3D Acoustic Tweezer Based on Time Reversal

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Background, Motivation and Objective

Acoustic tweezers, which can control the movement of particles by utilizing the momentum interaction between acoustic wave and objects, have attracted tremendous interest in the areas of additive manufacturing and precision medical treatment due to their advantages of non-contact, label-free, good biocompatibility and simple fabrication. However, till now, the manipulation environment of acoustic tweezers are still in homogeneous media, which does not match most of the actual application environment. Phase distortion will occur when sound waves pass through the inhomogeneous media, leading to unexpected acoustic field and inducing disappearance of the acoustic radiation force. In this study, using a self-developed 2D matrix array, we achieved 3D acoustic manipulation in inhomogeneous media by correcting the phase distortion with the time reversal method.

Statement of Contribution/Methods

A 1 MHz 256-element 2D matrix array, with a pitch of 2.8 mm and kerf of 0.2 mm, is designed and fabricated for 3D acoustic tweezers. The array is driven by the Veraosonic Vantage system. The PDMS particles with a size close to one ultrasound wavelength in water can be trapped, moved and rotated in the homogeneous media by dynamic regulation of acoustic field. In this study, a 2 mm thick aluminium sheet with 10 random holes is placed 30 mm in front of the array, which makes the media inhomogeneous. K-wave toolbox for Matlab is used to simulate the propagation of the waves emitted from a virtual sound point source in this inhomogeneous media. And the transmitting signals of each element for trapping the particles can be obtained by reversing the simulation acoustic pressure recorded at the array's surface (Fig.1(A)).

Results/Discussion

The results indicate that PDMS particles can be manipulated at specific foci in homogeneous media. In addition, when the aluminium sheet is inserted, the particles fail to be trapped because of the phase distortion. Time reversal method can correct these phase distortion, which makes the particles be precisely trapped and manipulated again in inhomogeneous media (Fig.1(D)). These results can help to promote the development of 3D acoustic tweezers towards the complex practical application.

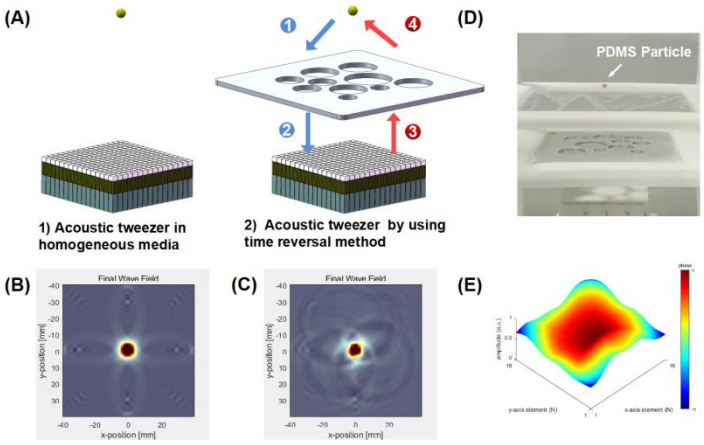

Fig. 1 (A) Sketch for experiment of time reversal. There are four steps in time reversal method: (1) Simulating the propagation of waves produced by virtual sound source; (2) Acquiring the simulation signal received by the transducer; (3) Transmitting signal obtained by time reversal. (4) Achieving acoustic tweezer. The simulation result of acoustic field in homogeneous media (B) and using time reversal method in inhomogeneous media(C). (D) Experimental result of trapping single particle. (E) The simulation result of transducer singal by using time reversal for single particle.