Contributed Papers

2:10

4pBAa3. Acoustic Signature: A focused ultrasound guidance technique with sub-millimeter accuracy. Thomas J. Manuel (BME, Vanderbilt Univ., 1161 21st Ave., South Medical Cent, Nashville, TN 37232, thomas.j.manuel@vanderbilt.edu), Aparna Singh (BME, Vanderbilt Univ., Nashville, TN), Jiro Kusunose, and Charles F. Caskey (Radiology, Vanderbilt Univ. Medical Ctr., Nashville, TN)

Accurate targeting is paramount for focused ultrasound (FUS) procedures. Here we describe a method for targeting FUS dubbed acoustic signature, which uses acoustic feedback from a target's unique reflection patterns to guide the transducer to a previously defined orientation. We demonstrate convergence to the desired target in a 3 degree of freedom (DOF) water tank scenario and a 5 DOF robotic arm scenario. We also tested the acoustic signature technique for targeting with a phantom skull on a 3 DOF motor stage and a 5 DOF manual stereotactic frame designed for transcranial FUS procedures in an MRI environment. In both the water tank and the robotic arm convergence tests, the method converges to the target. The convergence was sufficiently smooth for automated gradient descent. In the 3-DOF test, the net targeting error was 0.30 ± 0.27 mm (n = 10). In the stereotactic frame 5-DOF test, the targeting error was 2.11 ± 0.99 mm and 3.2 ± 2.2° (n = 10) summed rotational error. The accuracy of this technique is limited by the positioning apparatus. This method may enable precise and repeatable FUS targeting for therapies which require multiple FUS sessions at the same target.

2:25

4pBAa4. A phase-shifting method for computation reduction for high-frame-rate imaging. Jian-yu Lu (Bioengineering, The Univ. of Toledo, 2801 West Bancroft St., Toledo, OH 43606, jian-yu.lu@ieee.org)

High-frame rate (HFR) imaging using steered plane wave (SPW) or limited-diffraction beam has a high-temporal resolution and thus has found many applications. To further study the HFR imaging methods, computer simulations were performed. However, the simulations require a large number of computations, especially for 3D imaging with 2D array transducers for a large imaging volume. In this paper, a phase-shifting method was developed to reduce the number of computations. In the method, the grid points of the transmit and receive beams were calculated at 1-mm interval in the depth direction that is perpendicular to the transducer surface. The interval is much larger than the 1/4 of the 0.58-mm wavelength required for an accurate interpolation for millions of random scatterers in pulse-echo response without aliasing. Since the HFR imaging uses either SPW or LDB, the wave vectors of these beams are fixed at each frequency. Due to the fact that the amplitude of ultrasound beams changes very little over a couple of wavelengths, the interpolation in the depth direction was replaced with a phase shift. Results show that images reconstructed with the phase-shifting method removed the artifacts caused by aliasing when conventional tri-linear interpolations were used for 3D imaging.

2:40–2:55 Break

2:55

4pBAa5. 3D-printed gradient-index phononic crystal lens for transcranial focused ultrasound. Eetu Kohtanen (G. W. Woodruff School of Mech. Eng., Georgia Inst. of Technol., 771 Ferst Dr NW, Atlanta, GA 30332, ekohtanen3@gatech.edu), Ahmed Allam, and Alper Erturk (G. W. Woodruff School of Mech. Eng., Georgia Inst. of Technol., Atlanta, GA)

Transcranial focused ultrasound (tFUS) shows great promise as a noninvasive tool to treat neurological conditions such as essential tremor. The existing clinical phased array systems are mostly intended for ultrasound delivery to the center of the brain (as in thalamotomy for essential tremor), in addition to being complex and expensive. To seek an alternative focusing approach especially for the brain periphery, we explore a 3D-printed gradient-index (GRIN) lens as a simple and an orders of magnitude more cost-effective approach. The lens is constructed using a phononic crystal (PC) architecture with varying lattice geometry and hence refractive index distribution. Specifically, the lens uses an axisymmetric hyperbolic secant refractive index profile to focus ultrasonic waves generated by a 1 MHz single-element ultrasonic transducer. Finite element simulations are performed to design and analyze the GRIN-PC lens, and to explore the effects of various parameters such as the distance from the skull and the incidence angle. The numerical results are validated experimentally for a 3D-printed lens by scanning the 3D pressure field generated through a temporal bone. This cost-effective approach to tFUS can open new possibilities to 3D print lenses based on patient computed tomography scans for various applications from tissue ablation to neurostimulation.

3:10

4pBAa6. Reconstruction of thermoacoustic emission sources from proton irradiation using numerical time reversal. T. Douglas Mast (Biomedical Eng., Univ. of Cincinnati, 3938 Cardiovascular Res. Ctr., 231 Albert Sabin Way, Cincinnati, OH 45267-0586, doug.mast@uc.edu), David A. Johnstone (Medical Phys., Univ. of Cincinnati, Cincinnati, OH), Charles L. Dumoulin (Radiology, Cincinnati Children's Hospital Medical Ctr., Cincinnati, OH), Michael A. Lamba (Radiation Oncology, Univ. of Cincinnati, Cincinnati, OH), and Sarah K. Patch (Acoust. Range Estimates, Chicago, IL)

Dose delivery in proton beam therapy for cancer treatment can be mapped by analyzing thermoacoustic emissions measured by ultrasound arrays. Here, a method is presented for spatial mapping of thermoacoustic sources using numerical time reversal, simulating physical re-transmission of measured emissions into the medium. The spatial distribution of acoustic sources is shown to be approximated by the amplitude envelope of the time-reversed field, evaluated at the time of emission. Given calibration of the array sensitivity and knowledge of tissue properties, this approach approximately reconstructs the induced acoustic pressure, equal to the product of radiation dose, density, and Grueneisen parameter. Numerical time reversal is implemented using two models for array elements, as either ideal line sources or diffracting rectangular radiators. Demonstrated reconstructions employ previously reported measurements of thermoacoustic emissions from proton energy deposition in tissue-mimicking phantoms. For a phantom incorporating a bone layer, reconstructions account for the higher sound speed in bone. Spatial resolution of reconstructions, assessed by widths of reconstructed Bragg peaks, is improved in the array direction by incorporation of diffraction effects. In comparisons with corresponding Monte Carlo simulations, source distributions correspond well with simulated proton dose, while source localization with respect to room coordinates is improved by incorporating sound speed inhomogeneities.

3:25

4pBAa7. A straightforward method for simulating phase aberration with high fidelity using PDMS phantoms. Ying-Chun Pan (Biomedical Eng., Vanderbilt Univ., 5824 Stevenson, Nashville, TN 37232, ying-chun.pan@vanderbilt.edu), Christopher Khan, Katelyn Craft, Braden Huneycutt, Rachel Hecht, Eric Tang, and Brett Byram (Biomedical Eng., Vanderbilt Univ., Nashville, TN)

Phase aberration arises from the speed of sound heterogeneity in the imaging environment and degrades image quality. Accurate aberration simulation is essential for developing aberration correction methods. Existing works often apply an aberration value at each channel in simulation software, but this approach introduces aberration integration error, assumes a fixed profile across all beams, and does not account for harmonic generation. We propose to address these limitations by making a PDMS aberration phantom. The manufacturing process involves (1) integrating a software-generated profile into a 3D-printed mold, (2) treating the mold with acrylic lacquer to prevent cure inhibition, (3) casting the mold with PDMS and degassing for an hour, and (4) baking at 75 °C for 4 h before demolding. The phantom is smooth and retains software-specified root mean square and full width half max of the autocorrelation function, and can be placed at the transducer to simulate aberration with higher fidelity than software. OCT data suggests that 3D-printed molds are accurate to within 21 μm of the