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音響場で浮遊する複数試料の浮遊安定性

Stability of multiple samples levitated in an acoustic field

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1. Introduction

In recent years, contactless sample manipulation technology in midair has been attracting great attention in the fields of biochemistry and pharmaceutical science. One of the promising methods is the acoustic levitation [1). This method enables us to levitate, transport, mix, and evaporation of samples in resonant acoustic fields [2). The acoustic levitation method is also expected to be applied in microgravity environments, where it can levitate larger sample with lower acoustic pressure than that in 1G [3). Although the acoustic levitation method has an advantage over other levitation methods, the levitation instability such as interfacial vibration [4) and atomization [5) under the multiple droplet levitation condition needs to be investigated for improving the droplet stability in acoustic levitation. In the present study, we aim to understand the droplet-droplet interaction in acoustic levitation and optimize the levitation condition to improve the stability [6). In this paper, the effect of multiple droplet levitation in an acoustic field on the stability of levitation is discussed.

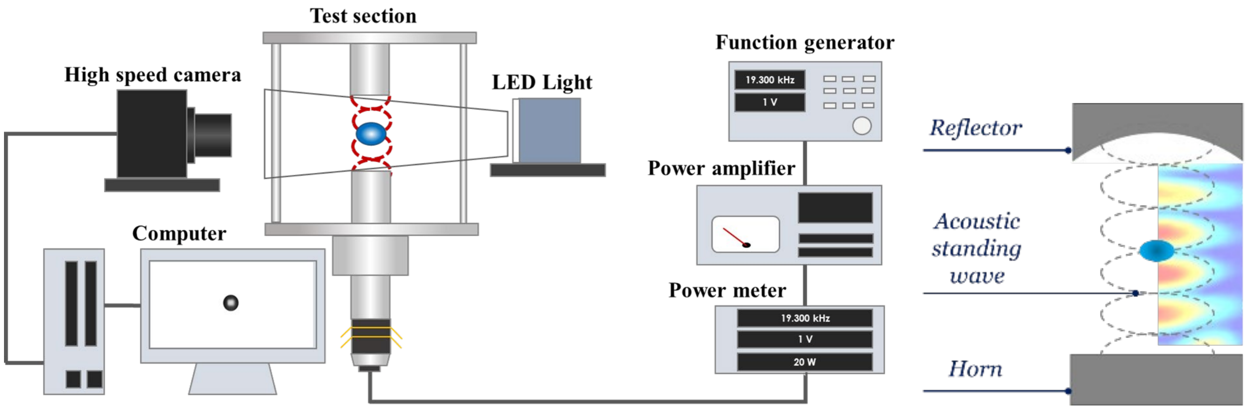

Figure 1. Schematic of acoustic levitator: (a) experimental setup and (b) levitation principle.

2. Experimental method

Figure 1 (a) shows a schematic diagram of the experimental setup used in this study. A sinusoidal signal generated by a function generator is input to the ultrasonic transducer. The ultrasonic wave is emitted from the tip of the lower horn connected to the ultrasonic transducer and is reflected by the upper reflector to form an acoustic standing wave between the horn and the reflector as shown in **Fig. 1 (b)**. A liquid droplet is injected using a syringe near the acoustic pressure node of the acoustic standing wave to levitate a droplet. A high-speed camera is used to capture the droplet motion using the backlight method, and the images are processed using a computer. The reflector shape used in this experiment has a radius of curvature of 36 mm (R36). The acoustic fields with the concave reflector demonstrated the higher levitation stability in the previous study [6,7]. The frequency is 19.3 kHz and the wavelength λ is 18 mm. The width of the horn and reflector is 36 mm (≈ 2λ). The distance between the horn and reflector is 48 mm (≈ $5\lambda/2$). The test droplet was water of approximately 2.0 mm (≈ $\lambda/10$) in equivalent diameter.

To study the levitation stability, we analyzed the horizontal translational motion of the levitating droplet [8]. The temporal center of gravity of the droplet was quantify by image analysis. We compared the horizontal translational motion of one, two, and three levitating droplets to better understand the droplet-droplet interaction in acoustic levitation.

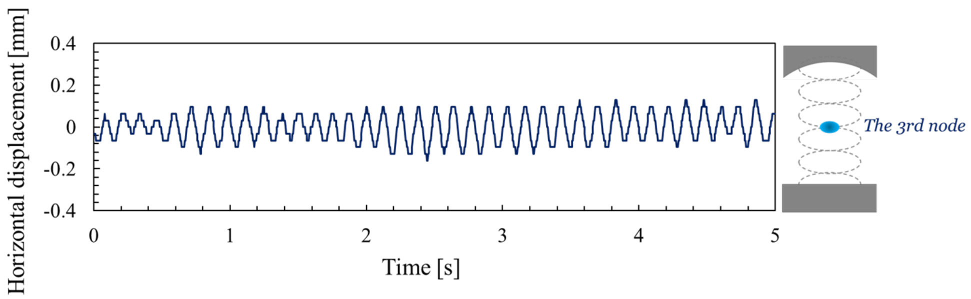

Figure 2. Horizontal displacement when a single droplet was levitated at the 3rd node.

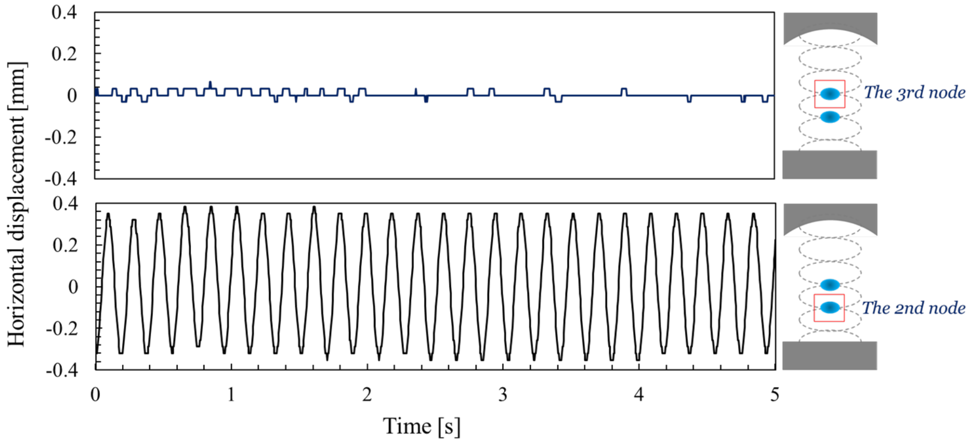

Figure 3. Horizontal displacement of the droplet when two droplets were levitated at the 2nd node and the 3rd node. The bottom graph shows the results for the 2nd node and the top for the 3rd node.

3. Results and discussions

Figure 2 shows the temporal translational motion in the horizontal direction with a single droplet. The levitating droplet position was near the 3rd node from the bottom horn. The results show unsteady translational motion with root-mean-square (RMS) displacement less than 0.07 mm.

Figure 3 shows the horizontal translational motion with two droplets. The droplets were levitated at the 2nd node (bottom) and the 3rd node (top). The displacement of the droplet at the 3rd node was smaller than that at the 2nd node. The reason for this result may be that the droplet at the 2nd node was stabilized by the droplet at the 3rd node. The RMS displacements of droplet at the 2nd node and the 3rd node were less than 0.24 mm and 0.02 mm, respectively.

Figure 4 shows the horizontal translational motion with the three droplets. The droplets were levitated at the 2nd node (bottom), the 3rd node (center), and the 4th node (top). The droplet at the 3rd node demonstrated a smallest displacement, while the those of droplet at the 2nd node and the 4th node were larger and droplets unsteadily vibrated. The RMS displacements for the 2nd node, the 3rd node, and the 4th node were 0.22 mm, 0.02 mm, and 0.11 mm, respectively.

Based on the results, the RMS displacement of the horizontal translational motion of droplet at the 3rd node for a single droplet was approximately 3.5 times larger than those at the 3rd node for two and three droplets. To better understand the oscillation characteristics of multiple droplets in acoustic levitation, we plan to analyze the translational motion by FFT and model the droplet behavior by the spring-mass model from the obtained frequency.

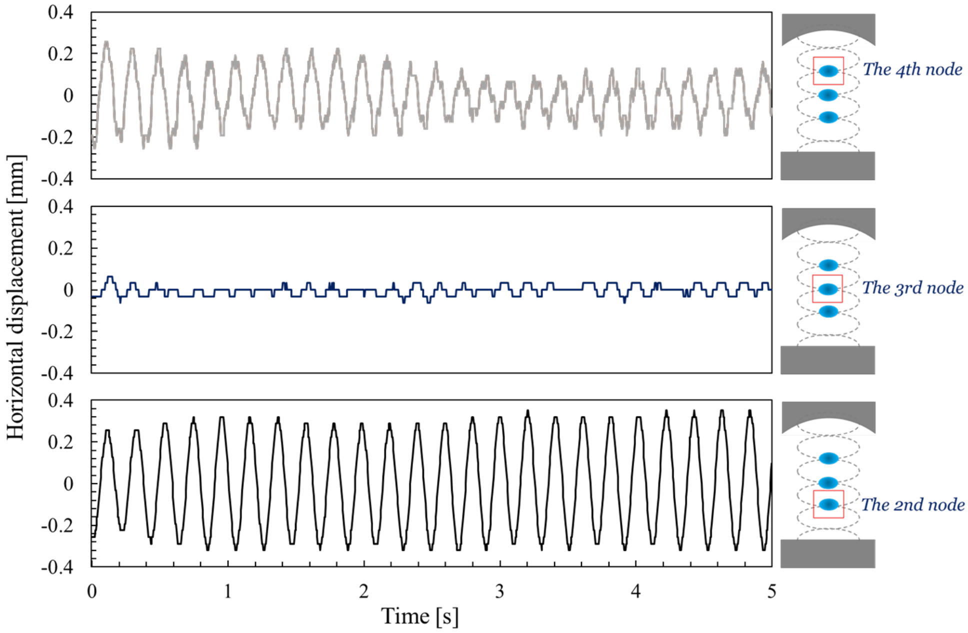

Figure 4. Horizontal displacement of three droplets were levitated at the 2nd node, the 3rd node, and the 4th node. The bottom graph shows the results for the 2nd node, the center for the 3rd node, and the top for the 4th node.

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