# Super-shear evanescent waves (SEW) for evaluation of elasticity in soft media

John J. Pitre, Jr.[1], Mitchell A. Kirby[1], Liang Gao[1], Tueng T. Shen[2], Ruikang K. Wang[1], Ivan Pelivanov[1], Matthew O'Donnell[1]

[1]Department of Bioengineering, University of Washington, Seattle, WA, USA
[2]Department of Ophthalmology, University of Washington, Seattle, WA, USA

## Background, Motivation and Objective

Super-shear evanescent waves (SEWs) are mechanical waves that can propagate on the surface of nearly-incompressible elastic solids at a speed approximately twice that of the bulk shear wave speed and attenuate with propagation distance. SEWs have been predicted theoretically and observed experimentally in a few studies, and their behavior has been connected to the complex roots of the Rayleigh equation. Because SEW propagation speed is proportional to the bulk shear wave speed, it may provide a simple method to estimate tissue elasticity in complex bounded media.

## Statement of Contribution/Methods

In this study, we generate SEWs on the surface of tissue-mimicking phantoms (bulk and thin-layer) and ex-vivo porcine corneas using acoustic micro-tapping (AuT) and monitor their propagation using high-speed phase-sensitive optical coherence tomography (OCT). AuT excitation used a cylindrically-focused 1 MHz air-coupled ultrasound transducer, which provided a spatially and temporally sharp push to the material surface, generating broadband mechanical waves. We tracked the propagation of the SEW local maximum $C_{SEW}$ and derived a theoretical approximation to the shear wave speed $C_s$ based on this measurement and the elastodynamic Green's function ($C_{SEW} \approx 1.9554\ C_s$). We validated these experimental measurements using numerical simulations with the OnScale solver.

## Results/Discussion

Figure 1A shows the XT plot of the surface velocity field for a 0.5 mm thick PVA phantom ($C_s$ = 3.8 m/s). The local maximum of the SEW (Figure 1A: marked by the dashed line, Figure 1B: marked by arrows) is clearly visible once it separates from the Rayleigh-Lamb modes. The peak travels with a constant super-shear velocity (7.41 m/s). Based on our theoretical analysis, this corresponds to a shear wave speed estimate of 3.78 m/s. Figure 1C shows SEW speed measurements as a function of shear wave speed for experiments in bulk phantoms with push durations of 100 µs and 200 µs. Measurements closely match both theoretical predictions from the Green's function and numerical solutions from the finite element model. Our results demonstrate that measurements of SEW speed can provide simple and accurate estimates of elasticity, even in layered tissues such as the cornea or skin.

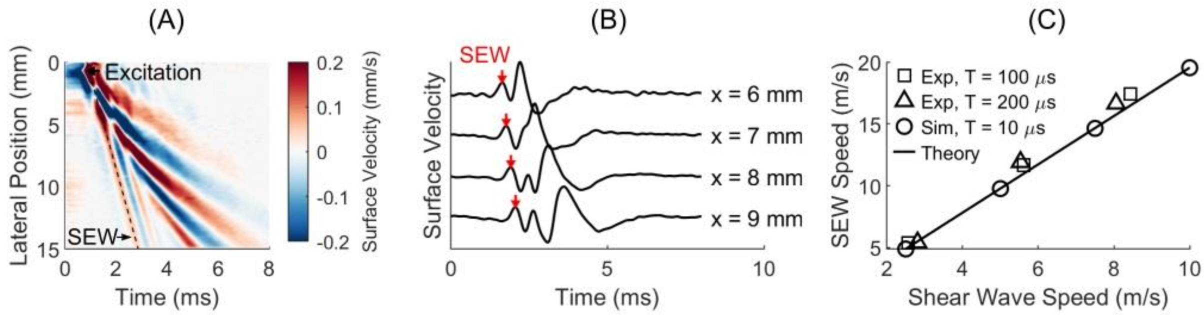


FIGURE 1. (A) XT plot of the surface velocity for a 0.5 mm thick phantom. The SEW local maximum is marked by a dashed line. (B) Surface velocity traces for the same phantom, with the SEW local maximum marked by arrows. (C) Comparison of experimental (squares, triangles), simulated (circle), and theoretical (line) SEW speed as a function of shear wave speed.