Shear Wave Optical Coherence Elastography

Rong Chen

Advisor: Takashi Buma

Department of Electrical, Computer, and Biomedical Engineering. Union College, Schenectady, NY, 12308.

INTRODUCTION

- **Shear Wave Elastography (SWE)**

1. Elastography is an imaging technology which shows the mechanical properties of tissue under noninvasive premises.
2. Pathological change of soft tissue can cause a change in mechanical properties such as softness.
3. Elastography is widely applied in diagnosing, therapy planning, and therapy assessments. For example, it can be used as breast cancer detection.
4. The concept is to mechanically deformed tissue while imaging, and we used shear wave in the lab.

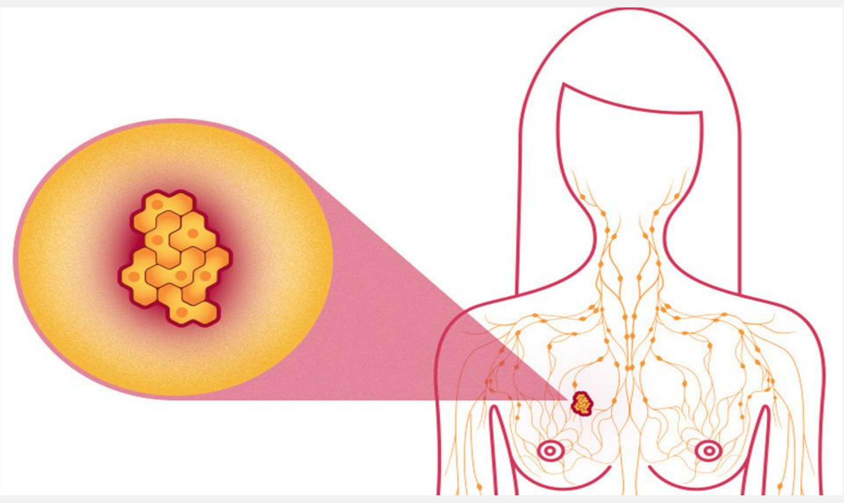

Figure 1: Pathological Change of Breast Soft Tissue (Breast Cancer)

- **Optical Coherence Tomography (OCT)**

1. OCT can produce 3D cross sectional imaging with micrometer resolution.
2. It is useful in studying small animal models such as zebrafish and chicken embryos.
3. OCT operates by emitting a light pulse from a pulse laser or a super illuminant diode (SLED) throughout the fiber and split into two paths by the coupler. One path goes to the reference mirror, and the other one goes to the sample arm. The reference mirror moves in a couple of certain scales to measure different depth information within the object. The light will backscatter when it touches the sample or the reference mirror to the detector.

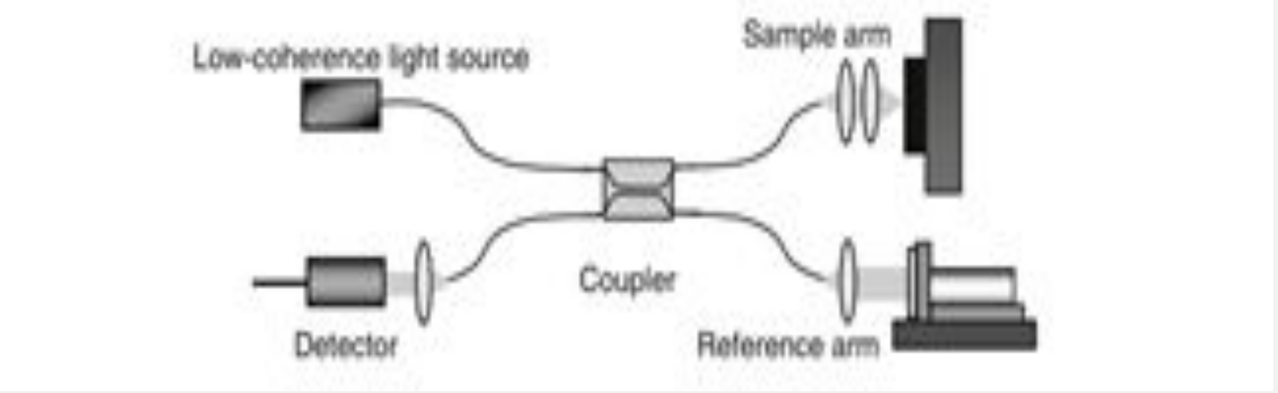

Figure 2: Simplified Operation of an OCT System

METHODS

- **Setup for OCE system**

1. Tissue mimicking phantoms were made of gelatin powder, distilled water, and milk.
2. The mechanical devices, the motor and the screwdriver (figure 4), were assembled to push the gelatin surface. We used the arduino to send commands from the computer to the motor.
3. The shear propagation only appears on the surface of the phantom. We generated shear waves and tracked the shear wave propagation. We measured the speed and compute the elastic modulus by the equation.

Shear Wave Speed → C_s; Shear Modulus → μ; Gelatin Density → ρ

$$C_s = \sqrt{\frac{\mu}{\rho}},$$

Figure 3: Shear Modulus Equation

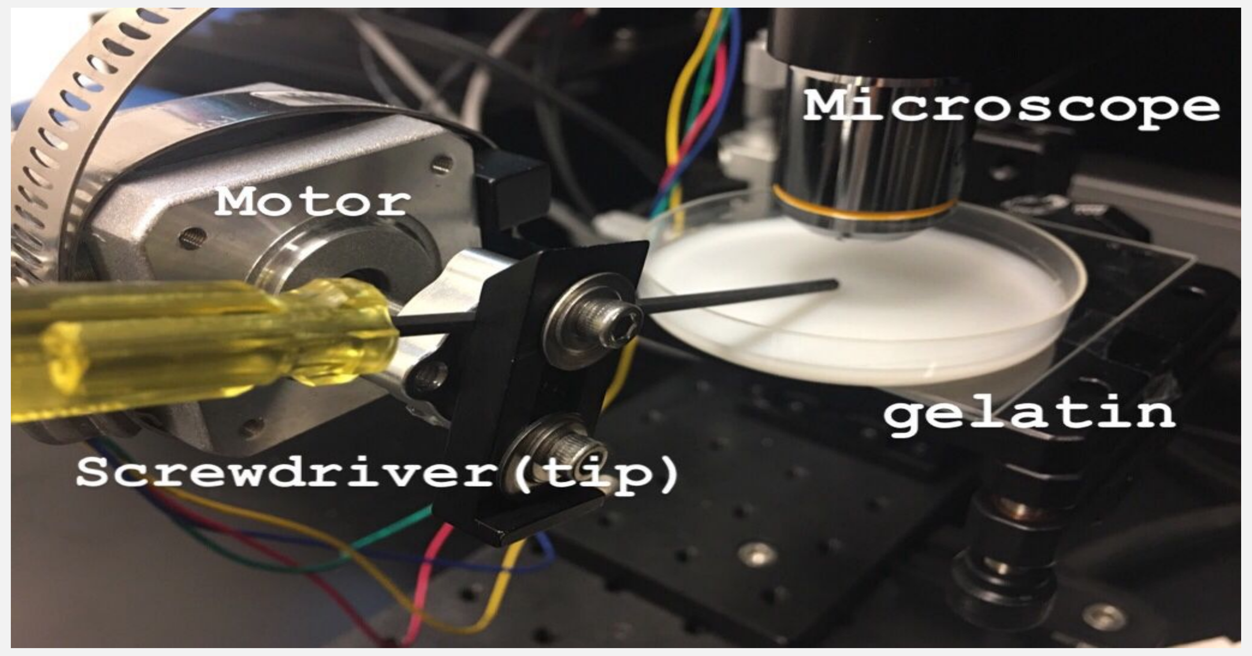

Figure 4: Mechanical Set Up of the OCE System

- **OCE Scanning**

1. There are also two scanning methods, 1D and 2D. 1D means the scanning mirror stays still, and the light beam keeps emitting the pulse on one spot. The reconstrued images only show the data over one spot. 2D scan means the light beam moves horizontally or vertically over a small space.
2. The reconstrued figures can be shown in B-mode images and C-mode images. B-mode displays the vertical cross-sectional images, and C-mode displays the horizontal cross-sectional images.

RESULTS

- **OCE Scan**

1. On the first two weeks, we demonstrated that the OCT system operated properly. OCT system was not able to identify two different concentrations.
2. Figure 5 shows the first frame of the phantom motion after it was pushed by the mechanical tip. It clearly showed the shear wave propagation. However, the motion was considered too big because, in reality, the shear wave propagation applied on animal or human tissue should have an amplitude within five to ten micrometers. Otherwise, the large shear wave propagation would affect the proper operation of tissue. In the figure, the amplitude was approximately two hundred millimeters.
3. Shear wave speed was measured by tracking the distance of a moving peak from frame 1 to frame 40. Table 1 shows the shear wave speed corresponding to different gelatin concentration.
4. We also tried to layer two different concentration of gelatin in one petri-dish. The upper layer was very thin and the recipe did not contain milk. This led a white line on the image because there were not enough particles in this phantom to backscatter light. The lower layer clearly showed the shear motion.

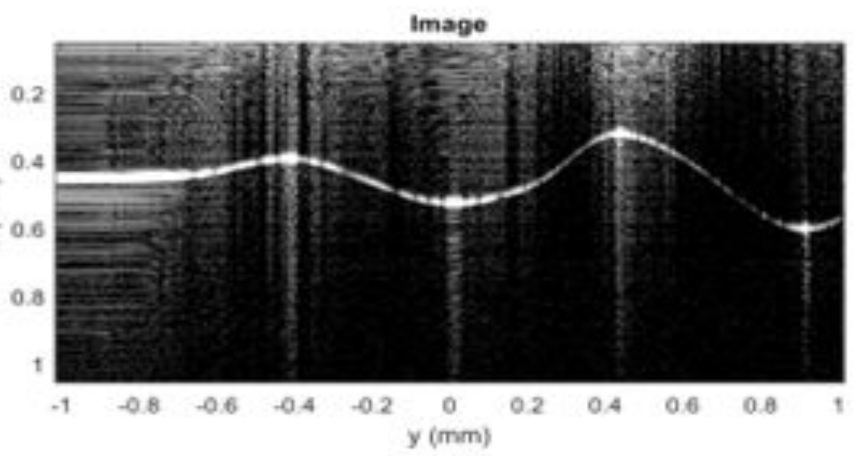

Figure 5: OCE Scan of the Shear Wave Propagation

Table 1: Shear Speed

Phantom concentration (%)	Shear speed (m/s)
4.04	3.8839
9.09	6.0106
13.04	17.1441

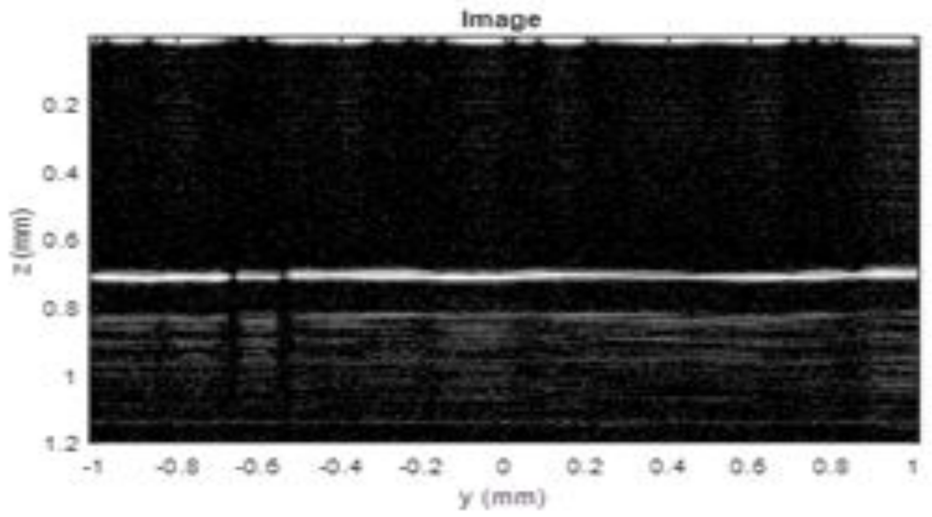

Figure 6: A Scan of a Two Layer Gelatin

CONCLUSIONS

1. Future work will involve further study on codes, lab setup, and gelatin recipe.
2. Replace the mechanical tip with a focused ultrasound transducer because this allows the shear wave motion to happen not only on the surface of the phantom but anywhere within the phantom.
3. Vary the milk concentration to obtain a more ideal visibility of the gelatin scanning image.

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REFERENCES

[1] Adel, Mohamed, Ahmed Kotb, Omar Farag, M. Saeed Darweesh, and Hassan Mostafa. 2019. "Breast Cancer Diagnosis Using Image Processing and Machine Learning for Elastography Images." 2019 8th International Conference on Modern Circuits and Systems Technologies (MOCAST), May.

[2] Maeva, A., M. Lee, and S. Foster. "Shear Wave Imaging at High Frequencies: A Feasibility Study in Tissue Mimicking Gelatin Phantoms." *2012 IEEE International Ultrasonics Symposium*, 2012.

[3] Popescu, Dan P., Lin-P'Ing Choo-Smith, Costel Flueraru, Youxin Mao, Shoude Chang, John Disano, Sherif Sherif, and Michael G. Sowa. "Optical Coherence Tomography: Fundamental Principles, Instrumental Designs and Biomedical Applications." *Biophysical Reviews* 3, no. 3 (June 2011): 155–69.

[4] Song, Shaozhen, Zhihong Huang, Thu-Mai Nguyen, Emily Y. Wong, Bastien Arnal, Matthew O'Donnell, and Ruikang K. Wang. "Shear Modulus Imaging by Direct Visualization of Propagating Shear Waves with Phase-Sensitive Optical Coherence Tomography." *Journal of Biomedical Optics* 18, no. 12 (December 8, 2013): 121509–1-121509–7.

[5] Tsochatzis, E.a., K.s. Gurusamy, S. Ntaoula, E. Cholongitas, B.r. Davidson, and A.k. Burroughs. 2011. "Elastography for the Diagnosis of Severity of Fibrosis in Chronic Liver Disease: A Meta-Analysis of Diagnostic Accuracy." Journal of Hepatology 54 (4): 650–59.

[6] Wang, Shang, Jiasong Li, Raphael E. Pollock, Irina V. Larina, and Kirill V. Larin. "Development of Optical Sensor for Soft Tissue Sarcoma Boundary Detection Using Optical Coherence Elastography." *IEEE SENSORS 2014 Proceedings*, 2014.