Ultrasound optical tomography using slow light filters

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Background, Motivation and Objective

Ultrasound optical tomography (UOT) is an imaging technique based on the acousto-optic effect that can perform optical absorption measurements with ultrasound resolution [1]. Simulations using the diffusion equation have shown that UOT may be able to image tissue oxygenation at depths larger than 5 cm in biological tissue [2]. Such imaging capability would be very useful at any hospital, e.g. for cancer tumor detection, or to measure tissue oxygenation across the heart. To validate these simulations we have experimentally characterized UOT signal strengths from highly scattering media.

Statement of Contribution/Methods

In Fig. 1 a simplified UOT setup is shown. Light traversing an ultrasound pulse focused inside a scattering medium is frequency-shifted via the acousto-optic effect. The frequency-shifted photons leaving the medium are discriminated from the unshifted photons using slow light filters tailored in the absorption profile of rare-earth-ion-doped crystals using laser pulses. These filters have a ~1 MHz bandwidth, >40 dB suppression of unshifted photons, and ~2π acceptance angle for scattered light. They also delay the frequency-shifted light by ~6 μs allowing time gating to separate the unshifted and frequency-shifted light. This allows for an accurate characterization of UOT signal strengths without interfering unshifted photons.

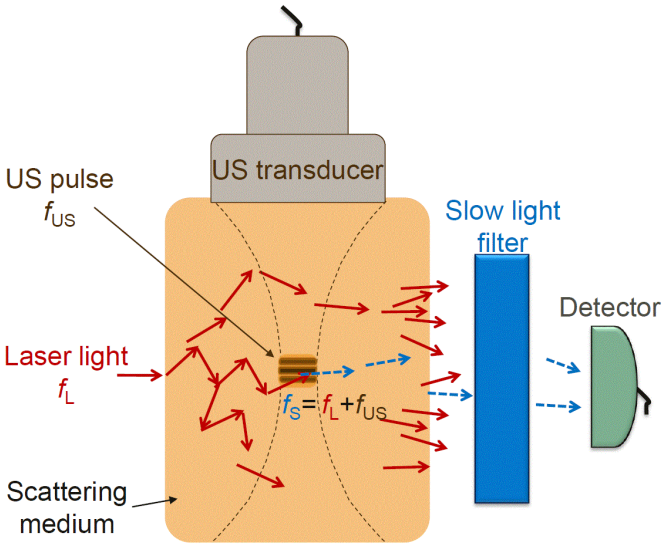

Fig. 1. Simplified UOT setup using slow light filters.

Results/Discussion

Our preliminary analysis show that experimentally measured UOT signal strengths agree with simulations based on the 1D diffusion equation. This result is an important first step to validate previous simulations [2] and to evaluate the imaging potential of UOT in general.

[1] H. Zhang, M. Sabooni, L. Rippe, C. Kim, S. Kröll, L.V. Wang, P.R. Hemmer. "Slow light for deep tissue imaging with ultrasound modulation". App. Phys. Lett. 100, 131102 (2012).

[2] A. Walther, L. Rippe, L.V. Wang, S. Andersson-Engels, and S. Kröll. "Analysis of the potential for non-invasive imaging of oxygenation at heart depth, using ultrasound optical tomography (UOT) or photo-acoustic tomography (PAT)", Biomed. Opt. Express 8, 4523 (2017).