Seminar: Implementation of Photoacoustic Imaging on Ultrasound Systems

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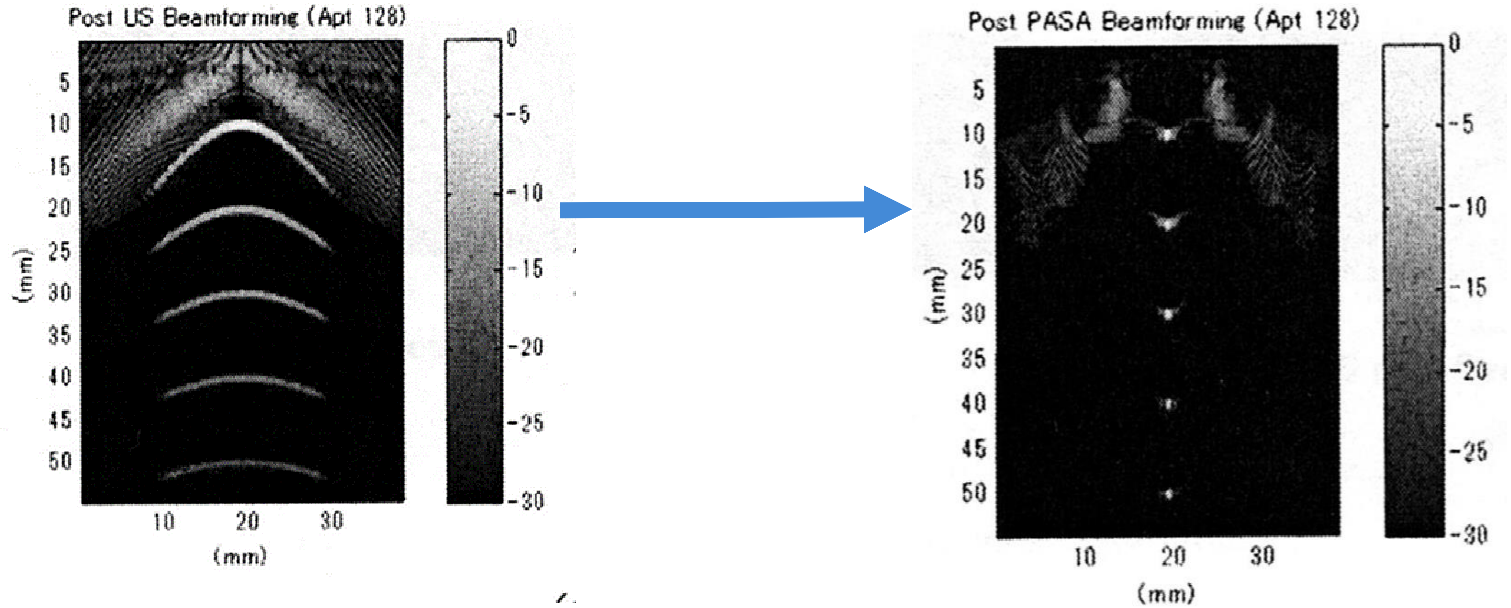
Recap- Our Project Goal

- Develop real-time photoacoustic imaging on a clinical ultrasound platform.



- We are not the only group interested in this subject.

Seminar Overview

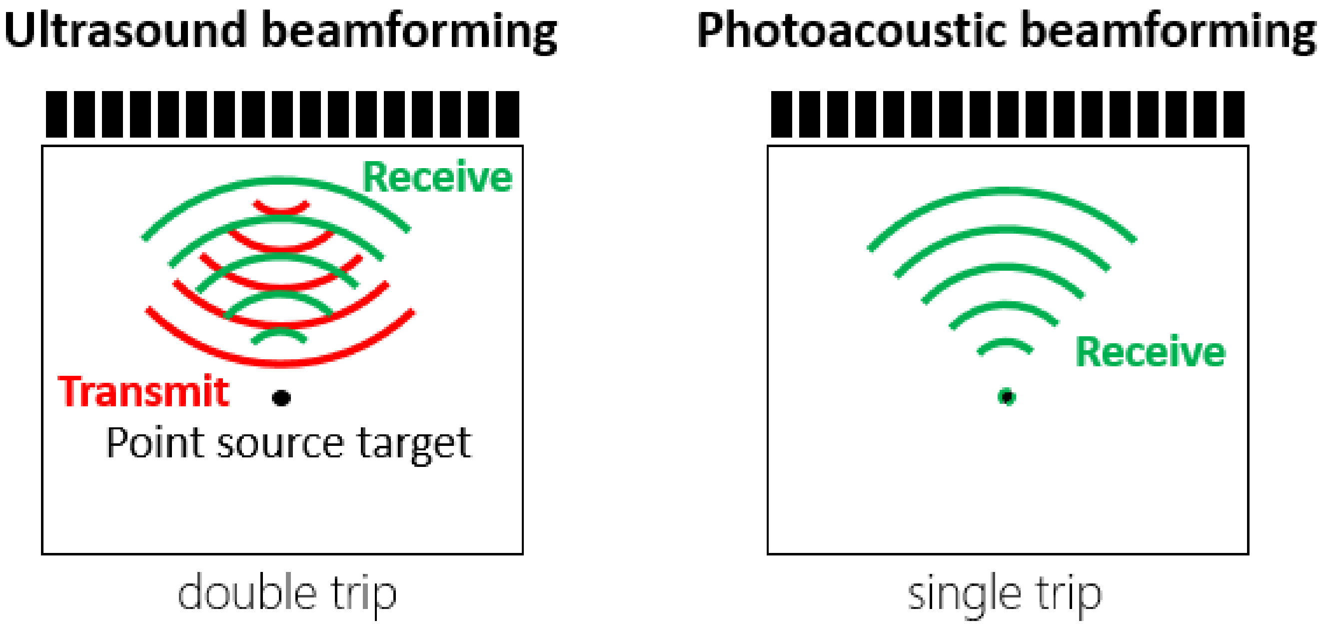
- Paper: “The applicability of ultrasound dynamic receive beamformers to photoacoustic imaging.”
- Authors: Tyler Harrison, Roger J. Zemp

- Main Goal: Achieve PA imaging on an US system.

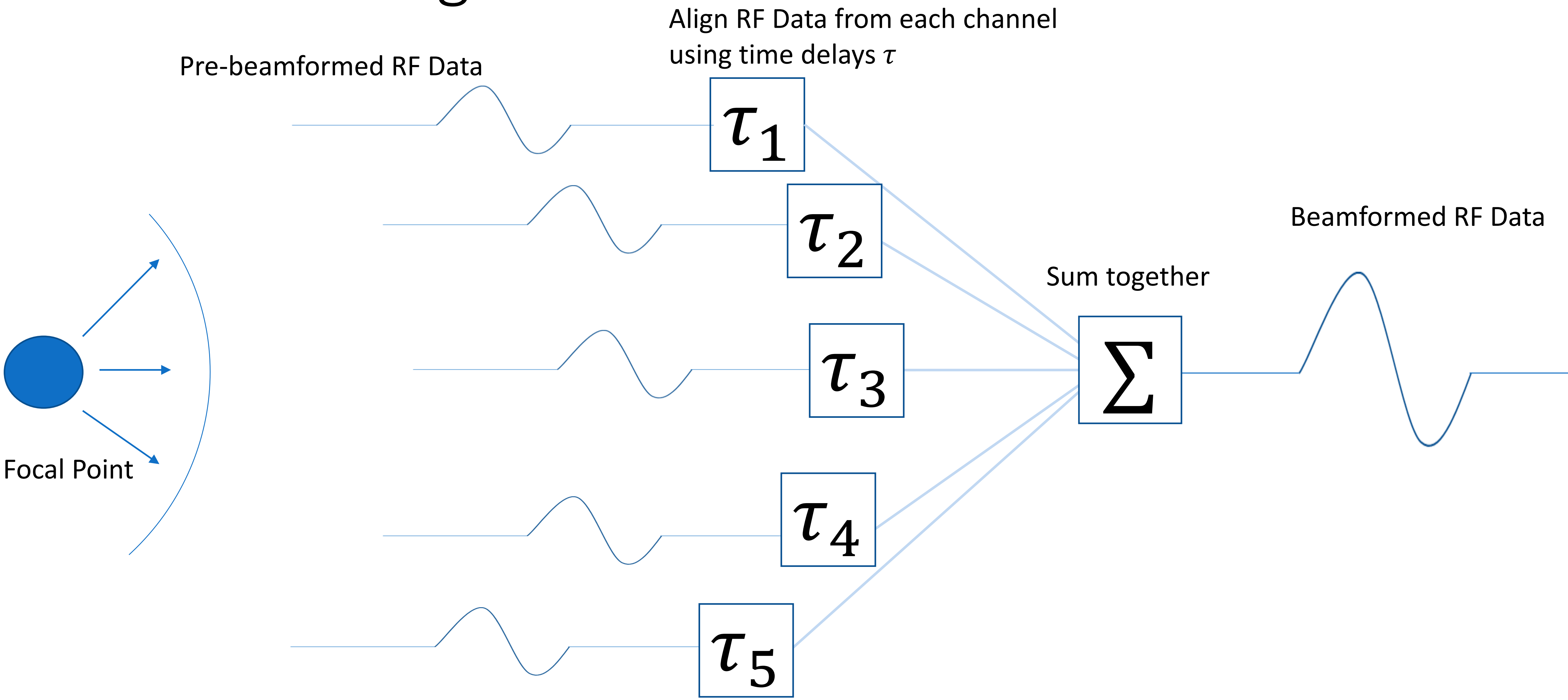
- Same project goal as ours. Presents an alternative approach for PA imaging that we can compare our approach against.

Problem Summary and Importance

- As mentioned last week, PA imaging has a wide variety of uses (cancer detection, blood vessel visulizations, etc.) but requires additional hardware.
- US systems beamform PA-derived signals incorrectly.



Beamforming Overview



Basic Theory (US signals)

$$R = ct/2,$$

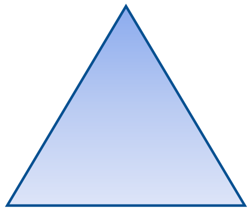
R – Distance from center of reconstruction line to image point.

c – speed of sound, *t*- travel time.
Divide by 2 since US signals are pulse-echo (signal travels twice the distance)

$$t_n(R, x_n, \theta) = \frac{\sqrt{(x_n - R\sin\theta)^2 + R^2\cos^2\theta}}{c}$$

Travel time t_n for element n, with lateral distance x_n from reconstruction line with steering angle θ

Lateral scanning: varying x_n, $\theta = 0$



Sector scanning: $x_n = 0$, varying θ

2nd Order Approximation (Simplification)

$$\tau_n(t, x_n, \theta) = -\frac{x_n \sin\theta}{c} + \frac{x_n^2 \cos^2\theta}{c^2 t}$$

US Time Delay Equation

Travel time for element n

"Steering" Term

"Refocusing" Term

$$\tau_n(t, x_n, \theta) = -\frac{x_n \sin\theta}{c} + \frac{x_n^2 \cos^2\theta}{2c^2 t}$$

PA Time Delay Equation

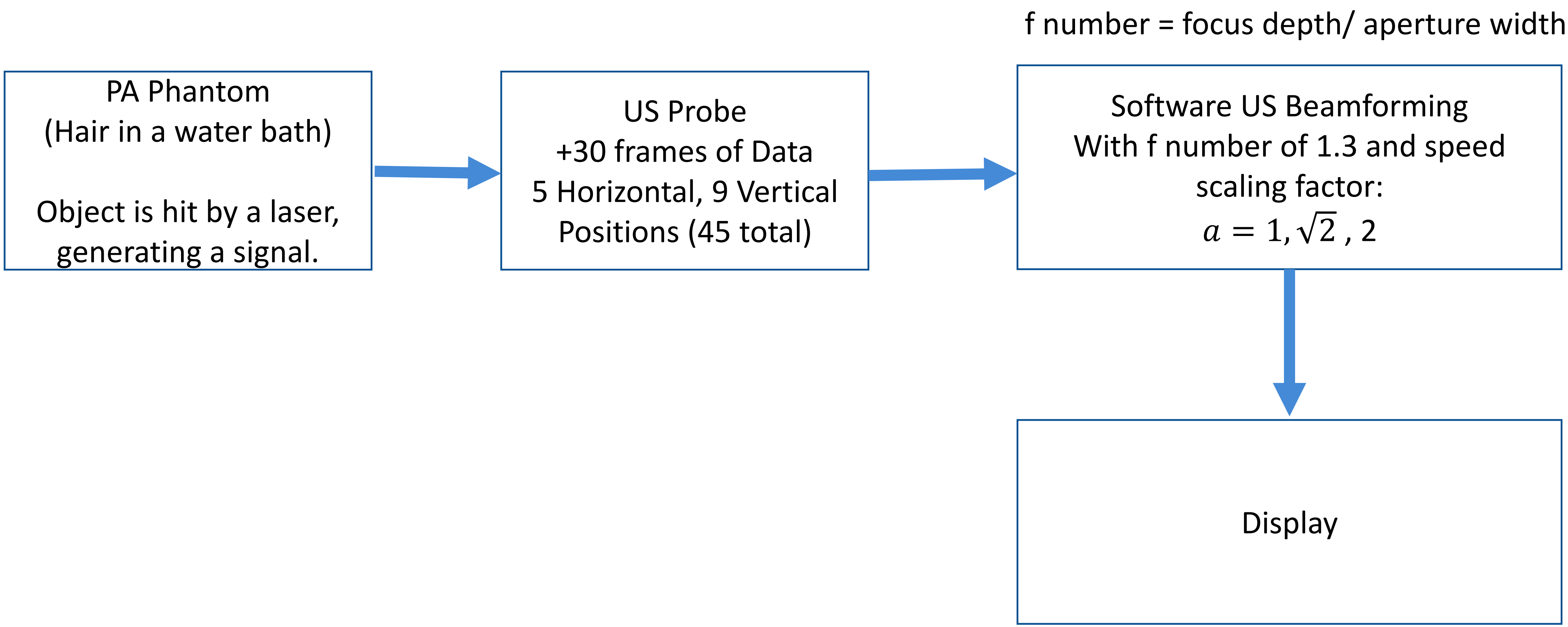
Main Idea behind PA Imaging

- Raw time delays are inaccessible.

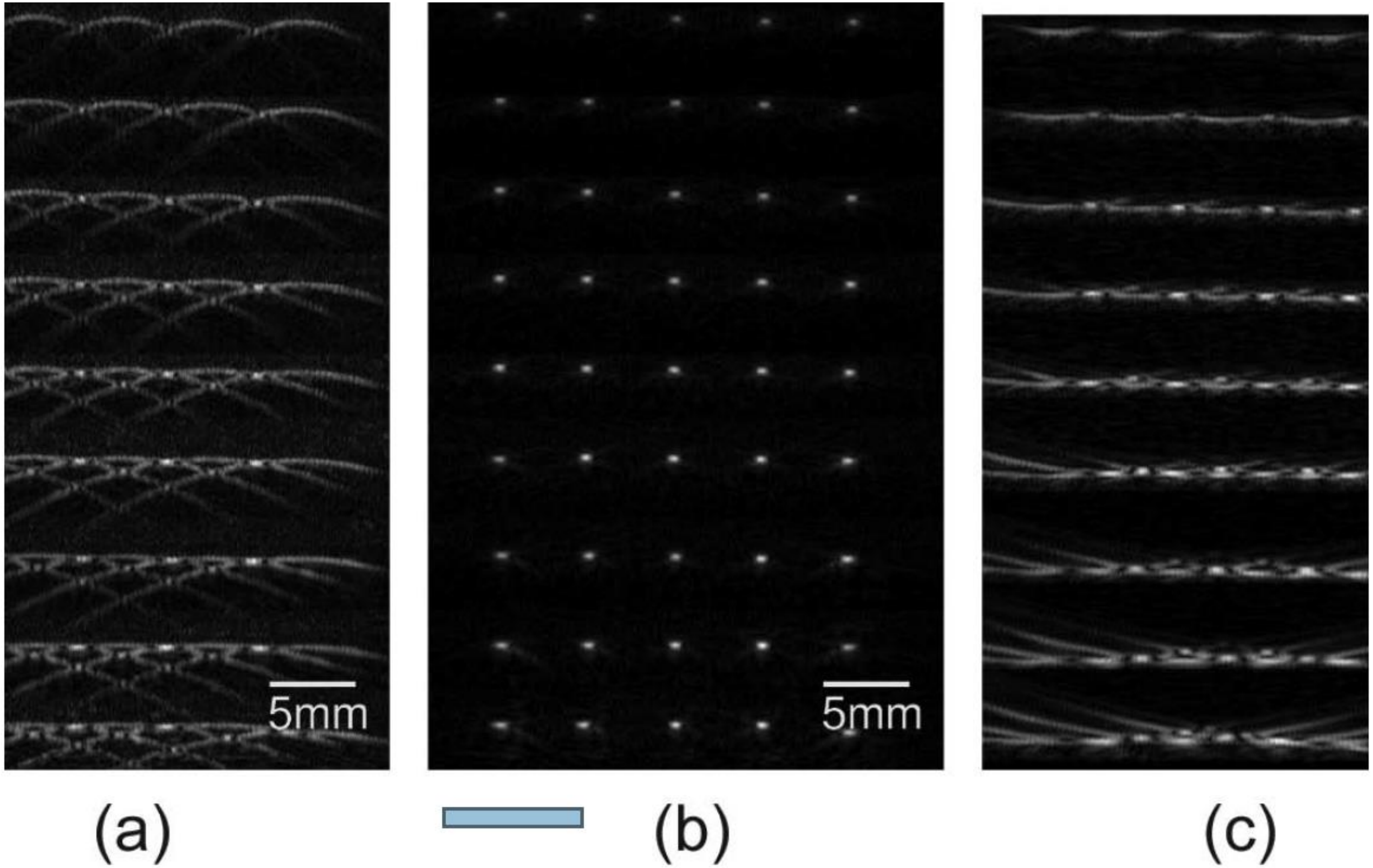
- However, some systems allow adjustment of speed of sound parameter $c = a * c_0$, where a is an adjustable scaling factor.

- So by setting a to the ‘proper’ value, we can “hack” the US beamformer to process PA signals more accurately.

Experiment Setup



Key Results (Linear Scanning)



(a) - Speed scaling of 1
(b) - Speed scaling of $\sqrt{2}$
(c) - Speed scaling of 2

Lateral Resolution improvement by a factor of $\geq$8 for optimal setting (b) in linear scanned image.

Significance and Relevance

- Demonstrates the capability of adapting US systems to perform real-time PA imaging.
- Significant improvements in PA image resolution on US system by altering the speed of sound parameter. (Simple to implement on appropriate US systems)
- More improvements in PA imaging possible (i.e. our project).

Flaws – Need to Adjust Speed of Sound!

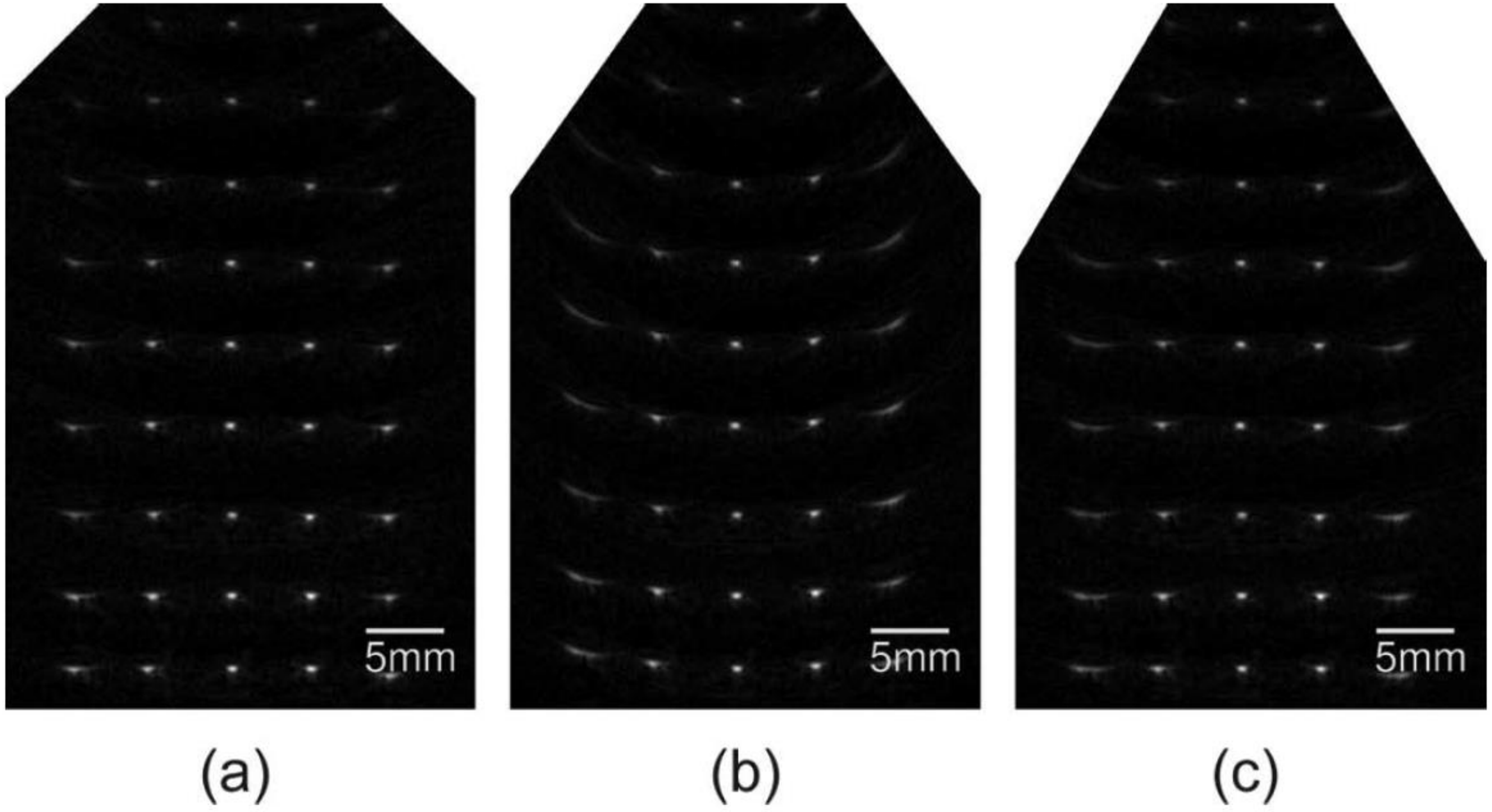


Fig. 4. Composite sector-scanned images using (a) PA beamforming and scaled-c US beamformer with $a = \sqrt{2}$ using (b) simple depth scaling, and (c) coordinate re-mapping.

Other flaws:

With speed scaling of $\sqrt{2}$ is not always sufficient.

-Depth scaling off
-Steering term off (noticeable in sector scanning)

-Need to further warp and process image (depth rescale, polar coordinate warping).

Possible Future Steps (Paper)

- More experimental setups (different PA phantoms, more US probes, etc.)
- More parameter adjustments (only 3 parameter values tested in paper).
- Test more US systems (Develop procedures to configure PA beamforming for each system).

Conclusion

- Paper presents a simple, cheap method to force certain US systems to beamform and display PA signal data.

- We hope to create a system that can perform just as well for a greater number of US systems. This paper serves as a good base for comparisons between our systems.

Reference

- Harrison, Travis, and Roger J. Zemp. "The applicability of ultrasound dynamic receive beamformers to photoacoustic imaging." *Ultrasonics, Ferroelectrics, and Frequency Control, IEEE Transactions on* 58.10 (2011): 2259-2263.