Ph.D. DISSERTATION DEFENSE

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Degree: Doctor of Philosophy
School/Department: Charles V. Schaefer, Jr. School of Engineering and Science / Physics
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Title: Broadening LiDAR's Applications Across Fields: An Exploration in Biomedical Imaging
Chairperson: Dr. Yuping Huang, Department of Physics, School of Engineering & Sciences

Committee Members: Dr. Yong Meng Sua, Department of Physics, School of Engineering & Sciences
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ABSTRACT

Since its inception in the early 1960s, Light Detection and Ranging (LiDAR) has rapidly advanced, demonstrating its capabilities across various fields. On the other hand, elastography is an important tool for biomedical diagnoses to differentiate between healthy and cancerous tissue. To date, no research has combined LiDAR technology with elastography, and this dissertation presents the first successful attempt to explore this uncharted field.

Initially, I verified that materials with different elasticities exhibit distinct responses to acoustic excitation. For example, when low-frequency sound waves are applied to an agar phantom, soft agar produces a stronger response than hard agar. This response is captured as varying oscillation amplitudes on the reflection photon counting histogram, as using a single photon counting LiDAR. With the aid of nonlinear optical frequency conversion, ambient light is effectively rejected, allowing for the detection of photon count oscillations with minimal noise. By performing a Fourier transform on the oscillations, I observed sharp peaks in the corresponding spectrum, enabling the calculation of the peak-to-noise ratio (PNR) at the sound wave's frequency. The PNR value is higher in the soft agar region and lower in the hard agar region, providing a reliable approach for constructing images based on elasticity in two dimensions.

I next extended the photon-counting elastography to deep tissue applications. My experiments show that photons can penetrate tissue phantoms, and by separately detecting back-scattered photons from different layers by their time of flight, three-dimensional elastograms can be reconstructed. Using 9.6 mW infrared laser at 1554 nm, I obtained a 3D elasticity-contrast image for a tissue phantom placed behind a titanium dioxide scattering medium with a single-path optical depth of 3.27 OD. This marks a new capability in biomedical imaging techniques with the potential for optical, *in vivo* measurement and imaging of deep tissues.