Photoacoustic Imaging with Schlieren Optics to Provide Real-Time Imaging

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Research Question

Wide-field photoacoustic microscopy (PAM) images are challenging to display in real-time because these images are reconstructed from multiple one-dimensional scans. This delay limits both research and clinical applications for PAM [1]. Schlieren optics is a technique that can visualize sound using standard microscope cameras. By combining Schlieren optics with PAM, this research aims to eliminate the need for image reconstruction from multiple one-dimensional scans.

Photoacoustic Effect

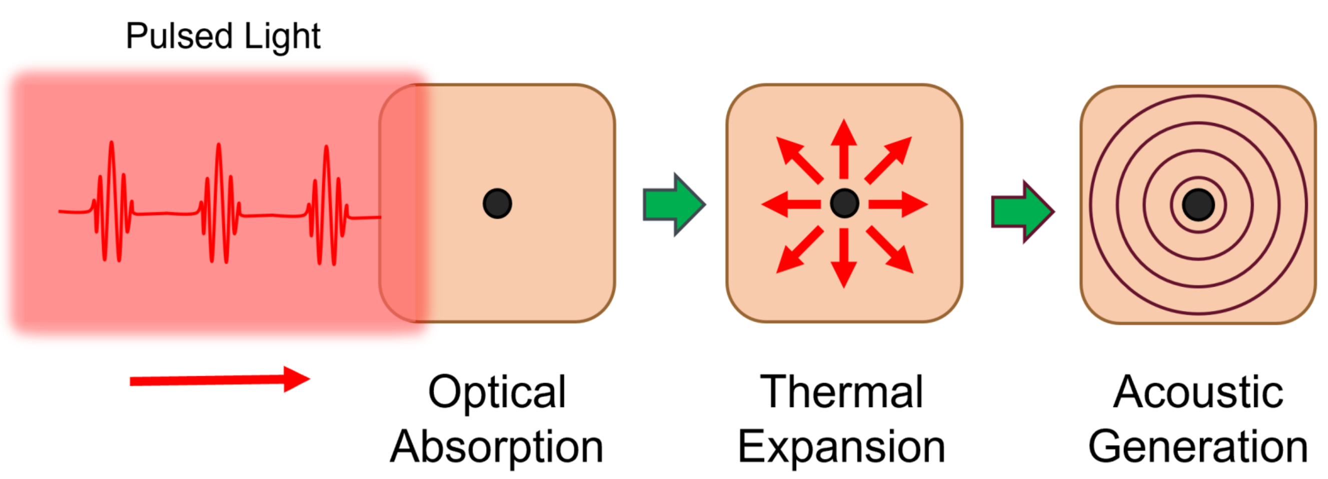


Figure 1: The photoacoustic effect begins with a medium absorbing pulsed nonionizing light. This causes thermal expansion, which generates acoustic waves. In photoacoustic microscopy, a laser creates a photoacoustic effect inside a tissue sample that can be detected and mapped into an image.

Schlieren Optics

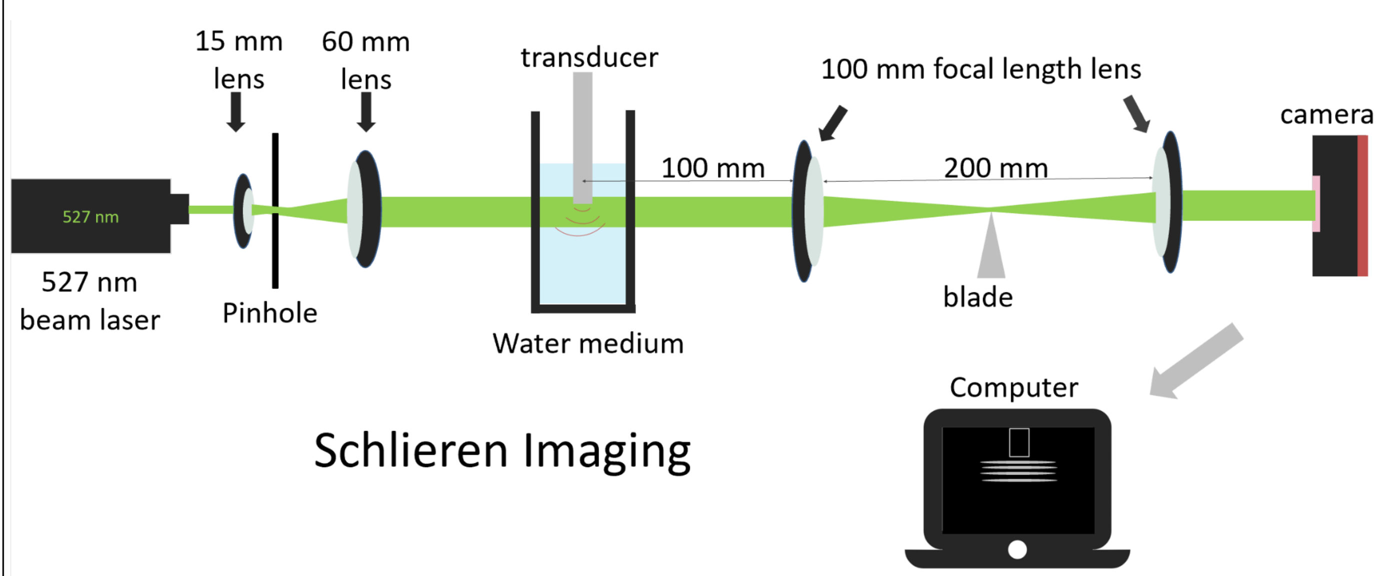


Figure 2: The Schlieren optical system visualizes transparent phenomenon as a result of sound, gas, and plasma [2].

Schlieren Optics Design

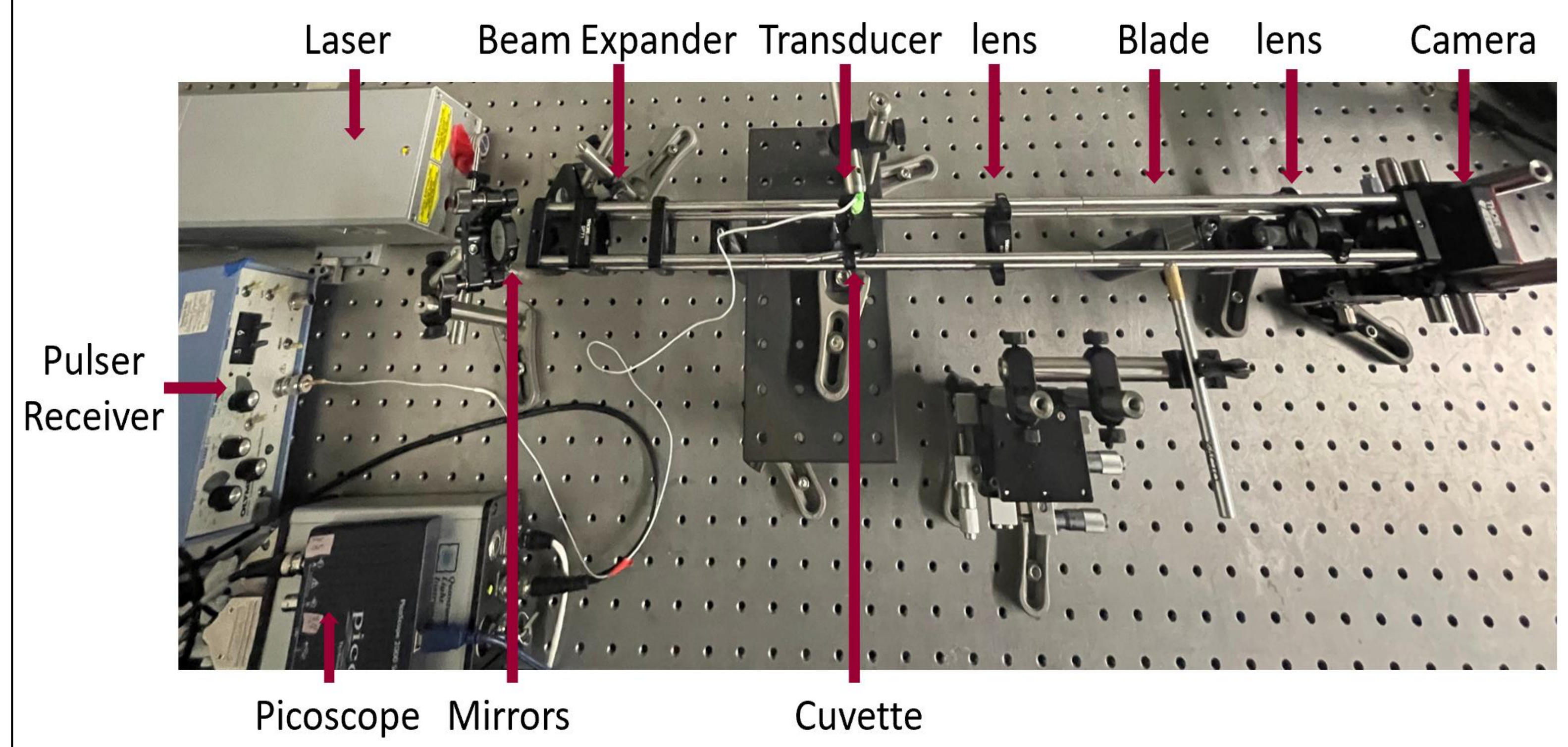


Figure 3: The Schlieren optical system bases its visualization off a medium's change on index of refraction. This setup serves as a positive control for the experiment. Once the sound waves from the ultrasound transducer can be visualized, the system will be capable of displaying the photoacoustic effect emitted from cells due to a laser pulse.

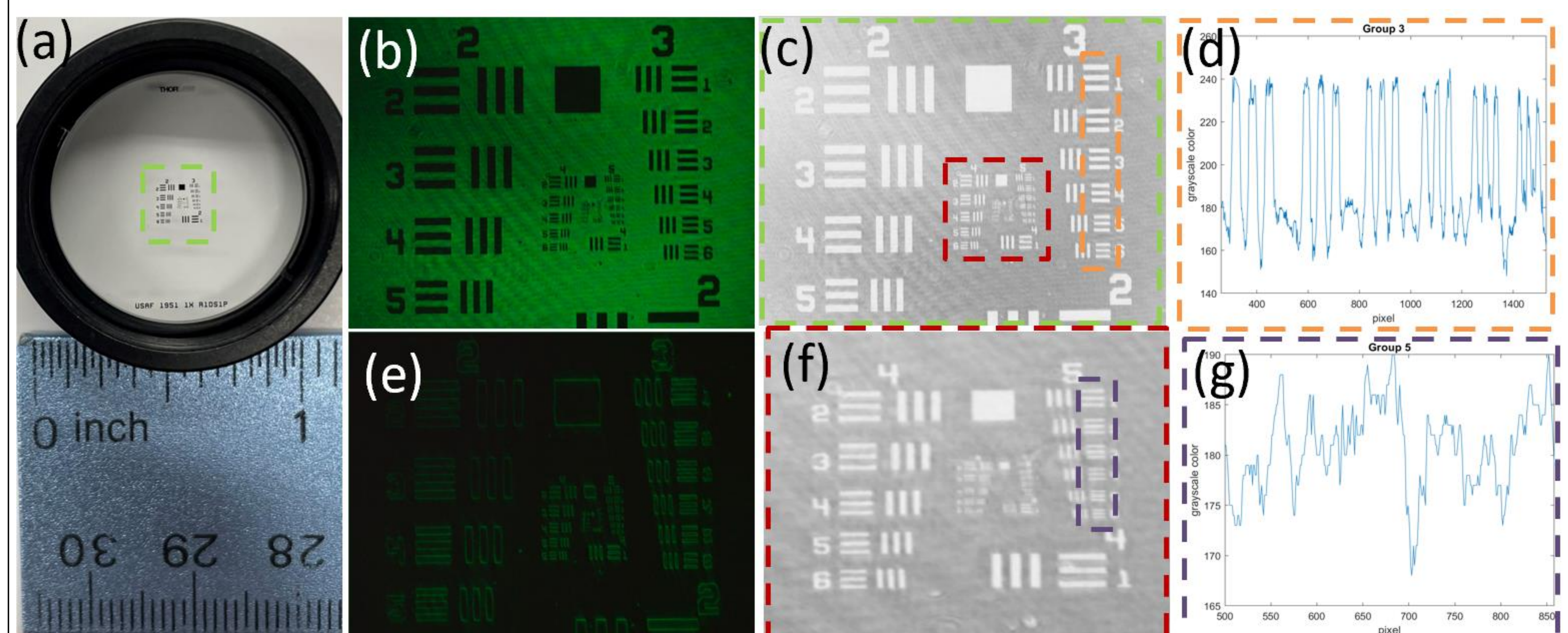
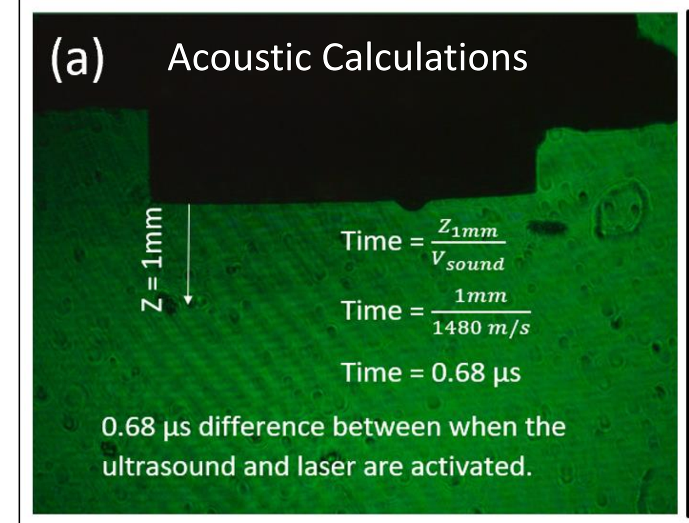


Figure 4: The U.S. Air Force Resolution Test (a) is used to analyze and validate the Schlieren optical system. The Resolution Test optical lens produces the resolution test (b) when placed inside the Schlieren optical system setup. The chart reveals the maximal resolution based on the visible group numbers and element numbers associated with a line pair. By analyzing the pixels on the image based on the color spikes with the Rayleigh Criterion, it is observed that Group 3 (c) clearly depicts 6 sets of three spikes on its corresponding MATLAB plot (d). This is due to proper resolution of the system. At Group 5 (f), the resolution begins to blur further with the final legible spike at element 6 according to the corresponding MATLAB graph (g). All further groups are too blurry to be depicted by the resolution of the system as increasing groups and elements become smaller on the U.S. Air Force Resolution Test. The picture (e) references the Air Force Target that is partially blocked by the knife edge to increase the sensitivity of the system through increasing diffraction.

Calculations



(b) Resolution Calculations

$$(Resolution\left(\frac{lp}{mm}\right) = 2^{Group+(element-1)/6}$$

$$(2)\ Resolution\left(\frac{lp}{mm}\right) = 2^{5+(6-1)/5} = 57.0\frac{lp}{mm}$$

$$(3)\ Resolution\left(\frac{\mu m}{lp}\right) = 17.5\frac{\mu m}{lp}$$

Figure 5: Image (a) shows the acoustic calculations for the time delay calculations between transducer and laser pulse. Image (b) shows that each line pair is equivalent to 17.5 µm for group 5 element 6 according to the resolution calculation

Image Analysis

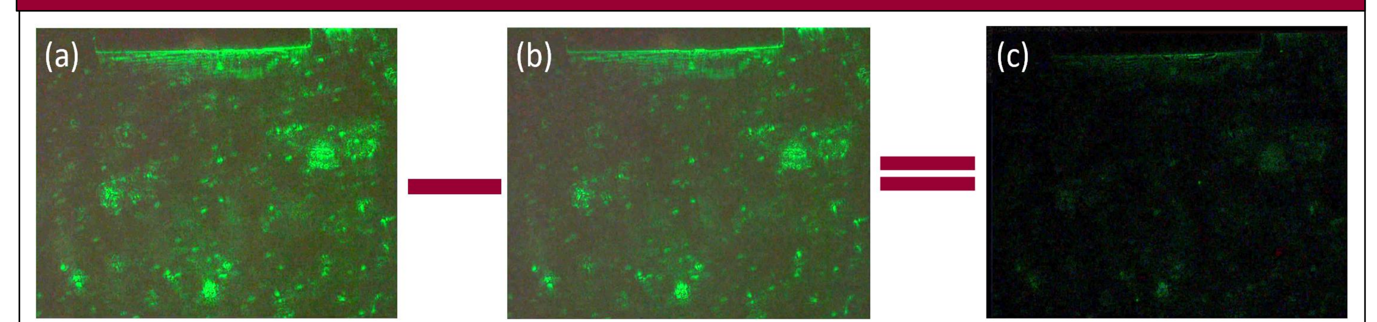


Figure 6: MATLAB was used to perform image analysis. Each frame (a) from a 400 V transducer firing video was subtracted from a controlled background frame (b). The remaining subtracted frame (c) illustrates the difference between a transducer firing and when it is not firing.

Future Goals

1. Image the ultrasound waves generated from the transducer.
2. Generate photoacoustic effect from cells and visualize with Schlieren optical system and DIC Scope.

References

[1] Yao, Junjie, and Lihong V Wang. "Photoacoustic Microscopy." *Laser & Photonics Reviews*, U.S. National Library of Medicine, 1 Sept. 2013, www.ncbi.nlm.nih.gov/pmc/articles/PMC3887369/.

[2] S. Samukawa, M. Hori, et al. "Schlieren Imaging: a Powerful Tool for Atmospheric Plasma Diagnostic." *EPJ Techniques and Instrumentation*, SpringerOpen, 1 Jan. 1970, epjtechniquesandinstrumentation.springeropen.com/articles/10.1140/epjti/s40485-018-0045-1.

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