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Non-Contact Acoustic Manipulation in Air

Teruyuki Kozuka†, Kyuichi Yasui, Toru Tuziuti, Atsuya Towata and Yasuo Iida (AIST)

1. Introduction

Using a standing wave field generated between a transducer and a reflector, it is possible to trap particles at nodes of the sound pressure field. In 1990's, such a study was done in a weightless field.[1)] Recently, manipulation of particles, droplets and aerosol in a gravitational field are being actively studied in many institutes.[2-4)] However, they are only studies on the trap of objects for their observation, but not on the transportation.

If the trapping position of an object is controlled, the acoustical manipulation will be applied more widely. The authors showed an acoustic manipulation technique to transport particles three-dimensionally using a standing wave field generated by four transducers in water.[5)] The present paper describes an advanced manipulation technique to realize transportation of small objects with this scheme in air. A standing wave field was generated by two sound beam axes crossing each other without using a reflector.

When an expanded polystyrene chip, liquid and tiny solid particles were put in the region of the standing wave field in air, they were trapped at nodes of the sound pressure. Moreover, by changing the phase difference between the transducers, the trapped position shifted.

2. Experimental apparatus

Figure 1 shows the experimental apparatus. Electric signals in two channels generated by a synchronized function generator (NF, 1964) are amplified with two power amplifier (ENI, 325LA, 50dB) and applied to each transducers (Honda, HEC-1540P2BF). The transducers are cylindrical bolted Langevin transducers of 67 mm in length and 15 mm in diameter with a flange of 21 mm in diameter. One of the planes of the transducer has a tap hole at its center, and the other plane is a flat circular plane without hole. The plane without hole is used as the sound source in the experiment. When the transducer is driven with 5 W and 40 kHz in input electric power and the resonant frequency, respectively, the displacement amplitude of the transducer is about 10 micron. With laser Doppler interferometer, it was confirmed that the entire surface vibrated equally both in the displacement amplitude and vibrating phase. Usually, the resonant frequency of the transducer is different from each other, the frequency is selected as an averaged one.

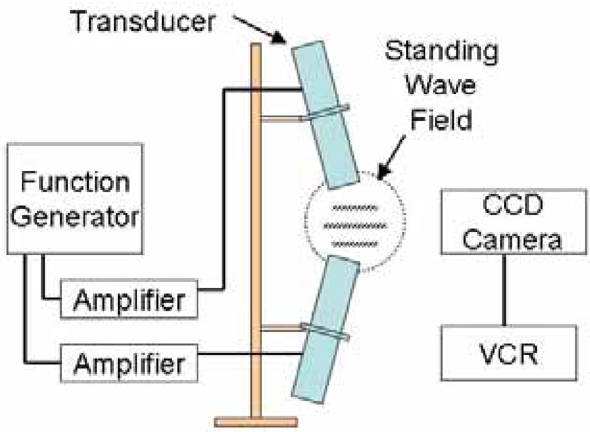

Figure 1. Experimental Apparatus.

When the sound beam axes from two transducers were crossed as in Fig. 1, a standing wave field was generated near the crossing point of them. If an expanded polystyrene chip was put in the region of the crossing sound beams, it was trapped at nodes of the sound pressure. The movement of trapped object was captured with a CCD camera and recorded with a VCR.

3. Experiment and discussion

The condition of the first experiment is that the distance between the two transducers is 18 mm, sound beam axes are crossed at 150 degrees, the frequency is 39.6 kHz, and the input voltage is about 100 to 150 volt. When water droplets were injected with a sprayer, mist was created on the transducer. The water droplets from the sprayer were not trapped directly, but the mist was trapped in the pressure nodes of the standing wave field. The result is shown in Fig. 2.

In the next experiment, smoke was poured into the sound field, the smoke flows along the several layers of pressure nodes or antinodes in the standing wave field formed by the crossed sound beams. It confirms the generation of the standing

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kozuka-t@aist.go.jp

wave field by crossed two sound beams using two sound sources.

Figure 3 shows the photograph of the trapped expanded polystyrene particles of 2 to 3 mm in diameter. The experimental condition is that the distance between the two transducers is 26 mm, sound beam axes are crossed at 140 degrees, and the frequency is 39.2 kHz. It is confirmed that the several particles are trapped at sound pressure nodes each of which is separated about a half wavelength.

The sound pressure can be calculated by the Rayleigh’s formula. Figure 4 is the calculated sound pressure distribution generated by two transducers under the same condition with the experiment. It shows that a standing wave field is formed as the nodes and antinodes of the sound pressure are seen as dark and bright lines, respectively. The particles are trapped at the sound pressure nodes. Furthermore, by changing the phase difference between the transducers, the trapped position is shifted. When the frequency is slightly different from each other, transportation at constant speed is realized.

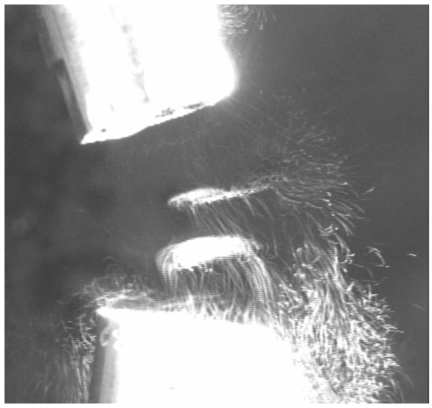

Figure 2. Trapped mist at nodes of the standing wave field.

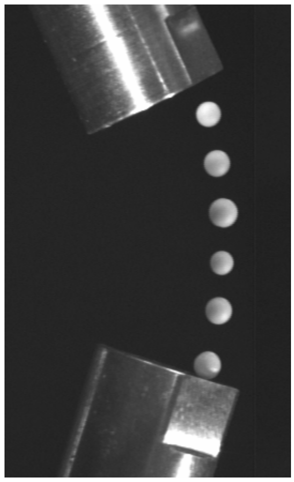

Figure 3. Trapped polystyrene particles.

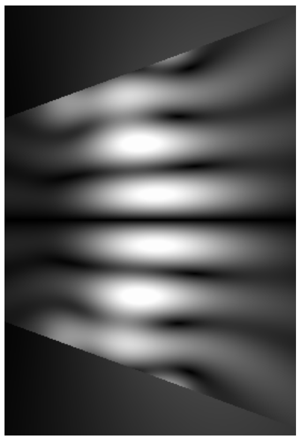

Figure 4. Calculated sound pressure distribution in the standing wave field.

4. Conclusion

The standing wave field was formed by crossing two sound beams generated by two bolted Langevin type transducers in air. Mist and expanded polystyrene particles were trapped at the sound pressure nodes of the standing wave field. Since the node of the sound field moves as the phase of the electrical signal to drive the transducer is shifted, it is possible to transport the trapped particles by changing the mutual phase among transducers. It was possible to realize manipulation of expanded polystyrene particles by controlling the sound field in air.

References

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