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Acoustic Holograms for Large-Volume Hyperthermia

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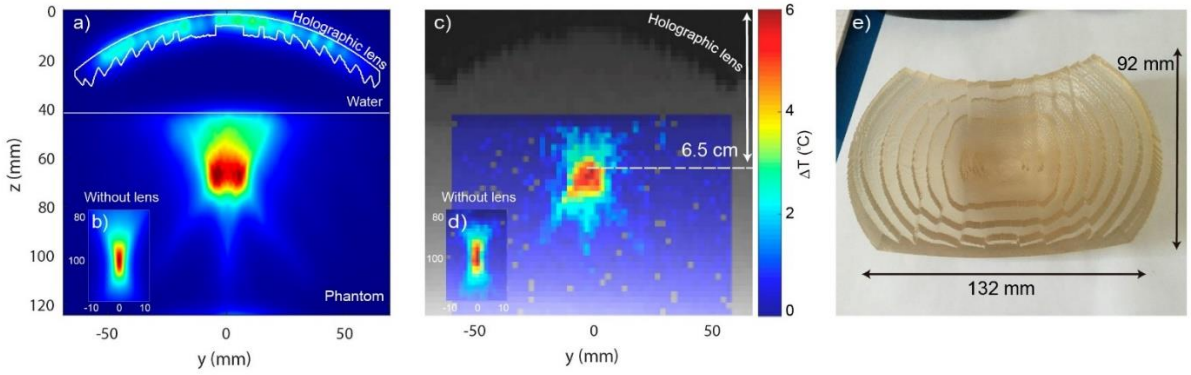
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The aim of this work is to study the performance of large-volume hyperthermia (HT) induced by acoustic holographic-modulated high-intensity focused ultrasound (AHmHIFU) in gelatin phantoms.

The acoustic hologram has been designed to expand the natural focus of a 1 MHz focused transducer using time-reversal methods and printed with stereolithography technique. Acoustic and thermal simulations were performed using a full-wave pseudo-spectral method with k-space dispersion correction to numerically integrate the linearized constitutive relations of acoustics. Holographic lens and transducer were coupled with ultrasound gel and temperature fields were characterized with Proton Resonance Frequency Shift MR-thermometry (MRT) at 1.5T.

Excellent agreement was found between thermal simulations of the AHmHIFU system and MRT temperature maps. ROIs inside which experimental temperature elevation was greater than 4 degrees were 11mm*16mm and 7mm*30mm with and without the lens/hologram, respectively. Most importantly, standard deviation inside these ROIs were equal to 12% and 40% of the maximum temperature with and without the lens. This demonstrates that a wider and more uniform heating region can be achieved using the holographic lens.

Large-volume AHmHIFU-mediated HT was successfully implemented in a gel phantom in deep targets, showing the capabilities of acoustic holograms to be used as a low-cost alternative for hyperthermia treatments. Thermal focus can be enlarged with a simple sonication, but it can also be matched to complex structures.



a) Thermal simulation for a 1cm wide hologram and b) for the transducer natural focus. c) MRI-thermometry measurement for the hologram and d) for the transducer natural focus. e) 3D printed hologram for thermal patterns.