Fabrication and verification of an endoscopic phased array for combined photoacoustic tomography and high-frequency ultrasound imaging

T. Landry[1], C. Samson[1], K. Latham[1], J. Brown[1], R. Adamson[1], [1]Dalhousie University, Halifax, Canada

Background, Motivation and Objective

Intrasurgical endoscopy is an important new emerging application area for high-frequency ultrasound. Our group has previously described a 64-element phased ultrasound array operating at 45MHz with a maximum lateral dimension of 4.2mm designed for use in minimally invasive, "keyhole" surgery.

We have modified this phased array by adding a pulsed laser illumination source to allow it to perform photoacoustic tomography (PAT) in addition to high-frequency B-mode imaging. This is combination of modalities is particularly appealing for minimally-invasive brain surgery where functional imaging performed with PAT could be co-registered with structural high-frequency ultrasound imaging. We present details on the fabrication of the device and on benchtop testing with hair targets.

Methods

The illumination source for photoacoustic tomography is an 808 nm pulsed diode bar laser with pulse energy of 500 µJ operated at a repetition rate of 1KHz. Light from the bar laser was coupled to a fiber array consisting of 30 200 µm-core multimode fiber optic cables. The other ends of the fibers were mounted around the periphery of the phased array transducer to provide illumination to the sample parallel to the imaging axis. The optical coupling efficiency of the system was 15.6%. Due to the square geometry of the device, adding the fibers did not increased maximum lateral dimension. The laser was externally triggered and synchronized to a custom 64-channel data acquisition system. Images were beamformed offline. The device was tested by imaging hair targets in a water tank.

Results/Discussion

The photoacoustic image of a hair target shown in Figure 1 has a lateral resolution of 165 µm and an axial resolution of 57.5 µm as compared to 80 µm lateral resolution and 80 µm axial resolution for B-mode ultrasound images taken with the array. The center frequency of the photoacoustic signal was 13 MHz, with a 10% bandwidth. The center frequency is limited by the minimum 28 ns pulse duration achievable with the bar laser. Photoacoustic images were collected at a frame rate of 1Hz and are displayed at a dynamic range of 30dB. The system demonstrates that photoacoustic tomography can be successfully integrated into high-frequency ultrasound micro-endoscopy devices for intrasurgical imaging.

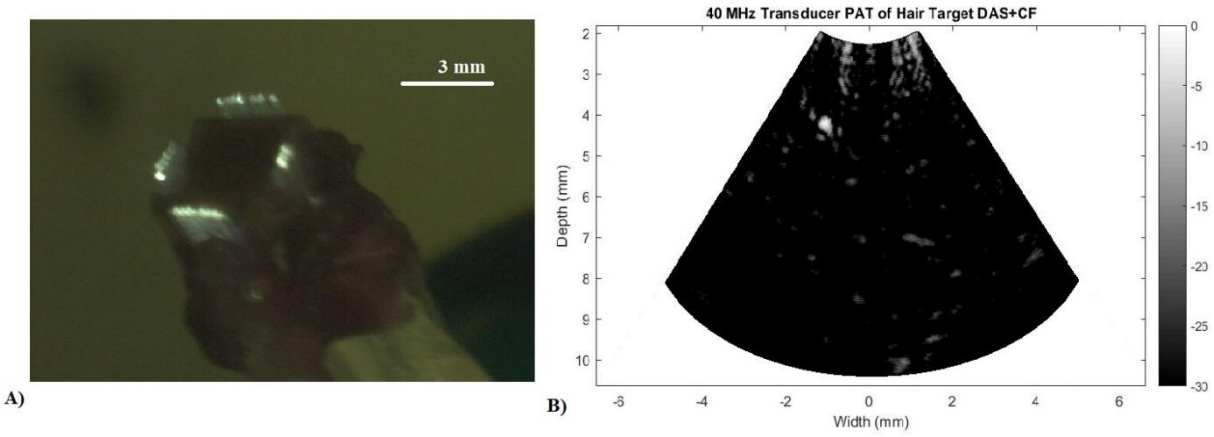

Figure 1 A) An Image of the fabricated endoscopic 64-element phased ultrasound array with 30 illuminated fibers. B) A reconstructed photoacoustic image of a 40µm hair target at a depth of 4 mm in a tissue mimicking phantom with 30 dB dynamic range.