Thermally-induced Optical Reflection of Sound (THORS) in Tissue Phantoms

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Introduction

Expanding on previous work using THORS to manipulate acoustic waves in air, we investigate this phenomenon in tissue phantoms using ultrasound and potentially providing new insights into deeper tissue penetration for biological imaging and detection. In this work ultrasonic waves are reflected off a thermally-induced optical barrier, generated by a pulsed-laser and monitored via a broadband ultrasonic transducer. As the laser passes through the tissue phantom, the photothermally-induced barrier is generated causing ultrasonic waves to reflect due to the abrupt change in compressibility (**Fig 1**). This can potentially provide a means of improving both the depth and resolution of ultrasonic and photoacoustic biomedical imaging. The work explores the expansion and characterization of this phenomenon for ultrasonic waves in condensed media (i.e. tissue phantoms)[1].

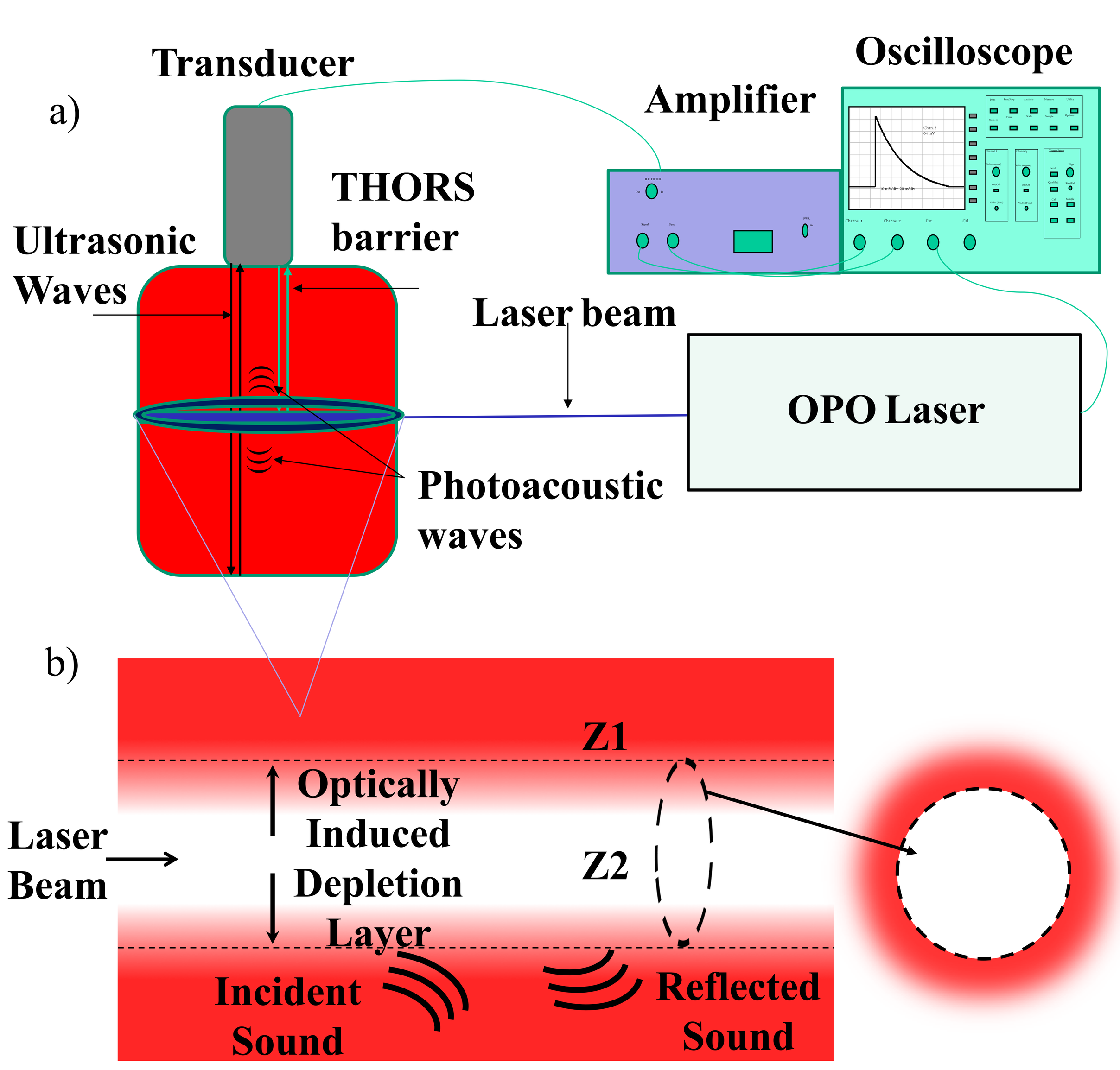


Fig 1. a) Experimental setup using ultrasound
b) Depiction of THORS barrier in tissue phantom

Experimental Procedure

Tissue Phantom Preparation [2]

To simulate optical and acoustic scattering in tissues, Bovine Gelatin tissue phantoms were prepared.

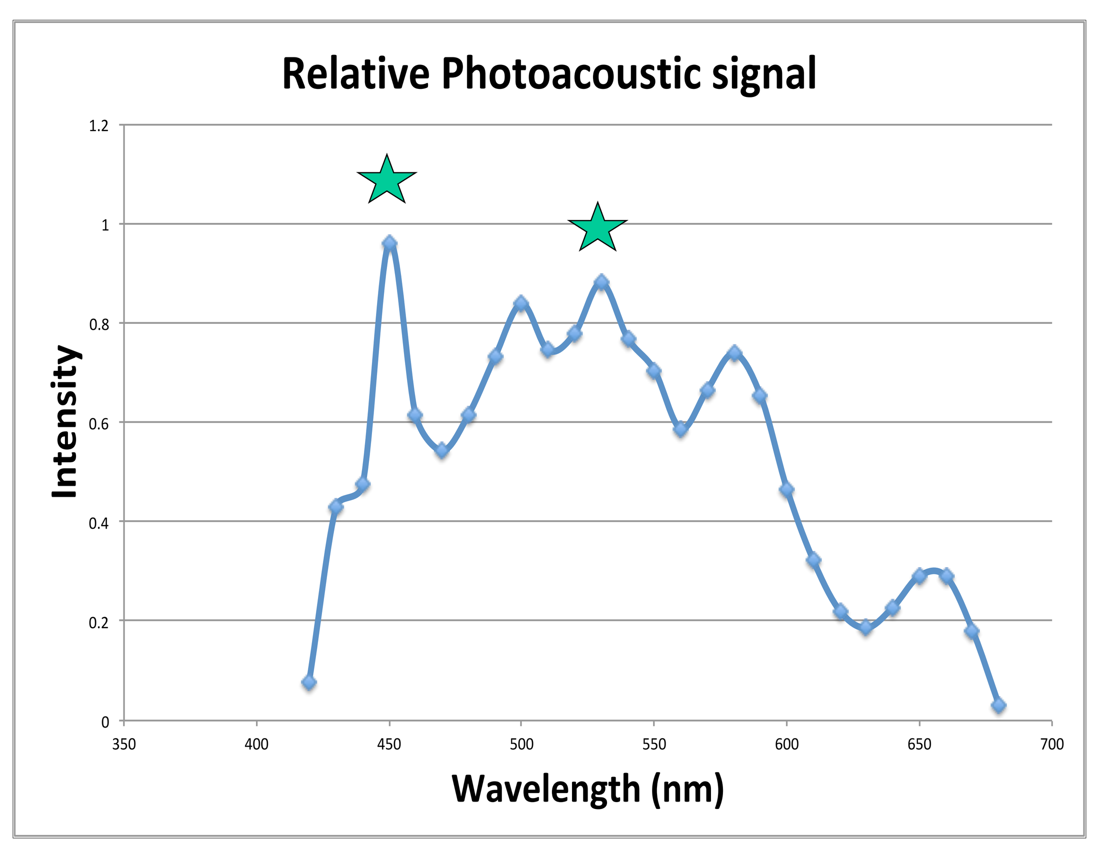
- 30 g Bovine Gelatin
- 400 mL DI water
- Tulip Red Dye stock solutions
- 1:5 stock dye solution to gelatin ratio

- Cube cut to approximately 30mm x 30mm x 30mm
- Concentrations of dye in tissue phantoms: no dye, 100 ppm, 375ppm, 875 ppm, and 1800 ppm

Results and Discussion

Photoacoustic spectrum of Tulip Red

Relative Photoacoustic signal was collected in order to determine the optimal wavelength and intensity to use for the tissue phantoms. The wavelengths chosen from the spectrum were 450 nm and 532 nm (**Graph 1**).



Graph 1. Ultrasound photoacoustic signal

Optimizing Barrier Generation in Tissue Phantoms

Tissue phantoms were doped with different concentrations of Tulip Red to provide maximal absorption while still allowing penetration through entire sample (**Fig 2**).

- Optical scattering coefficient similar to tissues (39 cm^{-1}) [3]
- Absorption at 532 nm was used due to higher laser power
- Penetration distances: 2 mm, 10 mm, 28 mm, 30 mm

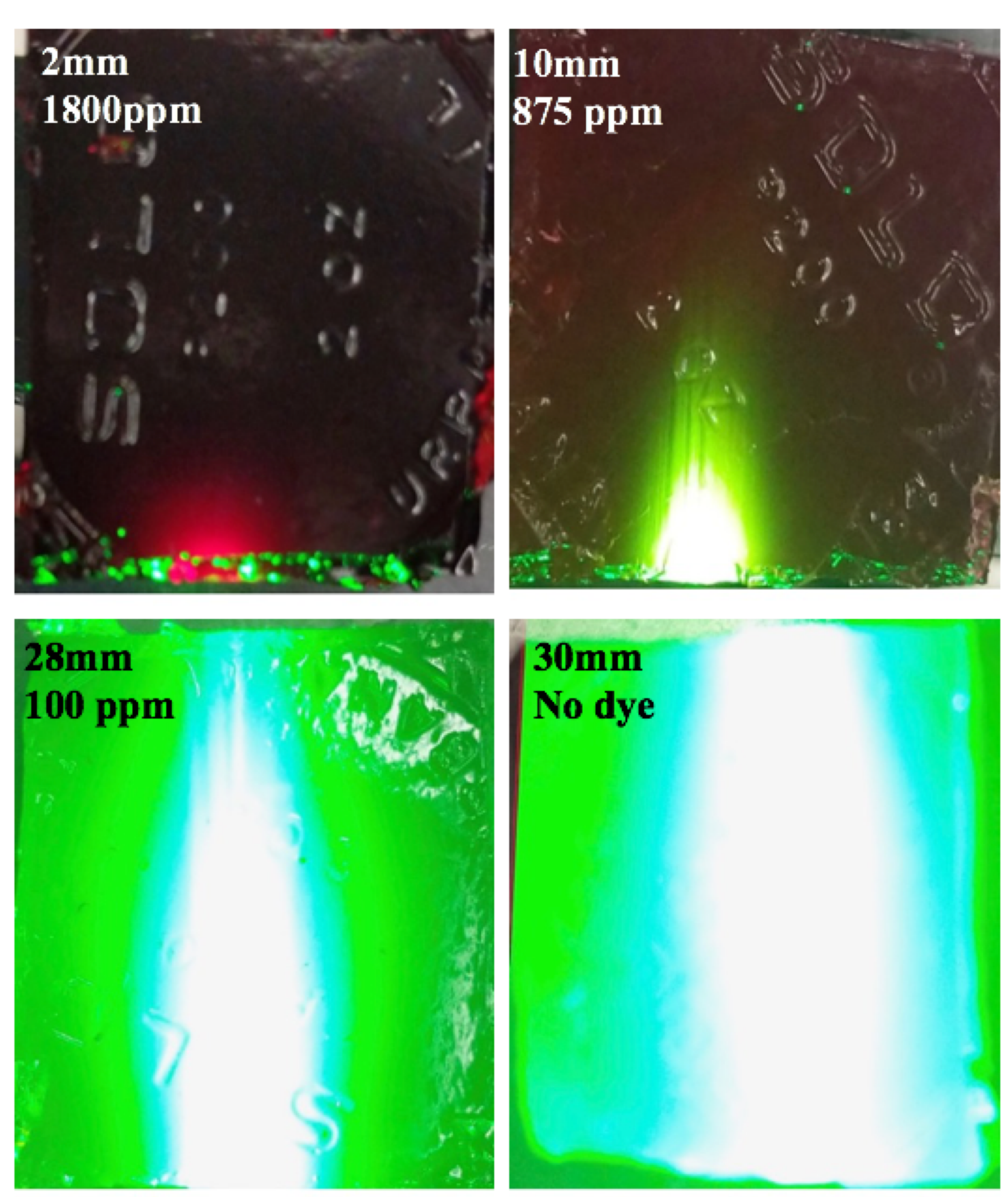


Fig 2. Images of Gelatin Phantoms

Ultra sound reflection data

In **Fig 3** below, the predicted time scale (expected THORS barrier) can be calculated based on the placement of the laser beam to the transducer and the speed of sound in tissue phantoms (1550 m/s).

- Laser pulse at time 0
- Transducer output pulse triggered within microsecond of laser
- Next is the photoacoustic signal, photothermally generated by the laser pulse
- The reflected signal is the time it took for the transducer output pulse to reach the back wall of the tissue phantom and return

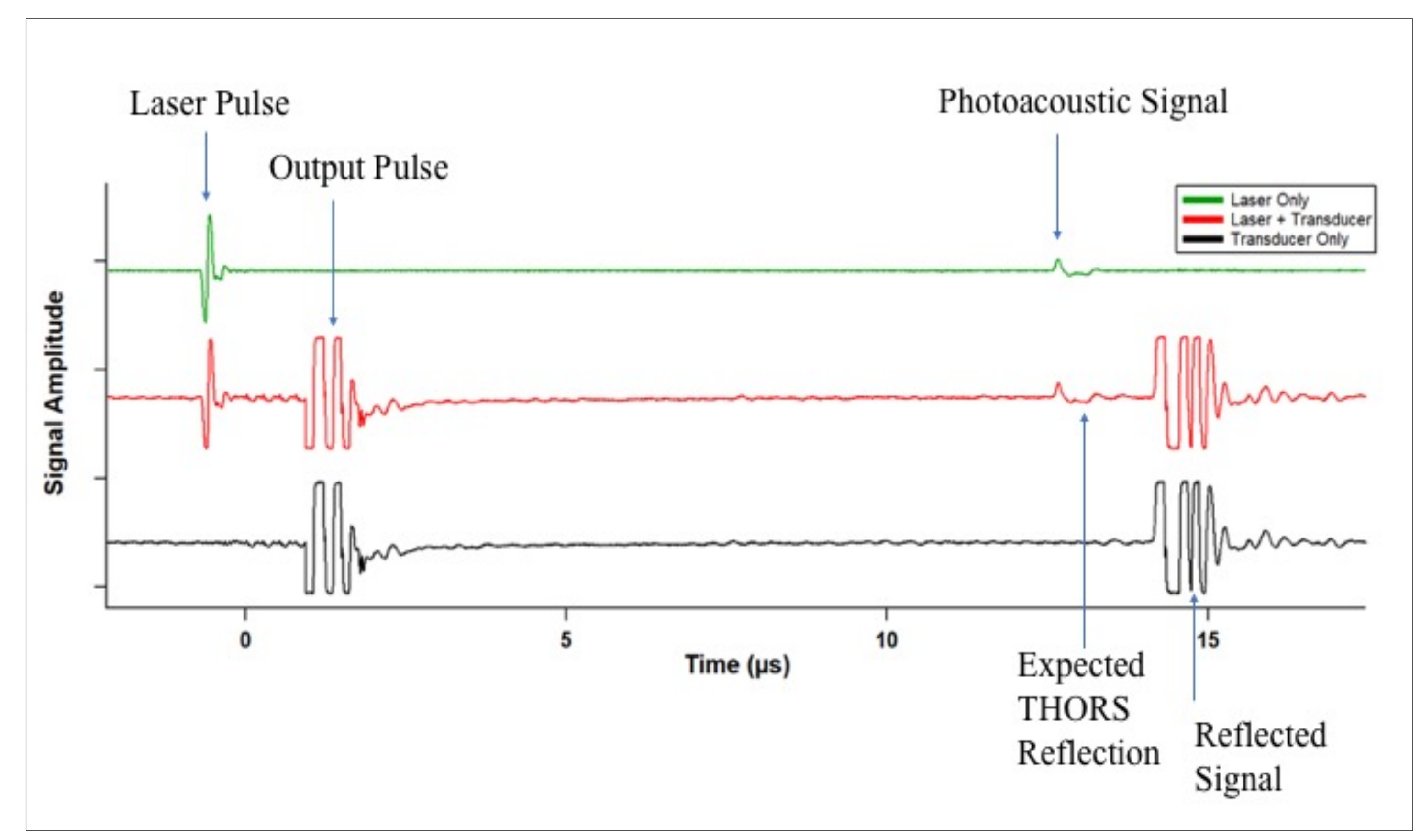


Fig 3. Ultrasound Reflection in no dye tissue phantom at 532 nm

Conclusion and Future Work

We have generated tissue phantoms with optical and acoustic scattering properties similar to soft tissues. Using tissue phantoms the optimal absorber (dye) concentration for THORS barrier generation was determined using 532 nm excitation.

Future studies will include optimization of THORS barrier generation within condensed media as well as investigation into the use of THORS for high resolution biomedical imaging. This work will also investigate the effect of pulse width of the optical channel on ultrasonic reflection efficiency at varying distances.

Acknowledgements

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