

An acoustic trap for submicron aerosol particles

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Submicron and nanometer particle levitation and trapping have important applications in physical research including mass spectrometry, light scattering measurements for particle sizing and others¹. Acoustic levitation in gases in a standing wave generated in levitators consisting of a plane transducer and reflector is limited to mm-size particles². This is because secondary streaming appearing within such levitators prevents positioning micrometer and submicron particles³. In our previous study⁴, we investigated quadrupole acoustic aerosol particle focusing in a three-dimensional channel of hyperbolic cross-section. Here we introduce adaptation of that wall configuration for quadrupole trap (Fig. 1)

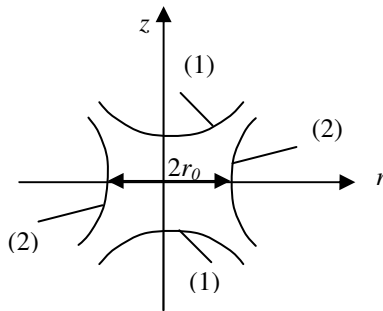


Fig. 1. Quadrupole axisymmetric acoustic chamber of hyperbolic configuration. The endcap transducers (1) and the ring transducer (2) generate acoustic pressure waves with amplitude p_s and frequency ω .

A similar quadrupole chamber with hyperbolic electrodes was employed for ions trap by means of an ac electric field⁵.

We consider a quadrupole acoustic chamber with wavelength, λ satisfying condition $\lambda \gg 2r_0$ (see Fig. 1). Under this condition and for small oscillations amplitudes the flow within the chamber may be considered incompressible and creeping.

Under such simplification we solve the unsteady Stokes creeping flow equations within the chamber. The obtained flow velocity pattern does not contain secondary streaming, normally present in oscillating flows². This situation is similar to that of the quadrupole acoustic channel⁴. The fluid velocity field is linearly distributed and vanishing at the chamber centre. This leads to particle drifting motion towards the centre.

For the particle trajectories we solve the three-dimensional Langevin equation

$$\frac{d\mathbf{u}_p}{dt} = \frac{\mathbf{u} - \mathbf{u}_p}{\tau} + \Xi_{Br}, \quad \tau = \frac{2 a^2 C}{9 \nu \Pi_\rho}, \quad (1)$$

Here $\omega = 2\pi f$ is the angular frequency, f is the acoustic frequency, \mathbf{u} and \mathbf{u}_p are the velocities of fluid and particles, respectively, τ is the Stokes relaxation time, a is the particle radius, ν is the fluid kinematic viscosity, Π_ρ is the fluid-to particle-density ratio and C is the Cunningham's slip correction factor, Ξ_{Br} is the Brownian acceleration. In the present circumstances where $\Pi_\rho \omega \tau \ll 1$, the Basset and added mass forces are negligible.

Figure 2 shows mapping of a 100 nm particle trajectory on the plane $z, r = \sqrt{x^2 + y^2}$. The particle is seeded at two locations $x_0 = y_0 = z_0 = 0.5$ and $x_0 = x_0 = z_0 = 0.25$ with the initial velocity coinciding with that of air.

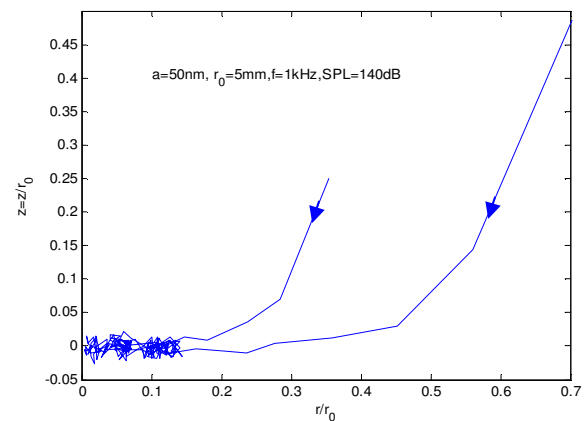


Fig. 2. Simulated random particle trajectories in a quadrupole acoustic chamber. r -radial particle distance from the origin.

It is seen that the particle approaches the chamber center and performs random walk there within a diffusion-broadened spot. We also show that the size of the spot decreases with increasing intensity of the acoustic field. Thus the acoustic field controls the particle's effective trapping volume.

¹Davis, E.J. (1997) *Aerosol Sci. Technol.*, 26, 212-254.

²Trinh, E.H. and Robey, J.L. (1994) *Phys. Fluids* 6 (11), 3567-3579.

³Vainshtein, P., Fichman, M., Shuster, K., and Gutfinger, C. (1996) *J Fluid Mech.* 306, 31-42.

⁴Vainshtein, P. and Shapiro, M. (2008) EAC Abstracts, Thessaloniki, Greece, August 2008, Abstract T05A007P.

⁵Wueker, R.F., Shelton, H., and Langmuir, R.V. (1959) *J. Appl. Phys.* 30, 342-349.