Photoacoustic Imaging with Schlieren Optics to Provide Real-Time Imaging

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Research Question

Widefield images are difficult to display in real-time with photoacoustic microscopy (PAM) because these systems only gather one dimensional scans per laser pulse [1]. It then takes time to reconstruct images from these scans. This disadvantage limits both research applications and increases clinical diagnosing times. We aim to test if a Schlieren optical system coupled with PAM can reduce image reconstruction time to the speed of the camera's frame rate.

Photoacoustic Effect

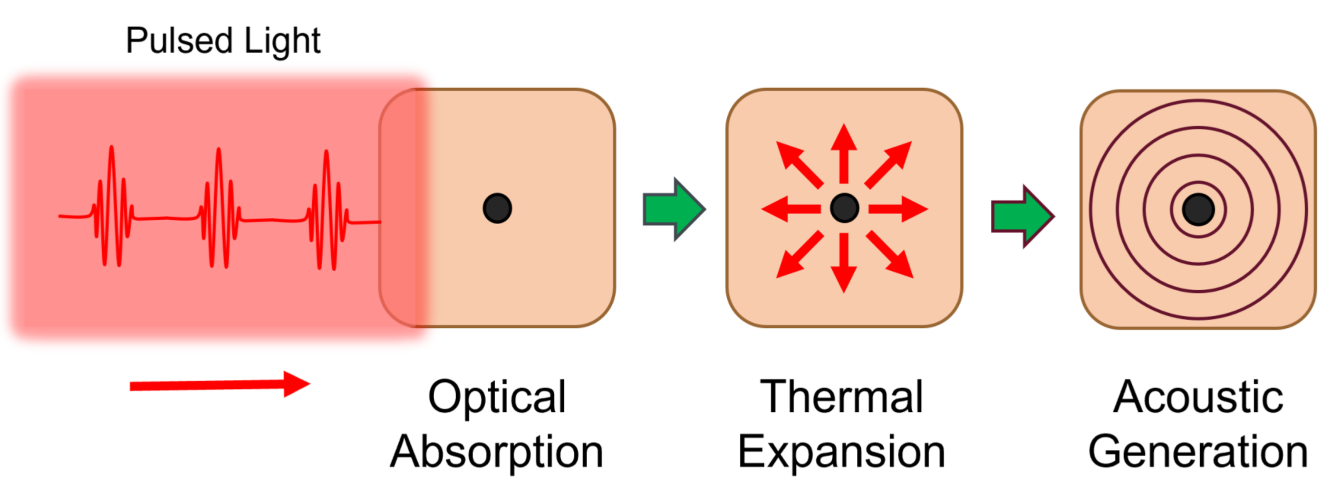

Figure 1: The photoacoustic effect begins with a medium absorbing pulsed nonionizing light. This causes thermal expansion, which generates acoustic waves. In photoacoustic microscopy, a laser creates a photoacoustic effect inside a tissue sample that can be detected and mapped into an image.

Schlieren Optics

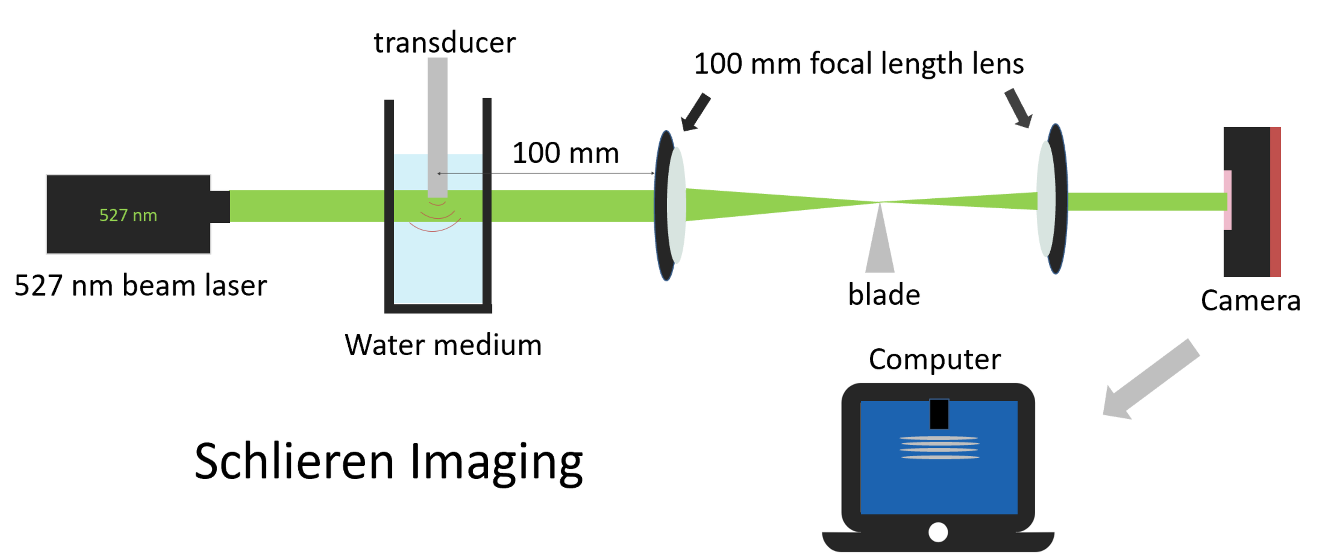

Figure 2: The Schlieren optical system visualizes transparent phenomenon as a result of sound, gas, and plasma [2].

Schlieren Optics Design

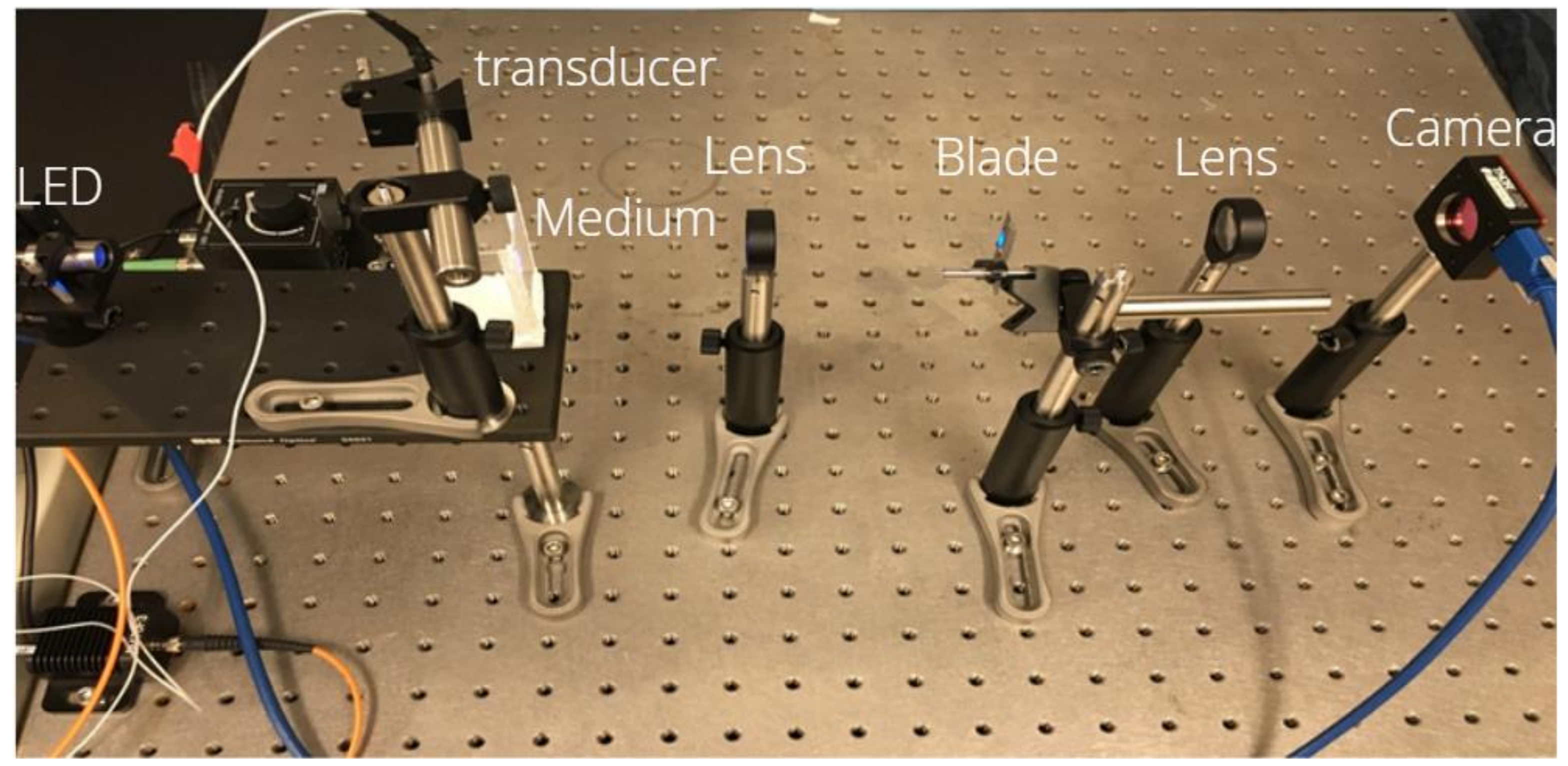

Figure 3: The Schlieren optical system bases its visualization off a medium's change in index of refraction. This setup serves as a positive control for the experiment. Once the sound waves from the ultrasound transducer can be visualized, the system will be capable of displaying the photoacoustic effect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

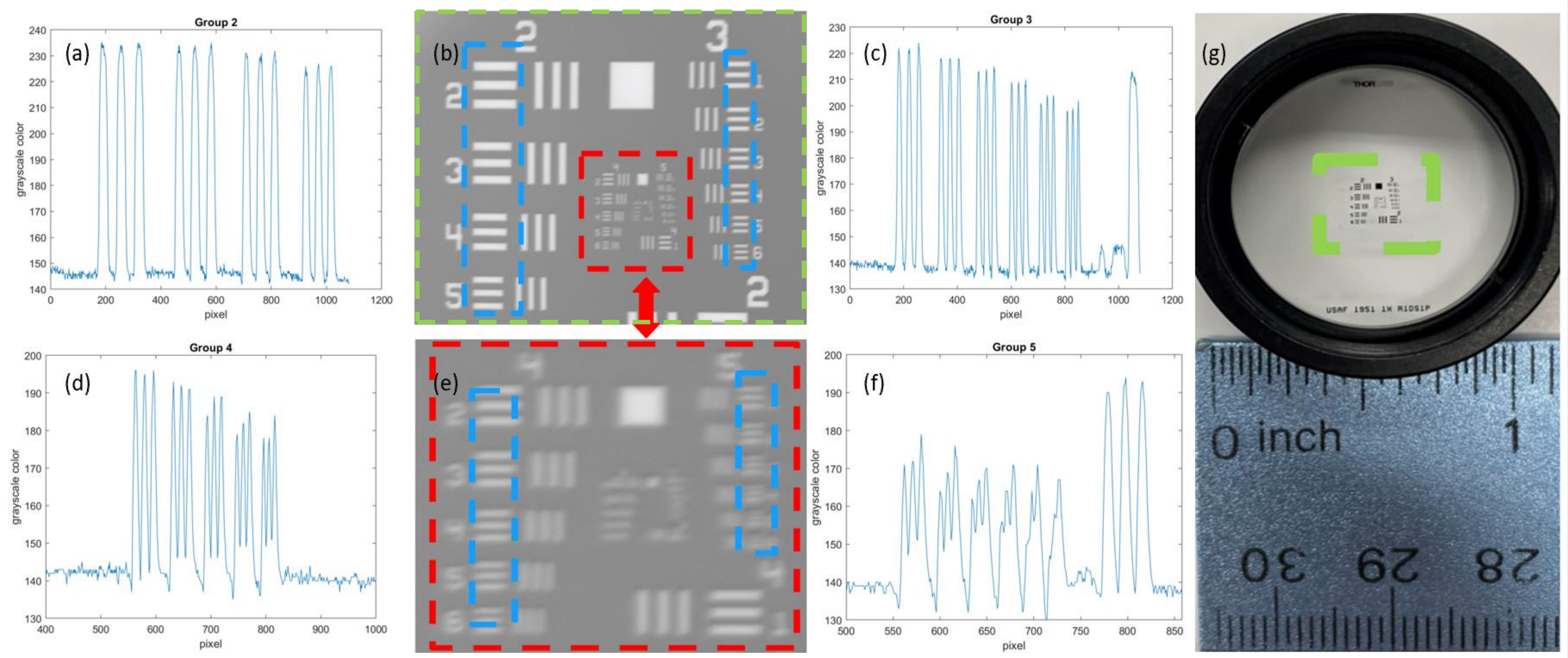

Figure 4: The U.S. Air Force Resolution Test (g) is used to analyze and validate the Schlieren optical system. The Resolution Test optical lens produces the resolution test (b) when placed inside the Schlieren optical system setup. The chart reveals the maximal resolution based on the visible group numbers 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 2 (a), Group 3 (c), and Group 4 (d) all can be depicted by the system due to proper resolution. At Group 5 (f), the resolution begins to blur further with the final legible spike at element 6. 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 center of (b) is (e) zoomed in to show the decreasing resolution as the group and element numbers increases.

Acoustic Calculations

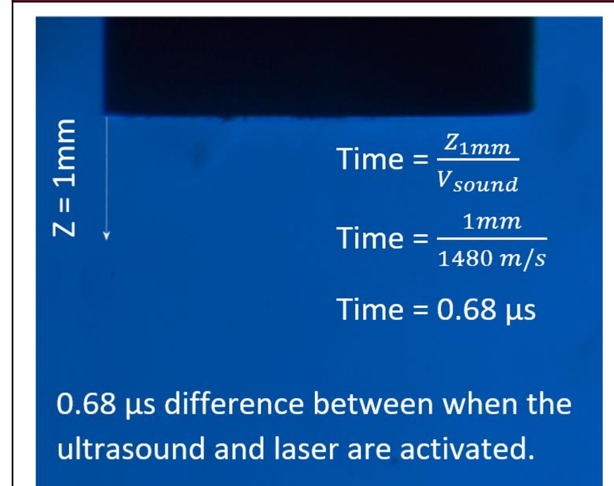

Figure 5: Image of the transducer from Schlieren optical setup with time delay calculations between transducer and laser pulse.

Resolution Calculations

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

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

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

Each line pair is equivalent to 17.5 µm. This is derived from the resolution formula for element 6, group 5.

Future Goals

1. Align Schlieren optical system with laser and knife edge.
2. Image the ultrasound waves generated from the transducer.
3. Generate photoacoustic effect from cells and visualize with Schlieren optical system.

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.