A Flexible Array Transducer for Noninvasive Ultrasonic Retinal Stimulation: A Simulation Study

Yanyan Yu[1,2], Zhiqiang Zhang[1,2], Feiyan Cai[1,2], Yang Xiao[1,2], Min Su[1,2], Qiuju Jiang[1,2], Qifa Zhou[3], Mark S. Humayun[3], Hairong Zheng[1,2], and Weibao Qiu[1,2]

[1]*Paul C. Lauterbur Research Center for Biomedical Imaging, Shenzhen Institutes of Advanced Technology, Chinese Academy of Sciences, Shenzhen, China;*
[2]*Shenzhen Key Laboratory of Ultrasound Imaging and Therapy, Shenzhen 518055, China;*
[3]*Ginsburg Institute for Biomedical Therapeutics, Roski Eye Institute and Biomedical Engineering, University of Southern California, Los Angeles, CA 90033, USA;*

Background, Motivation and Objective

Retinitis pigmentosa and age-related macular degeneration can cause vision loss in people. Neurostimulation has proved to be an effective method for the restoration of visual perception lost due to retinal diseases. However, the clinically available retinal neurostimulation method is based on invasive electrodes, making it a high-cost and high-risk procedure. Recently, ultrasound has been demonstrated to be an effective way to achieve noninvasive neurostimulation. However, lens tissue in the eyeball has high acoustic absorption, so most of the ultrasound energy is likely to be absorbed by the lens tissue, especially when high-frequency ultrasound is used. In this work, a novel racing array transducer with a contact lens shape is proposed for ultrasonic retinal stimulation.

Statement of Contribution/Methods

The transducer is flexible and placed outside the eyeball, similar to the application of a contact lens. Ultrasound emitted from the transducer can reach the retina without passing through the lens, thus greatly minimizing the acoustic absorption in the lens. The discretized Rayleigh–Sommerfeld method was employed for the acoustic field simulation, and patterned stimulation was achieved. The focal length of the ultrasound stimulation was set to be about 24 mm, which is the typical diameter of an adult eyeball. A 5 MHz racing array transducer with different element numbers was simulated to optimize the array configuration.

Results/Discussion

The results show that a 512-element racing array is the most appropriate configuration considering the necessary tradeoff between the element number and the stimulation resolution. The stimulation resolution at a focus of 24 mm is about 0.6 mm. A more complex pattern with three characters, “CAS”, which is an abbreviation of Chinese Academy of Sciences, can also be constructed by the proposed racing array transducer. The derived ultrasound field “CAS” in the X–Y plane is shown in Fig. 1(right). The obtained results indicate that the proposed racing array design of the ultrasound transducer can improve the feasibility of an ultrasound retinal prosthesis.

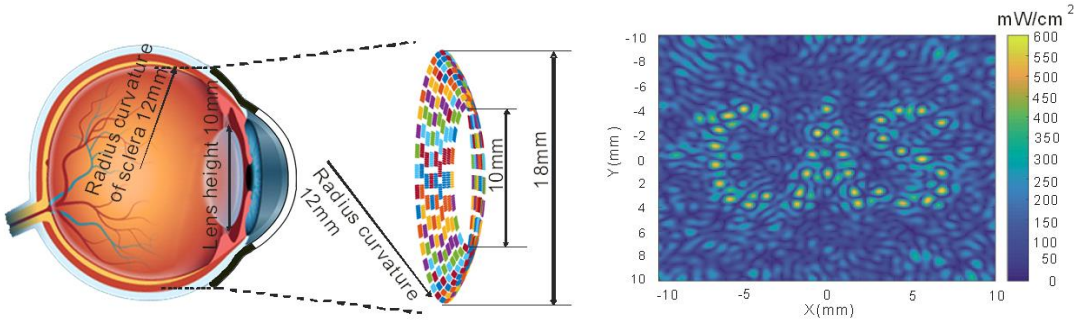

Fig. 1. (Left) The proposed racing array device in this study for ultrasonic stimulation; (Right) Acoustic intensity distribution of the “CAS” (Chinese Academy of Sciences) pattern in the X–Y plane.