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Development of a Multielement Focused Ultrasonic Actuation System for Medical Microrobot Applications

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Abstract

The precise contactless manipulation of the therapeutic agent in fluids plays a vital role in enhancing the efficiency of targeted drug delivery. Among the many approaches that have been studied, the acoustically-based method demonstrates a combination of advantages contactless manipulation, high biocompatibility, label-free and non-invasive manipulation. However, challenges such as precise control, limits on maneuverability, *in-vivo* environment, and small working space need to be conquered to bring the acoustic actuator to the medical application field. In this doctoral study, these challenges were address by focusing on designing, developing, and improving a multielement-focused ultrasonic actuation system for medical microrobot applications in the biomedical field.

The first part of the doctoral dissertation presents a new multielement-focused ultrasonic actuator system. The system comprised three main subsystems: (1) a multielement-focused ultrasonic array (UA), (2) the high-voltage and high-frequency amplifiers, and (3) the software control user interface. The UA was designed and fabricated in a single-side shape and positioned in three circular layers to generate maximum acoustic pressure at the focal point with the planned number of transducers. Compared to the other systems using an ultrasonic transducer, the developed UA has great potential to apply in *in-vivo* experiments and generate a uniform pressure field map at focus. The driver amplifier was designed to drive an ultrasonic transducer (UT) in a wide range of frequencies from 1 Hz to 40 MHz and a high-voltage range from 10 Vpp to 200 Vpp. The software control user interface was developed with a modular design that is easy to implement and operate the proposed acoustic actuator system.

In the second part, the dissertation presents a novel control algorithm to make holographic acoustic tweezers for three DoFs translation and two DoFs rotation of microrobot. The proposed system is the first system that can manipulate microrobots in five DoFs in water using single-side UA. The proposed methodology is characterized and validated through simulations, *in-vitro*, and *ex-vivo* experiments.

In the final, the critical problems of small working space and the imaging in *in-vivo* environment were solved by implementing the proposed system with a commercial ultrasound probe and a robot arm. The microrobot based on superparamagnetic iron oxide nanoparticles (SPION) and macrophage cell are developed and tested for the targeted tumor therap. The performance of the system shows the promising result for precise manipulation of a microrobot in medical applications.

[사용언어:영어]