Abstract and Introduction

- The goal of this project is to design and implement an ultrasonic transmit beamformer for studying the development of tumors in vivo using optical coherence elastography (OCE). In OCE, images are formed by probing the elastic properties of tissue. A known pressure load is applied to the sample and by modulating the acoustic radiation force, highly localized 'palpation' can be performed. Optical Coherence Tomography (OCT) is used to measure the resulting displacements in the sample, thus allowing for the determination of strain. In vivo imaging of tumor microenvironment mechanics holds great promise for cancer research and clinical diagnosis.

- In this system, commercial beamforming ICs will be used due to higher delay resolution (<1 ns) that can be achieved. A microcontroller will be used to control the system, as well as to interface to a computer by UART to communicate with a LabVIEW GUI that controls OCT image acquisition. To generate enough pressure from each transducer, it is necessary to use high voltage (+/-50V) pulsers at the output of each beamformer channel to drive the PZT directly. Pulses with frequencies of up to 10MHz will be generated by this system.

- This system mainly includes five parts: LabVIEW GUI on PC, Microcontroller, transformer beamformer IC, Ultrasound Transmit Pulser and Custom Laser Cut PZT array.

Background and Motivation

- Cancer mechanobiology research over the past decade has changed the view of cancer – no longer is stiffness viewed as a 'symptom' of tumors, but extracellular matrix (ECM) stiffness can actually trigger the onset of malignancy (Paszek et al., Cell, 2006; Wirtz et al., Nat. Phys., 2011).

- Compared to other methods including MRE (Magnetic Resolution Elastography) and Ultrasound Elastography, OCE has superior resolution. As shown in the figure below, MRE has resolution limit of 2mm, ultrasound elastography has resolution of 100-500μm and OCE has the resolution limit of 10μm which is superior to MRE and ultrasound. Thus, OCE has very promising prospect of application to cancer research and diagnosis. It can be used image the viscoelastic mechanical properties of tumor development.

Low Voltage Beamformer PCB Design

- LM96570 is an eight-channel beamformer to generate multi-channel pulses. This chip is usually used for medical ultrasound applications. LM96570 has eight positive (P) and negative (N) output channels. When operating at pulse rates of up to 80MHz, each channel can have delays of up to 102.4μs. Beamformer ICs for Pulse and Phase Generation determines the number of pulses, pulse widths and delays between each channel. From LM96570, we expect to get 1-10MHz pulses. However, we will only get Low Voltage (3.3 V) delayed pulse from this beamformer IC.

Output Pulse Modulation System Design

- The pulse generated needs to be amplitude modulated by a separate near-sinusoidal signal (V' ≥ 0) from our LabVIEW-based OCT software in the 10 Hz to 20 kHz frequency range. A Variable Gain Amplifier (VGA) will be implemented in order to modulate the output pulse from LM96570.

Future Work

- Pressure load will be provided by a 2D piezoelectric PZT (lead zirconate titanate) transducer phased array. Pressure waves will be generated by voltage pulses applied to the PZT transducer. By applying time delayed pulses to each transducer element of the array, it is possible to generate an electronically steerable beam (localized palpation point for OCE).