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Heating effects on infrared laser spatial selectivity in the cochlea

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Recently, the use of laser light has been demonstrated by experiments in vivo on gerbils, mice, guinea pigs and cats to stimulate the auditory nerve in acutely and chronically deafened cochleae for a wide range of wavelengths, including 532 nm, 808 nm, 980 nm, 1450 nm, 1850 nm, 1870 nm, and 1940 nm. The detailed biophysical mechanism behind laser neural stimulation has been the subject of hot discussions. Current evidence suggests that one of the possible mechanisms is the photothermal reaction resulting from absorption of laser energy by water in tissue. However, heat conduction can induce an increase in the temperature within the cochlea and change the spatial selectivity of activation. To the best of our knowledge, there is a lack of direct measurements of the temperature rise in cochlea in vivo during laser stimulation, due to the complicated cochlea structure and the deep location in bulla on the experimental approach. Fortunately, numerical modeling can overcome these experimental limitations to analyze the spatial and temporal temperature rise in cochlea. We analyzed the effects of heat conduction on the increase in temperature within the cochlea using a 3D model that simplifies the spiraled cochlea as a rotational symmetric structure. The time-dependent heat conduction model is solved using the finite element method. In order to see how serious heat accumulation is, taken as an example the cochlea is stimulated simultaneously by infrared laser pulses at a few sites in its first turn. The temperature rise in time domain and spatial domain is simulated for different laser pulse energies and repetition rates. Our numerical results show that heat conduction enlarges the laser stimulation zone in the target tissues, and therefore limits on the laser's spatial selectivity, but by adjusting the stimulation schemes of the laser pulse-trains, such as laser repetition rate and laser power, the laser selectivity can be optimized.

Biography

Dr. Kaiyin Zhang graduated from Jilin University, China, in 1993, with a Bachelor degree in physics, and graduated with a Master degree in physics from the same university in 1997. In 2007, Dr. Zhang received a Ph.D degree from the Weizmann institute in Israel, and worked in the Medical Higher School of Hannover as a postdoc in 2008. From 2009, Dr. Zhang joined Fuyang Normal College School of Physics and Electronic Engineering. From 2008, he has focused on laser application in medical. After that he came back China, and work in the Faculty of School of Physics and Electronic Engineering in the Fuyang Normal College. Dr Zhang's research topics include laser Raman spectroscopy in medical science, laser-cochlea stimulation, and near-field enhanced Raman spectroscopy.

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