

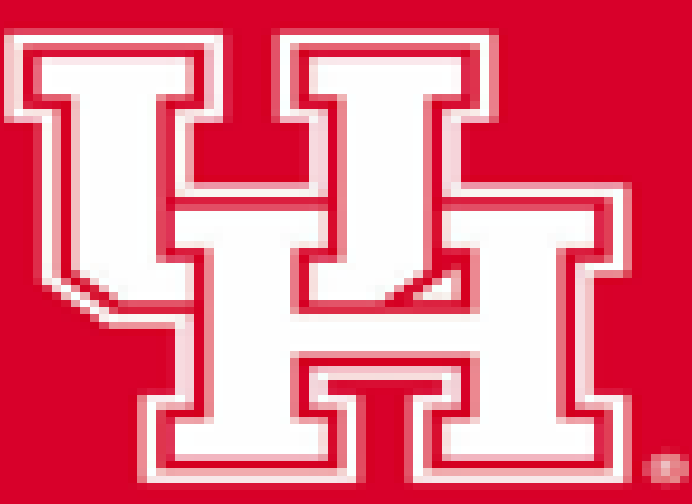


Bio-adhesive patch utilizing reverberant OCE for detecting Systemic Sclerosis

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Background and Objective

Systemic sclerosis or scleroderma is a rare autoimmune disease that causes skin and organ fibrosis due to excess collagen buildup, leading to thickened, hardened skin. **Our project aims to develop a wearable bio-adhesive elastography patch that non-invasively monitors skin stiffness, to distinguish between healthy individuals and systemic sclerosis patients.**

Materials and Methods

Our final prototype was made of:

- Brassiere adhesive
- 5 piezo transducers
- 3D-printed stencil

We used Optical Coherence Tomography to analyze the reverberant field in our samples.

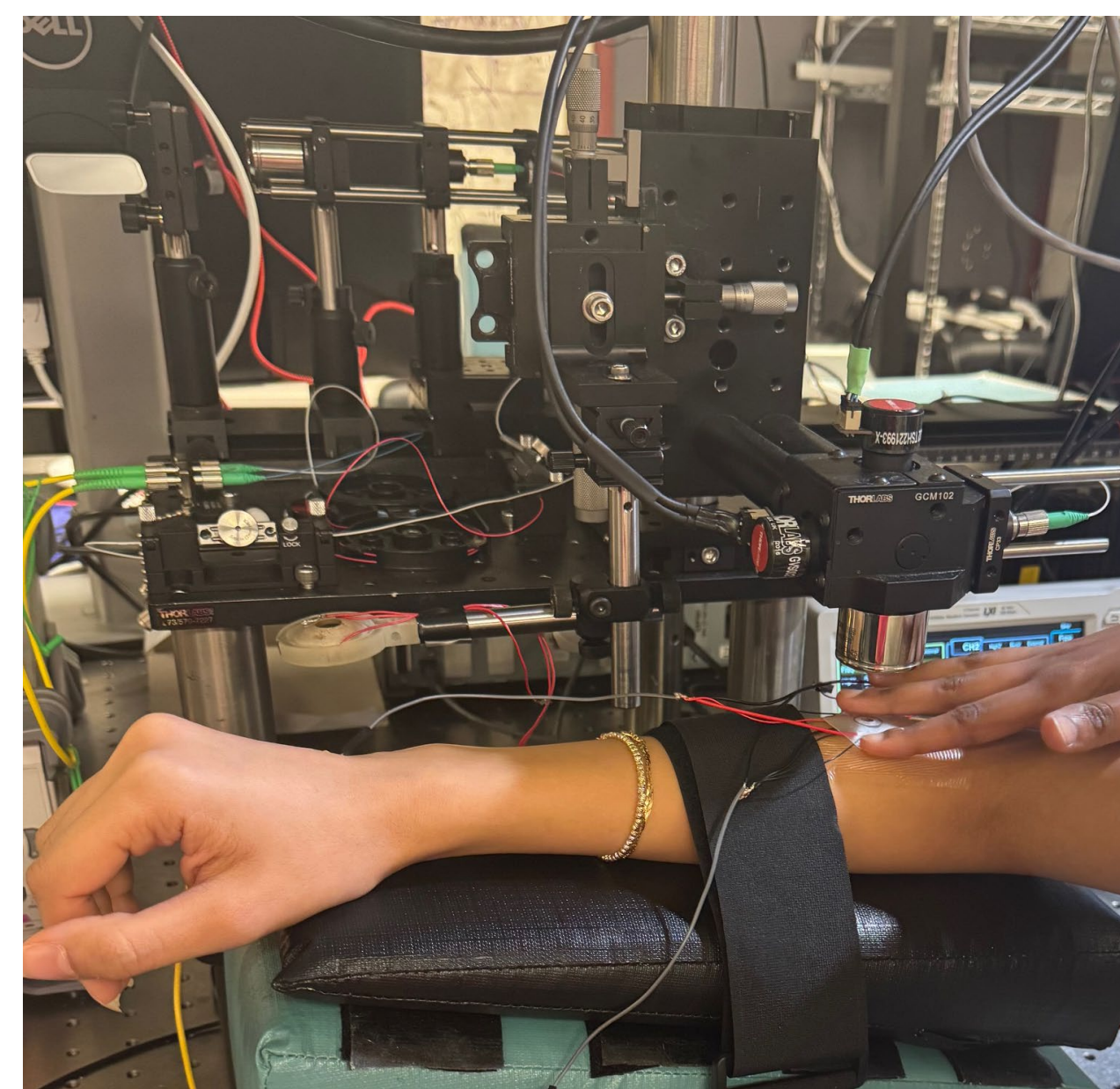
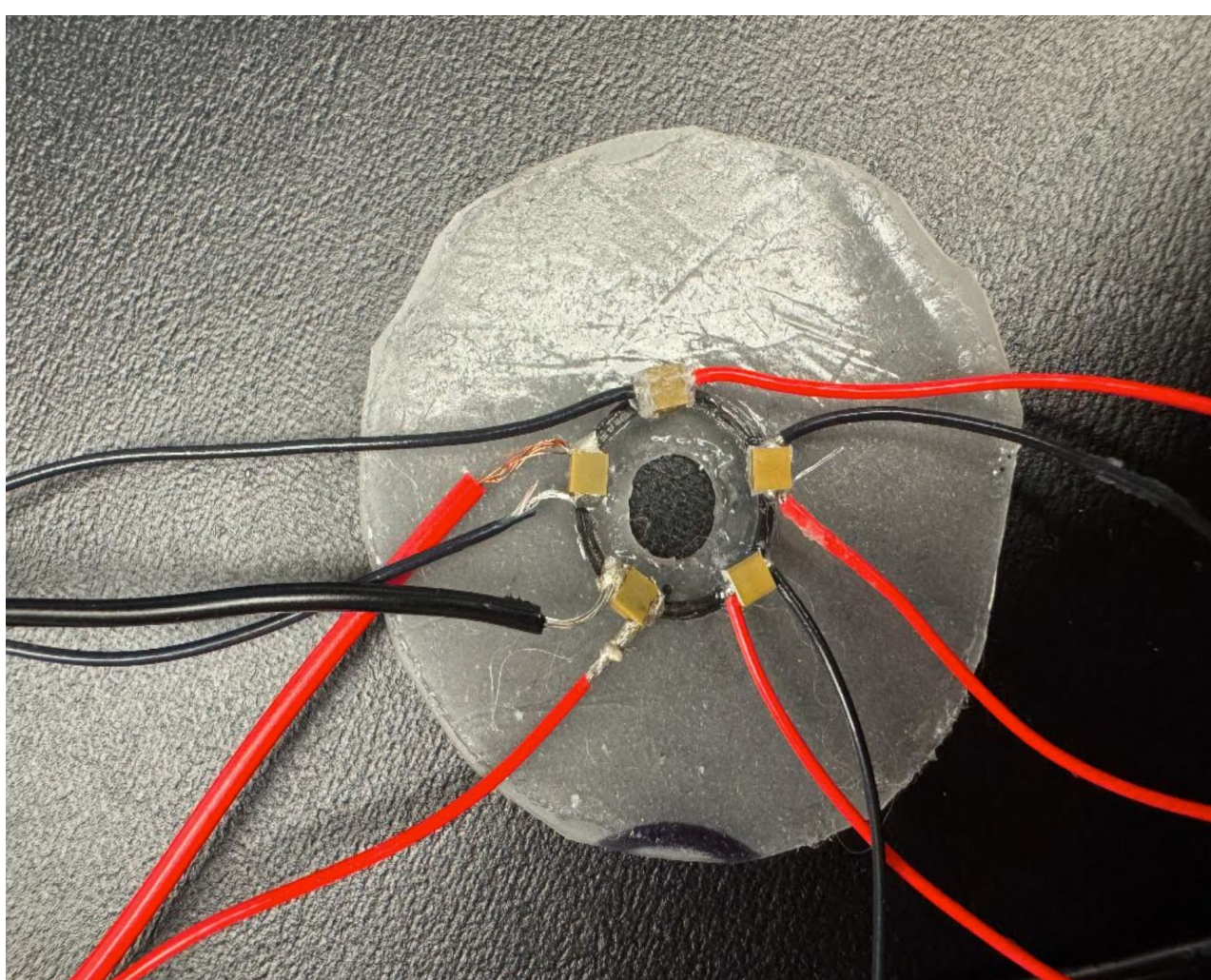
Equations used

(1) Young's modulus is calculated from the density and wave speed $E=3\rho c^2$

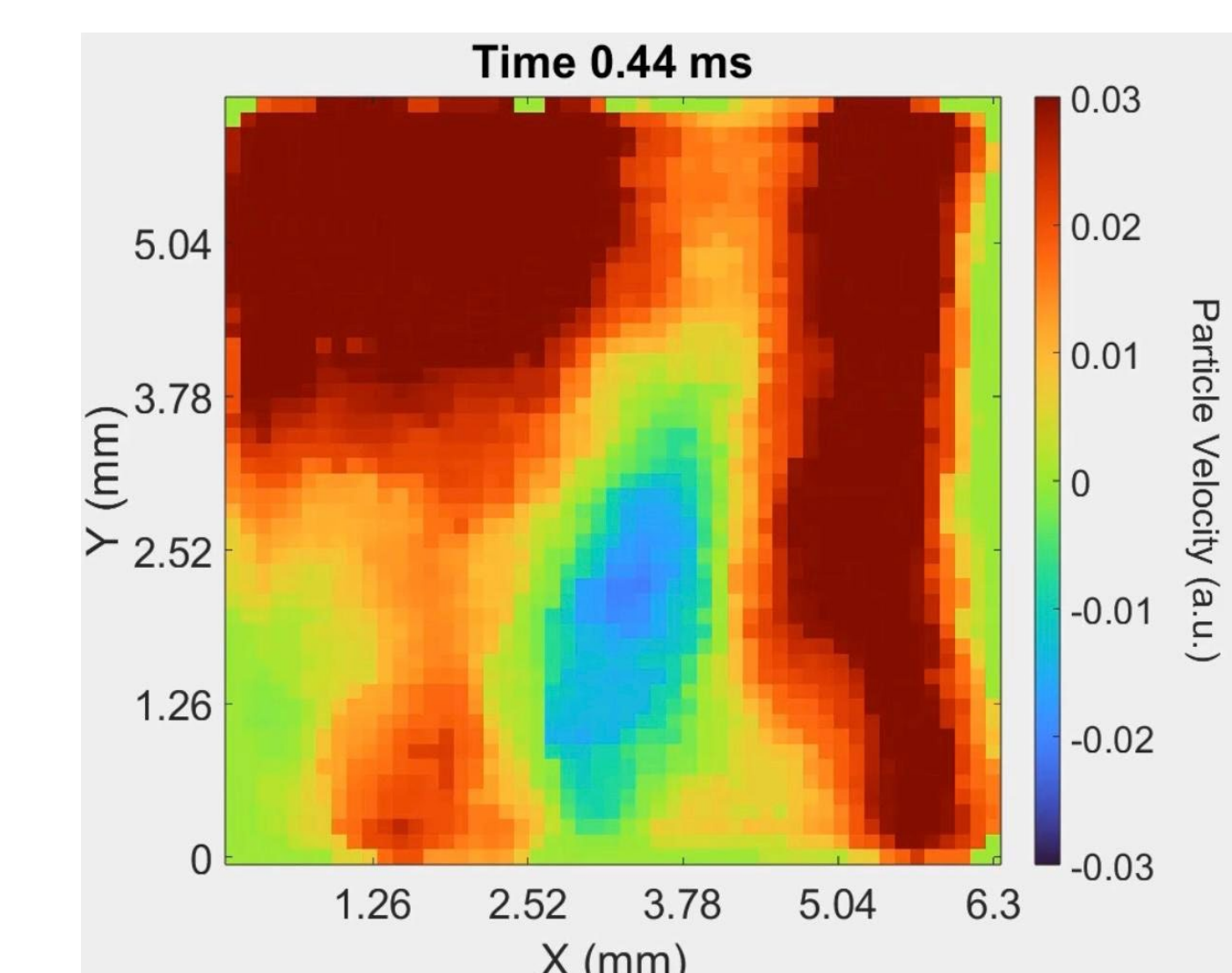
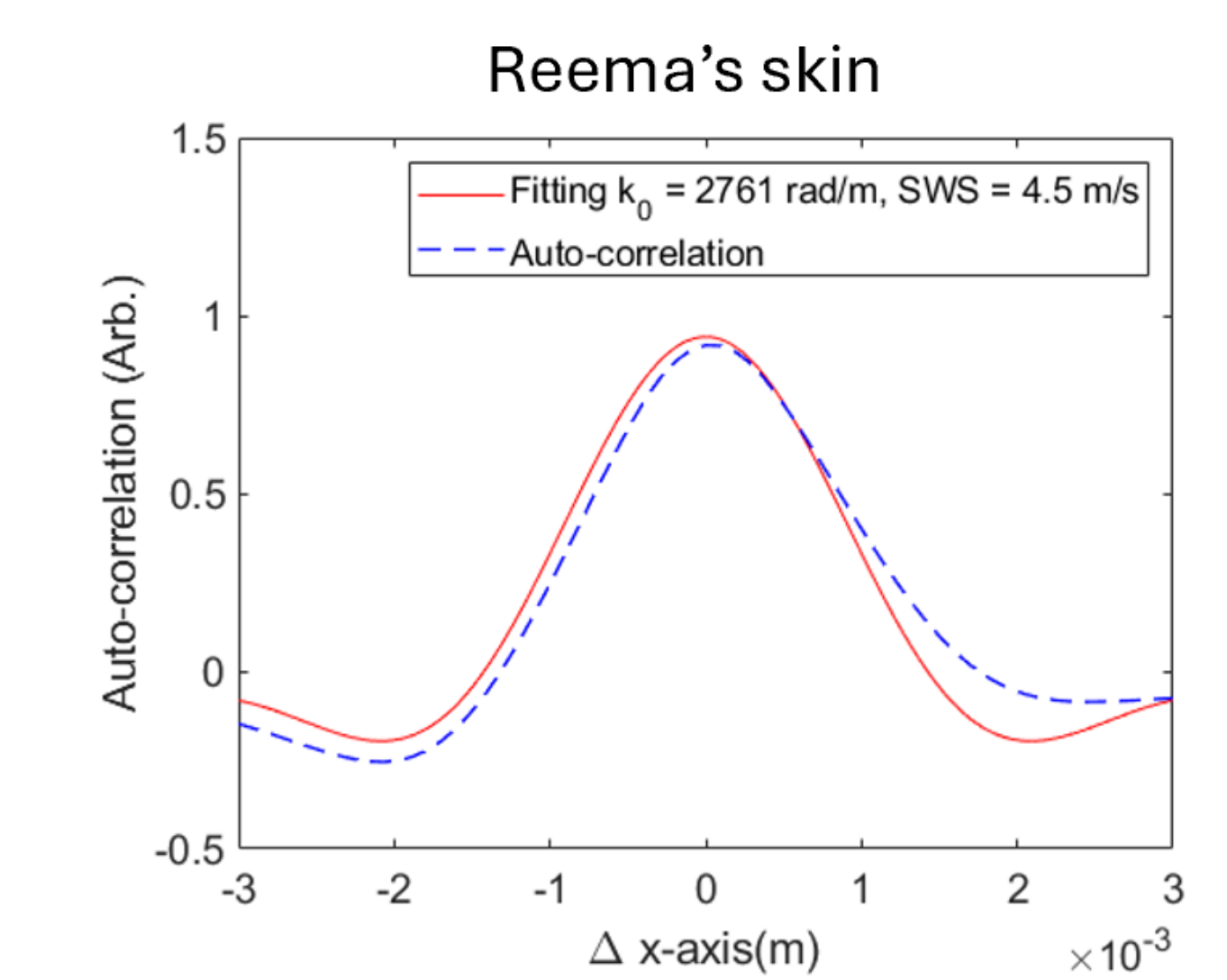
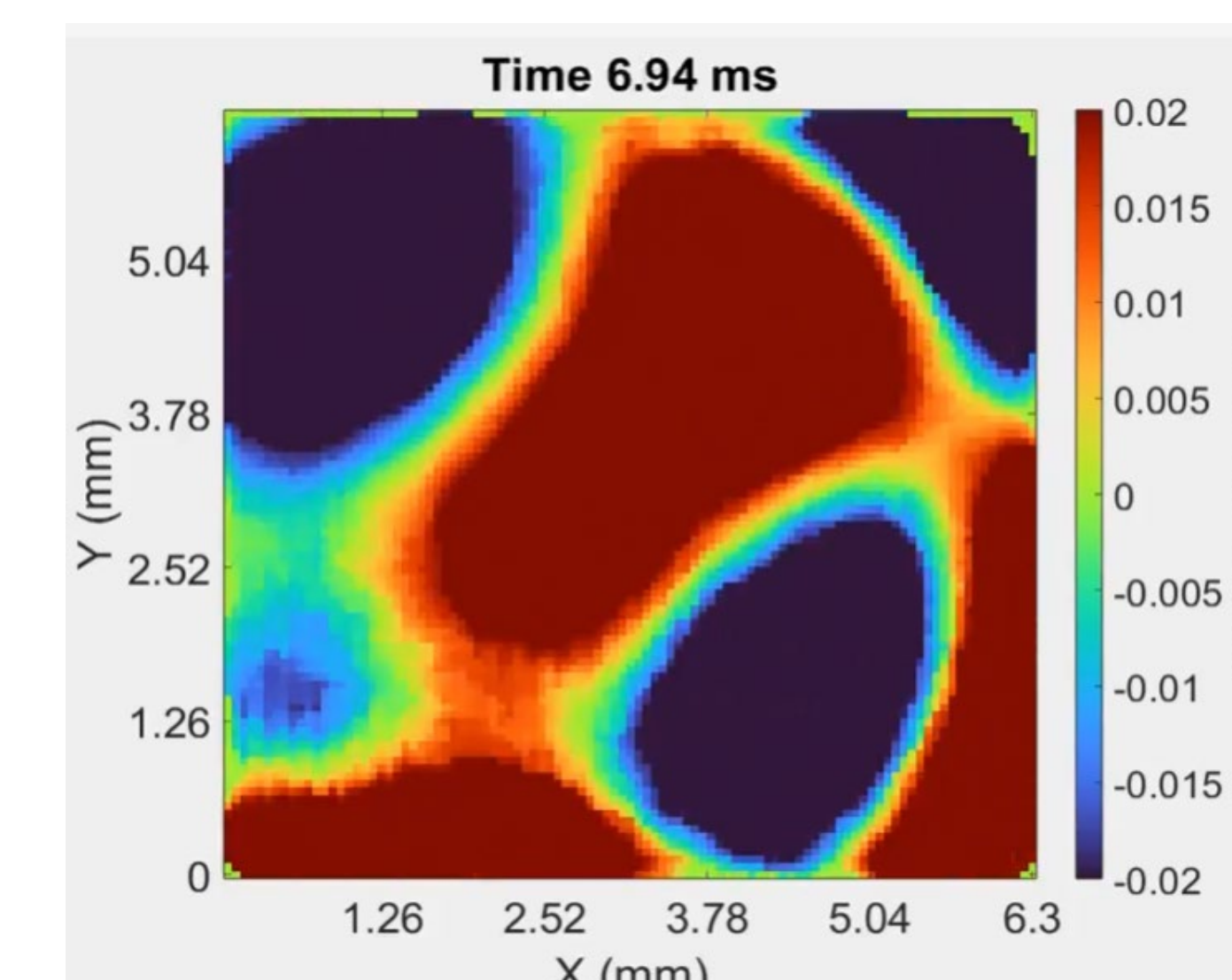
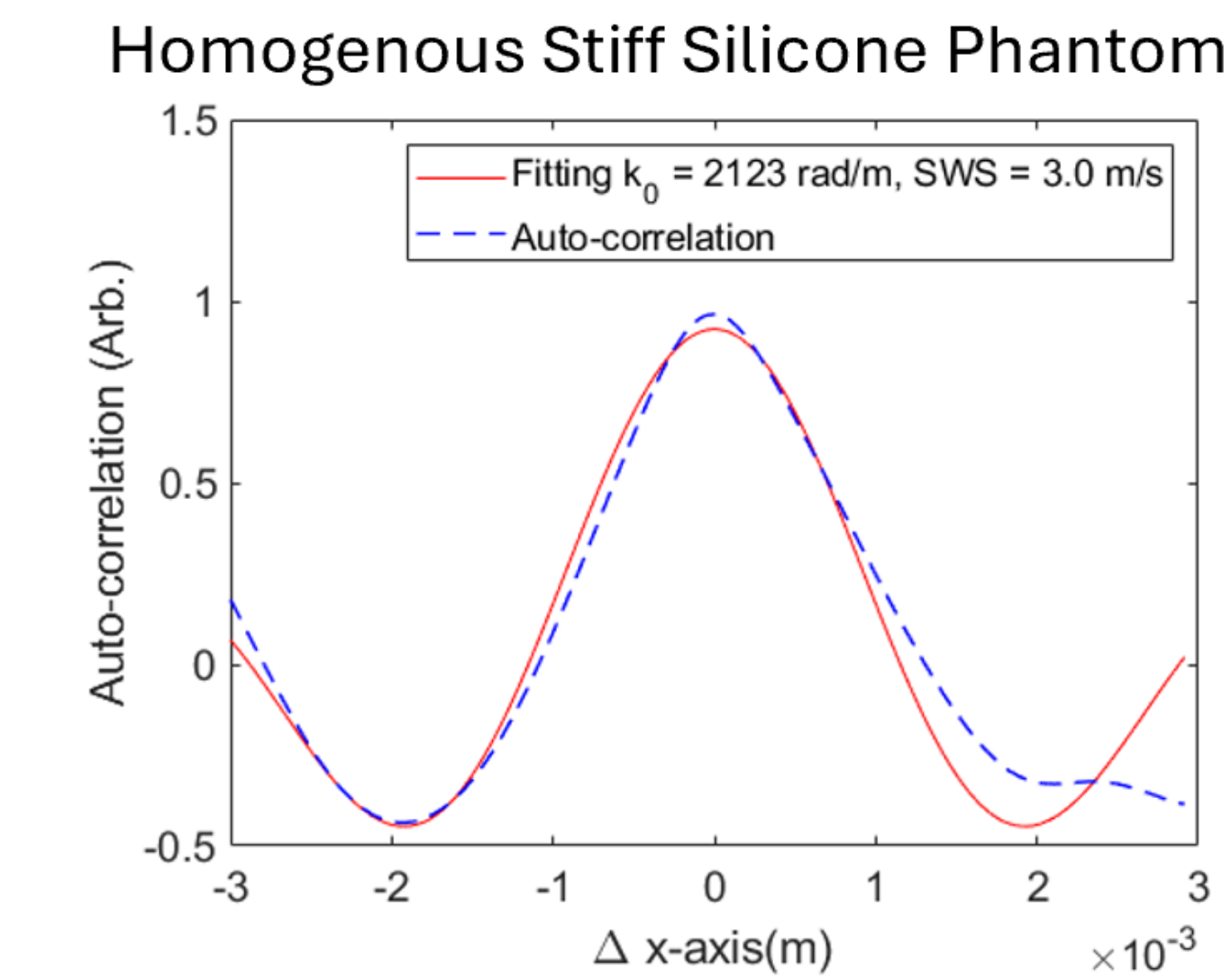
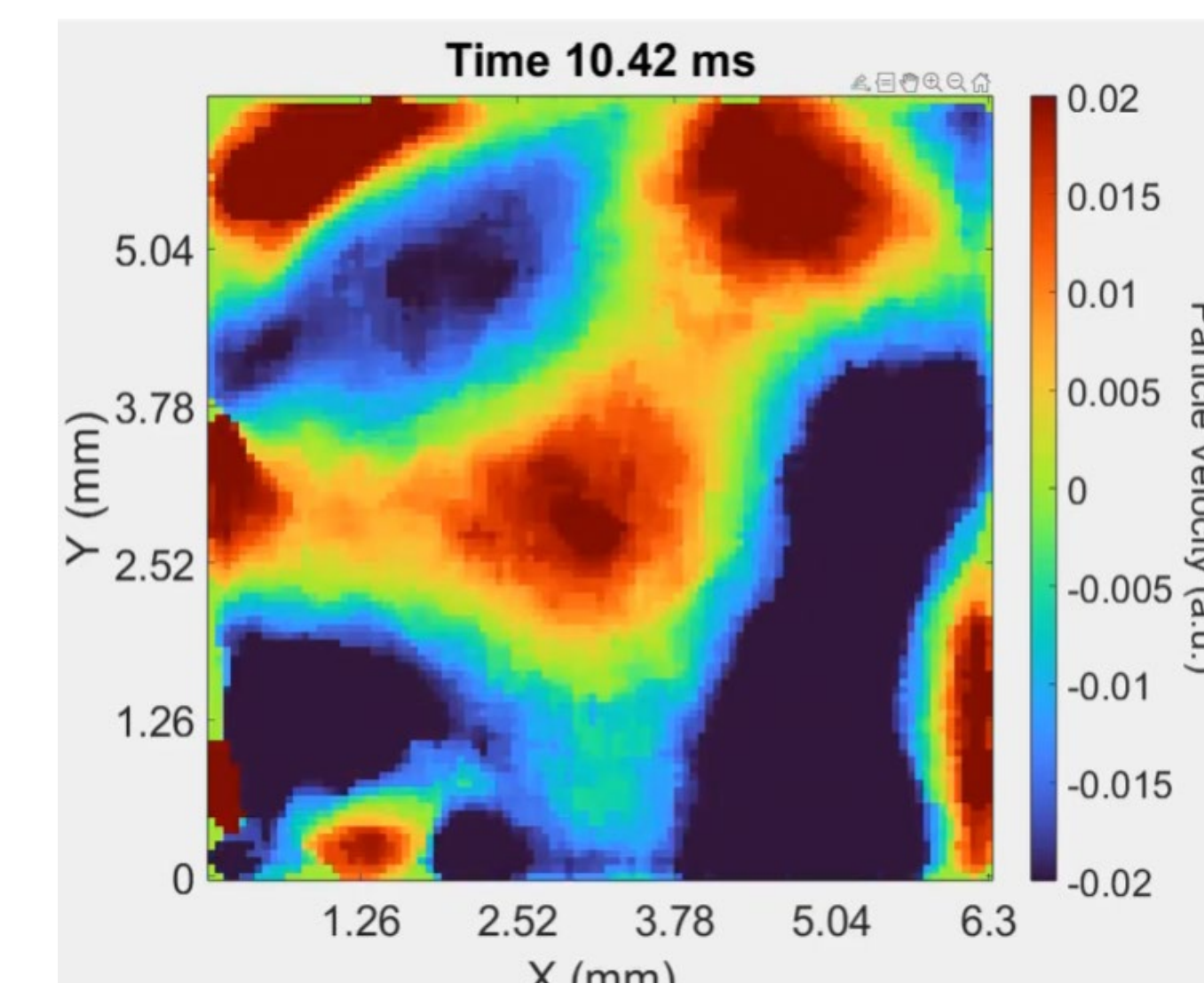
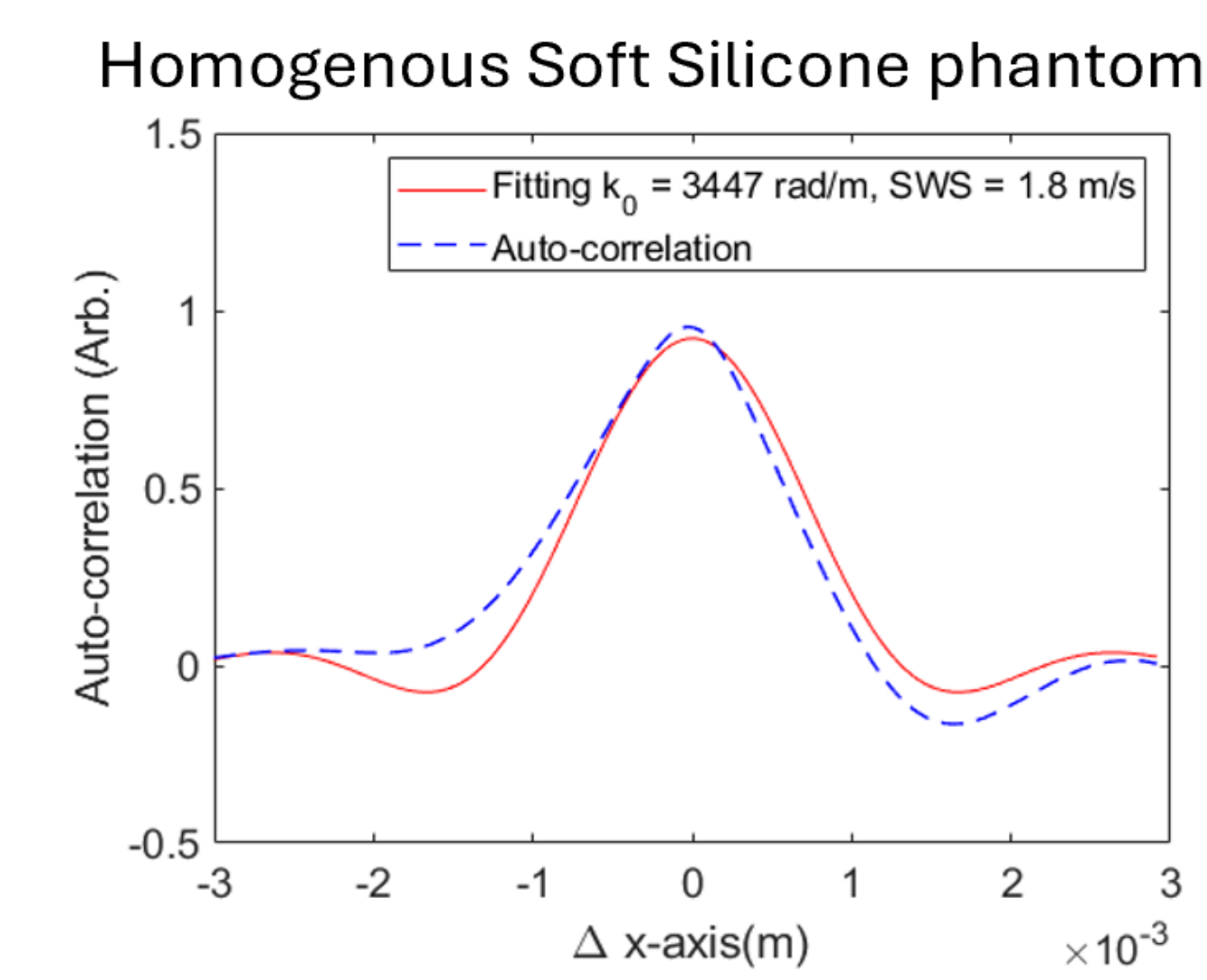
(2) Local wave number k is estimated via 2D auto-correlation and profile fitting in a reverberant field $k=2\pi/\lambda$

(3) Wave speed is related to frequency and wavelength $C=f\lambda$

(4) Bessel function $B_{v_z v_z}(\Delta \epsilon_x) = \frac{\beta}{2} \left[j_0(k\Delta \epsilon_x) - \frac{j_1(k\Delta \epsilon_x)}{k\Delta \epsilon_x} \right]$



Results

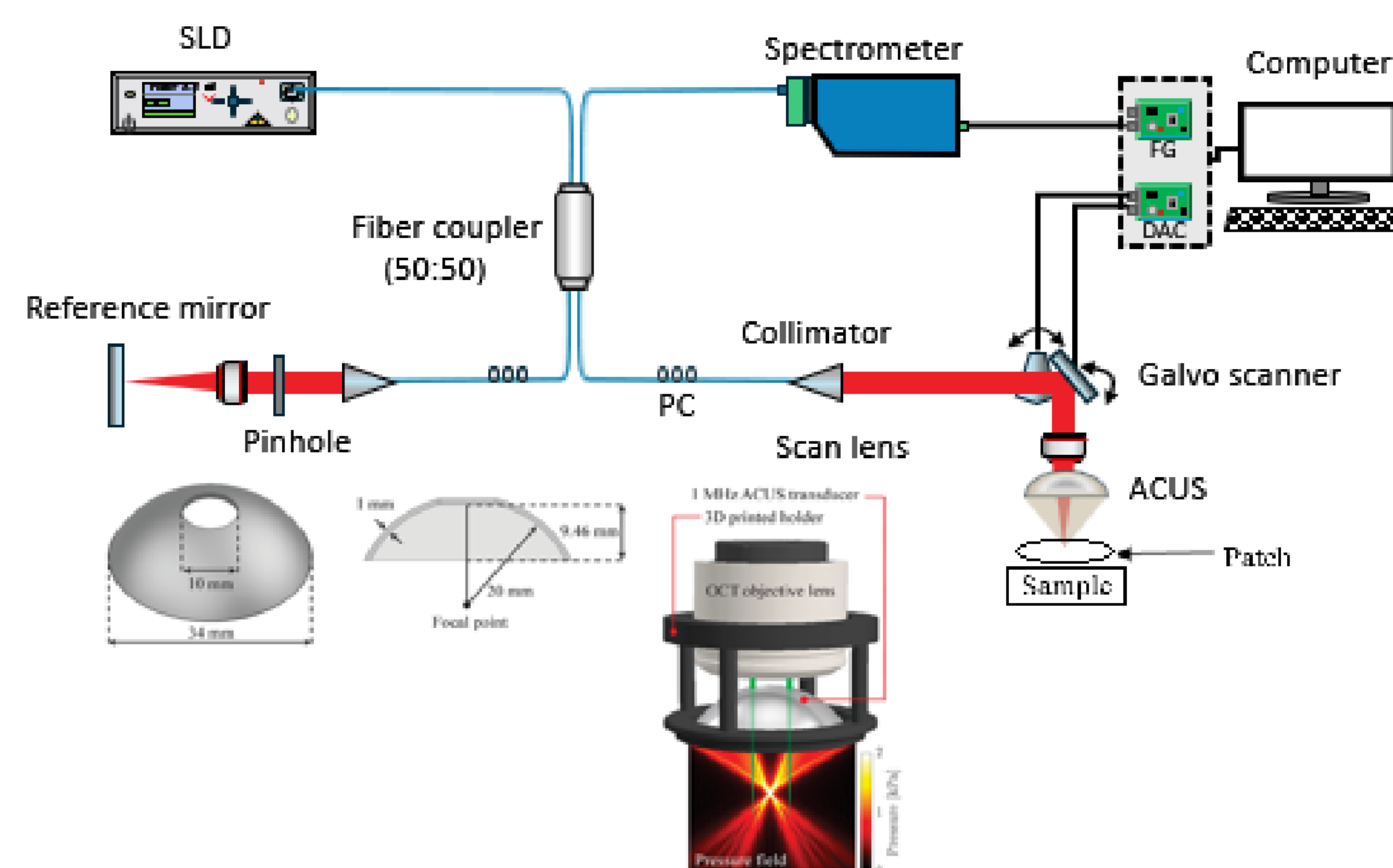


Young's Modulus	
Soft	7.296 kPa
Stiff	25.650 kPa
Skin	66.825 kPa

The kPa relates to the elasticity of skin. The normal kPa of skin is between 15-40 kPa. As shown in the table, the lower the kPa, the softer the sample.

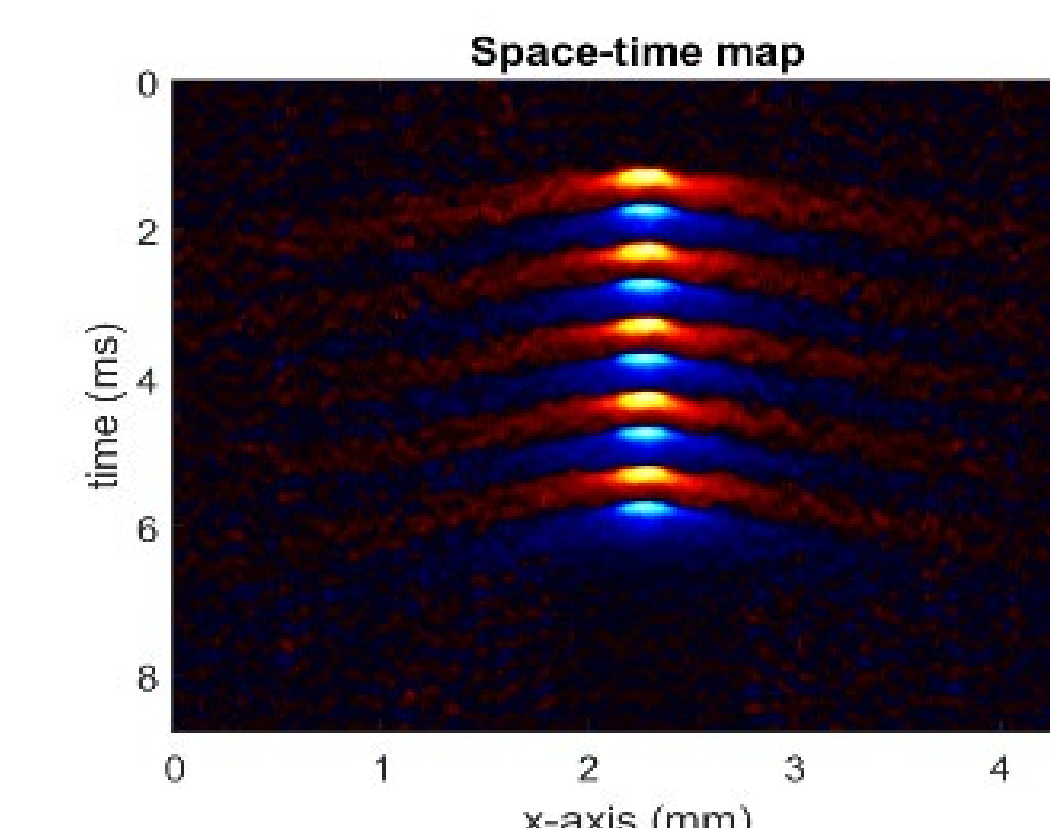
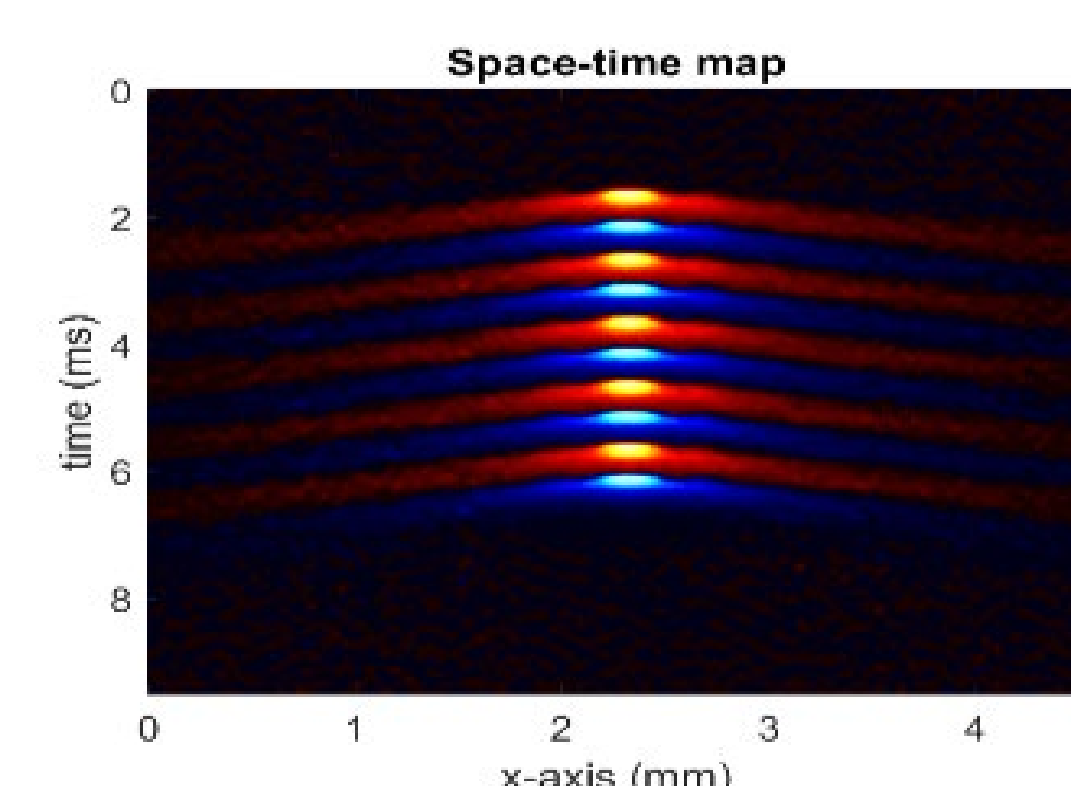
- The speed of the reverberant waves determines how stiff the sample is.
- Piezo transducers were activated by an electrical signal, causing mechanical deformation that was transferred to the sample.
- The frequency used in our experiments was 1 kHz. Reema's skin was imaged at 2 kHz.

Schematic



Validation

	Shear-wave OCE	Reverberant OCE
Soft	1.59+/-0.12	1.80
Stiff	2.87+/-0.07	3.00



*This validation was done using ACUS-OCE.

Conclusion

Our bio-adhesive patch accurately distinguished stiff and soft tissues in various phantoms, validated by ACUS-OCE, showing promise as a diagnostic tool for skin diseases like Systemic Sclerosis.

References

Zvietcovich F, Larin KV. Wave-based optical coherence elastography: A 10-year perspective. *Prog Biomed Eng.* 2022;4:012007.

Singh M, Zvietcovich F, Larin KV. Introduction to optical coherence elastography. *J Opt Soc Am A.* 2022;39:418–430.

Ormachea J, Parker KJ. Elastography imaging: A 30-year perspective. *Phys Med Biol.* 2020;65.