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Mechanism of droplet manipulation using surface acoustic wave

SAW による液滴搬送メカニズム解明に関する研究

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1. Introduction

Surface acoustic waves (SAW) radiate longitudinal waves when liquid is loaded onto the SAW propagating surface. Because of this phenomenon, droplet manipulation is possible [1]. The mechanism of droplet manipulation using SAW is not clear. It is important to know manipulation mechanism of droplet using SAW for actual applications.

To understand droplet manipulation, measurements of radiation pressure in the droplet are necessary. As frequency of the SAW device is high and droplet size is small, a conventional hydrophone cannot be used. In this paper, we propose using a flat spring with a strain gage to measure radiation force in the water tank.

2. Droplet manipulation

A SAW device was fabricated on a 128°YX-$LiNbO_3$ single crystal. Radio frequency (RF) signal was fed to an interdigital transducer (IDT). When a RF signal is applied to the IDT, the SAW is generated. The frequency and power of the signal was fixed at 50.67 MHz and 1.0 W, respectively. A droplet of 1μl was placed onto the SAW device. The manipulation results are shown in **Fig. 1**. A droplet was manipulated in the SAW propagation direction. From the observation results, the droplet do not manipulate uniformly. First, the side of the droplet that is moving advancing is manipulated. Then, the opposite side is manipulated by dragging. Therfore, it leads to droplets that can be manipulated efficiently in the droplet interface from the not advancing direction. However, it is not understood how to manipulate droplets with the force inside.

Fig.1 : Droplet manipulation by SAW.

3. Radiation pressure measurement system

We measured the radiation force from SAW in the tank. The measurement system is shown in **Fig. 2**. When the SAW device enters the liquid interface, a longitudinal wave is genarated. The radiated force bent the flat spring. As a strain gage is put on the spring, the radiation force can be obtained.

In this paper, we measured three different cases. First, we measured the relationship between the applied power and radiated force. Second, we measured the relationship between the applied power and distance of the tip of the spring in the water. The SAW radiate longitudinal waves in the Rayleigh angle direction in the liquid. To change the distance of the spring, we measured in which distance it was bent the most. Finally, we measured the decay of radiated force in the liquid. We measured by changing the distance between the spring and the SAW device.

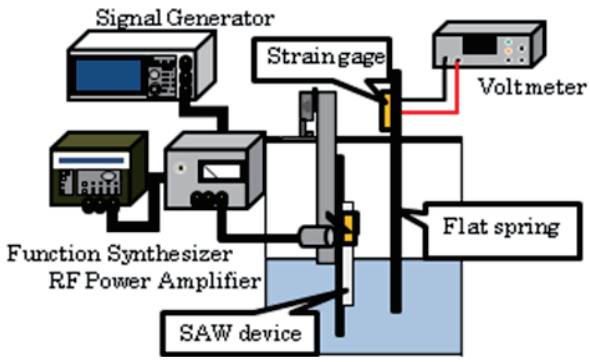

Fig. 2 Measurement system.

4 Results and discussion

4.1 Relationship between applied power and force

The applied power was varied from 0.5 to 3.0 W. The distance between the spring and the SAW device was fixed at 2 mm. The distance of the tip of the spring from the water was 10 mm. The relationship between the applied power and radiated force is shown in **Fig. 3**.

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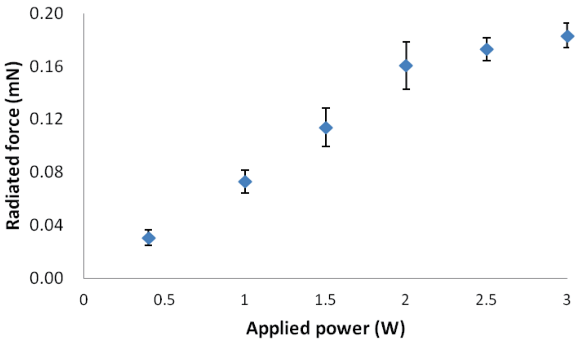

Fig. 3. The relationship between the applied power and radiated force.

As the applied power increased, the strain of the spring also increased linearly. The theoretical formula of the SAW streaming force is expressed as follows:

$$F = - \rho \, (1+\alpha^2)^{3/2} \, k \, \omega^2 A^2 \quad (1)$$

where ρ, k, ω, and A are the density of droplets, propagation constant of the SAW, angular frequency and amplitude of the SAW, respectively[1]. The amplitude is known from previous experiments to be proportional to the power [2]. Therefore, the result we obtained is appropriate.

4.2 Distance of the tip of the spring

The applied power was fixed at 2.0 W. The distance between the spring and the SAW device was 2 mm. The distance from the tip of the spring to the water surface was varied. The relationship between the applied power and distance of the tip of the spring in the water is shown in **Fig. 4**. As the distance of the tip of the spring in the water increased, the bend grows, and reaches the maximum value when the 10 mm. We measured the decay of radiated force in the liquid in this condition.

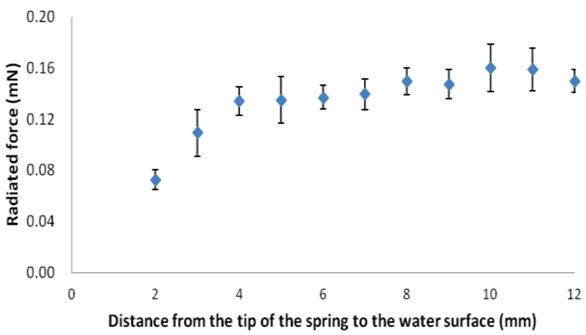

Fig. 4. The relationship between the applied power and radiated force.

4.3 Attenuation in the liquid

The applied power was fixed at 2.0 W. The distance between the spring and the SAW device was varied. The distance of the tip of the spring from the water was 10 mm. The relationship between the distance between the spring and the SAW device is shown in **Fig. 5**. The distance of the spring and the SAW device increases, force bending the spring decreases. It takes a constant value from 7 mm. We considered that this could be influenced by the sreaming of the water interface generated by the SAW [3].

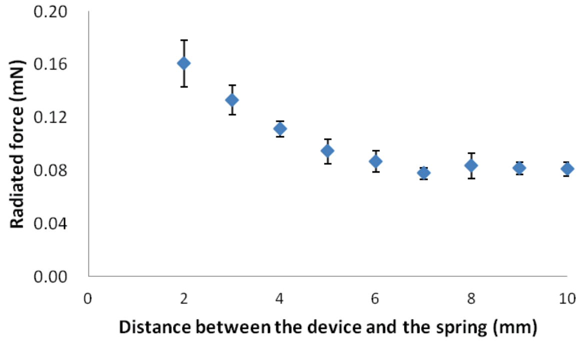

Fig. 5. The relationship between the spring and the SAW device.

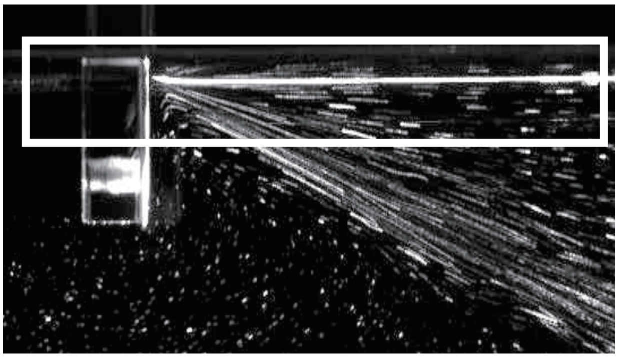

Fig. 6. Streaming near the water surface.

5 Conclusion

In this paper, we measured the radiation force caused by the SAW device in the tank using the flat spring of phosphor bronze. Fundamental characteristics of the radiated force from the SAW device were obtaind experimentally. In future work, we will attempt to derive the theoretical formula of radiation pressure. Then, we can compare theoritical and experimental values. Using this knowledge, we must measure the radiation force in the droplet to understand and clarify the droplet manipulation mechanism using the SAW device.

References

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