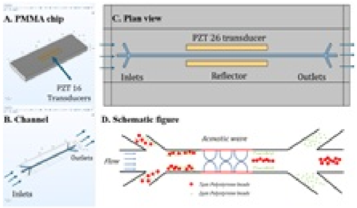


**Figure 1** : Figure 1. Acoustofluidic chip design and particle separation: (A) chip layout, (B) channel geometry, (C) top view, (D) size-based separation.