Determination of acoustic wave directionality using probe beam deflection technique for photoacoustic and ultrasound imaging

A. **Goals:** The goal of this project is to develop a reconstruction algorithm for photoacoustic tomography based on the probe beam deflection technique. The probe beam deflection technique is used instead of the piezoelectric transducers which are used as the classical acoustic emission sensing technology.

B. **Brief Description:** Photoacoustic tomography (PAT) has been extensively explored; however, most applications of PAT employ conventional pressure transducers. This project demonstrates the ability of the probe beam deflection technique to detect the propagating acoustic energy produced in PAT. A ray tracing algorithm was designed to work with k-wave techniques implemented by Treeby and Cox allowing for the simulation of the interaction of probe beams and acoustic wave fronts. The simulation model allows for the prediction of the intersection points of the probe beam with the surface of a quadrant photodiode (QPD), resulting in close agreement with the QPD signal obtained in experiment. It will be shown that the probe beam deflection technique can be used to determine the direction of a travelling wave front. The ringing effect of a transducer is also eliminated with this sensor. We are now developing an image reconstruction algorithm based on this acoustic emission sensor. We have early work showing that this sensor can improve spatial and temporal resolution in PAT.

C. Heights of Achievements this semester:

- Completed experiment resulting in PAT signals from chicken liver and vial of human blood.
- Expanded simulation to include thermal response of optically excited tissue.
- Working to expand ray tracing algorithm for irregular wavefronts. (To calculate 3-D Snells Law, the simulation must always be able to compute the plane tangent to the wavefront. For random wave fronts this is accomplished by contouring the dataset and calculating the tangent plane using a contour map)
- Built complex 3-D phantoms for imaging and have matched simulation signals to those received from similar objects in experiment with minimal error.
- Have shown that the probe beam deflection technique can be used to determine the acoustic emission vector of an acoustic emission as it intersects the optical beam path.
- Submitted Journal Paper to IEEE Sensors.

D. Problems/Concerns that prevent your progress:
None, thanks to SIVIRT, UTSA and UTHSCSA I have all the resources I need to achieve my project goal

SIVIRT

UTSA

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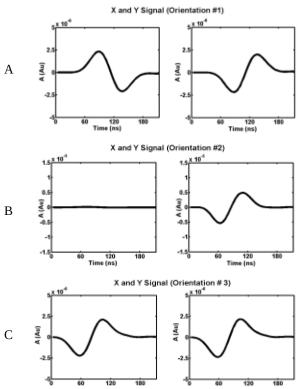
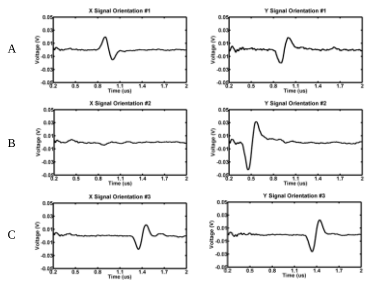
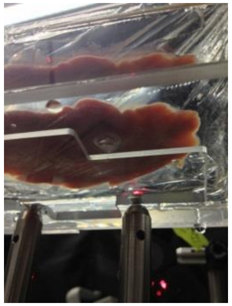
Photodiode Signals

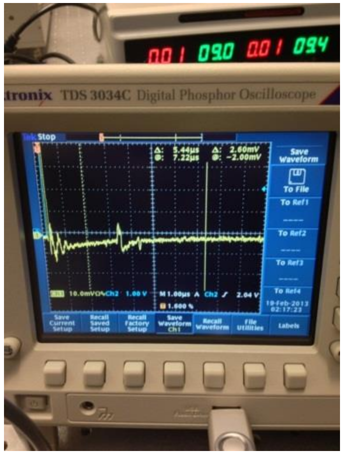
Simulation **Experiment**





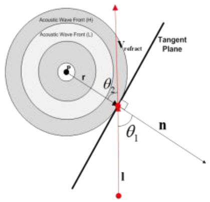
Experiment PBDT Chicken Liver/Human Blood





Acoustic Wave Simulation

Theory



$$V_{refract} = \left(\frac{n_1}{n_2}\right)\left(\left(\frac{n_1}{n_2}\right)\cos\theta_1 - \cos\theta_2\right)\mathbf{n} \quad if\ n\cdot -l \geq 0 \qquad (6a)$$

$$V_{refract} = \left(\frac{n_1}{n_2}\right)\left(-\left(\frac{n_1}{n_2}\right)\cos\theta_1 + \cos\theta_2\right)\mathbf{n} \quad if\ n\cdot -l < 0 \qquad (6b)$$