Real-time, Swept-beam Spectroscopic Photoacoustic/Ultrasound Imaging – Pre-clinical System

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Background, Motivation and Objective

Photoacoustic (PA) imaging has had limited clinical impact for many reasons, but one primary barrier has been the bulky, expensive, and low repetition-rate laser typically used, resulting in low frame-rate images and a system with a large physical footprint. The purposes of this study are: (1) to develop an integrated photoacoustic/ultrasound (PAUS) scanner appropriate for typical applications in ultrasound clinical labs; (2) to achieve real-time spectroscopic imaging for procedure guidance and molecular imaging; and (3) to overcome major practical issues for clinical spectroscopic imaging, including in-depth fluence variation with wavelength and motion artifacts during wavelength sweeping.

Statement of Contribution/Methods

The concept of swept-beam PA imaging combining multiple sequential single fiber tissue illuminations into a resultant image was discussed in our prior work. Its primary advantage is that it can use low-cost, compact, diode-pumped lasers instead of bulky and expensive solid-state devices. Here we combine the swept beam concept, a unique compact laser (providing pulse-to-pulse wavelength tuning at 1-kHz rates), and a scanning fiber-optic delivery system integrated with a high-frequency (15 MHz) US linear array into a real-time spectroscopic PAUS system. A fiber array spans the US array on two lateral sides and is scanned sequentially using optimized pulse sequences. By coherently compounding sub-images from each fiber light source, integrated PAUS images are produced at a 50-Hz spectroscopic video rate. Finally, the high (1 kHz) sub-image frame rate can be leveraged for quantitative spectroscopic imaging by correcting for motion between different wavelength image frames using US speckle tracking, and by compensating in-depth fluence dependence using sub-images at different fiber positions.

Results/Discussion

Real-time in vivo spectroscopic imaging (715 to 875 nm) of nano-drug delivery has been demonstrated in mice. The compact PAUS system can provide not only conventional high-quality US images with all associated modes, but interleaved, fluence-corrected, spectroscopic PA imaging at a 50-Hz video rate appropriate for real-time clinical applications.

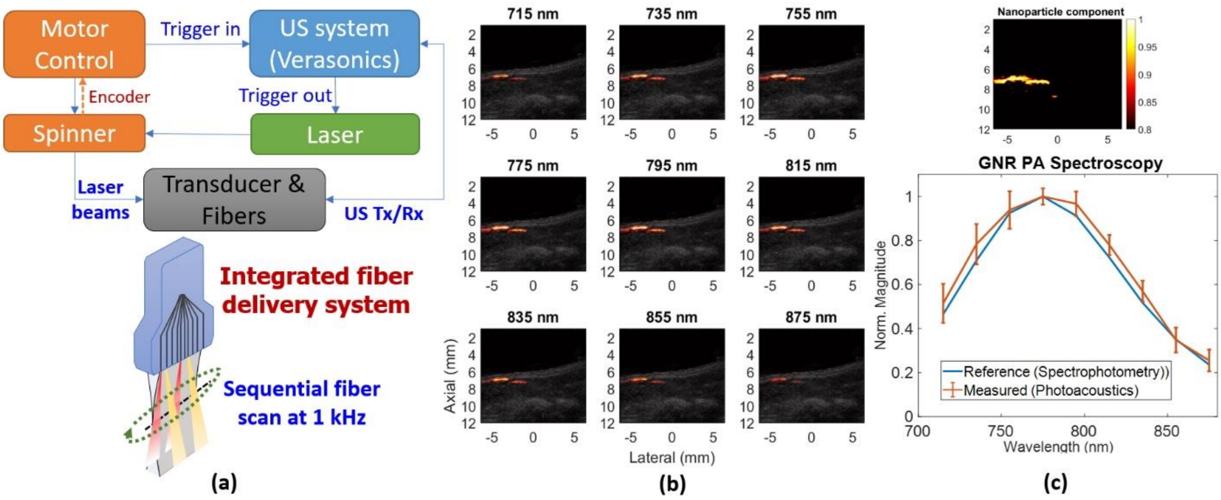

Fig. 1: (a) Real-time spectroscopic PAUS system with an integrated fiber delivery system. (b) *in vivo* spectroscopic imaging (715 to 875 nm) of gold nanorod (GNR) injection. (c) GNR spectrum measured with PAUS (below, red line) and spectroscopic imaging (above) using projection onto the reference GNR spectrum (blue line).