The role of primary and secondary acoustic radiation forces on the contactless manipulation of liquid droplets in mid-air

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Background, Motivation and Objective

Acoustic levitation of liquid droplets is of great interest in analytical chemistry, pharmacy and biology. Recent advances in acoustic levitation allow to move and merge multiple droplets individually. Multiple levitated droplets are subjected to the primary acoustic radiation force and to the secondary forces caused by the waves scattered by adjacent droplets. The primary force is the main responsible for the levitation, it has to be strong enough to counteract gravity but cannot exceed a critical value, that would cause droplet disintegration. Secondary forces are of particular importance when merging droplets, since they cause an attractive force that contributes to the coalescence process. Here, we present an acoustic levitation system for manipulating droplets in two dimensions and we investigate how the primary and secondary radiation forces affect the manipulation and the merging of multiple droplets in mid-air.

Statement of Contribution/Methods

The primary and the secondary acoustic radiation forces between two water droplets are investigated in a multifocal point acoustic levitator consisting of an array of 256 ultrasonic 40 kHz transducers on top of a plane reflector. Water droplets are suspended and moved horizontally by controlling the phase of each transducer. Two droplets are levitated separately and acoustically moved closer until they coalesce. The movement of the droplets is captured by a high-speed camera and a tracking algorithm is used for determining the total radiation force on each droplet over time. In addition, the primary force is determined numerically by using a numerical model that combines a matrix method with the Gor'kov equation, and the secondary force on each droplet is determined by numerical simulations based on the Finite Element Method.

Results/Discussion

The manipulation capability of the levitation system is demonstrated by transporting and merging water droplets in mid-air. The experimental trajectories of the droplets present a good agreement with the simulated ones. The experimental and numerical results show that the secondary force is small for large distances between the droplets. However, when the droplets are sufficiently close to each other, the secondary force dominates over the primary force, causing a strong attractive acceleration between the droplets. A good understanding of the radiation forces involved in the contactless manipulation of droplets will be of vital importance for designing reliable acoustic levitation systems for liquid processing in the areas of biology, pharmacy and chemistry.