Toward Design of a Handheld Probe for Combined Laser, Ultrasound and Elasticity Imaging

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Background, Motivation and Objective

Combined laser, ultrasound and elasticity (CLUE) imaging is an imaging technology capable of ultrafast and contrast-enhanced ultrasound (US), multi-wavelength photoacoustics (PA) and shear wave elasticity imaging (SWEI). However, clinical implementation of CLUE imaging requires a compact handheld probe which integrates US array of transducers and a light delivery system for optimal performance in each imaging mode. It is known that sensitivity of PA and light-and-sound imaging is best if both ultrasound and light beams overlap as much as possible including the entry area on the surface. A stand-off is one possible solution yet it has several deficiencies including displacement of an elevational focus, decreased spatial resolution, and reduced efficiency of shear wave generation. In this paper, we introduce a new design and test the performance of a CLUE imaging probe.

Statement of Contribution/Methods

The conceptual design of CLUE imaging probe is shown in Fig. 1A. To redirect the US beam while preserving the location of the elevational focus of L11-4 array transducer, a cylindrical convex reflector (95 mm curvature) and a right angle prism were used. Light was delivered through the prism using fiber optics with varying area of irradiation. Overall, ultrasound and light beams overlap with a 3° angle. To test the probe, the experiments were conducted using a phantom (7% gelatin, 5% silica particles) with an inclusion (12% gelatin, 5% silica particles, 3% graphite) having ultrasound, optical and elasticity contrast. The phantom was irradiated with 5-ns laser pulses at 1064 nm wavelength, and imaged using Verasonics Vantage system.

Results/Discussion

US and PA images of the phantom with inclusion, and map of shear waves propagating through the inclusion are shown in Fig. 1B, 1C and 1D, respectively. In all images, the inclusion can be easily identified. In our design, curvature of the US reflector allows adjustment of the elevational focus in the ultrasound imaging plane. If necessary, another US array transducer could be added on the other side of the prism to enable, for example, PA imaging and shear wave excitation at low frequency and US imaging at high frequency. Also, the design of CLUE imaging probe is compact and comfortable for handheld operation.

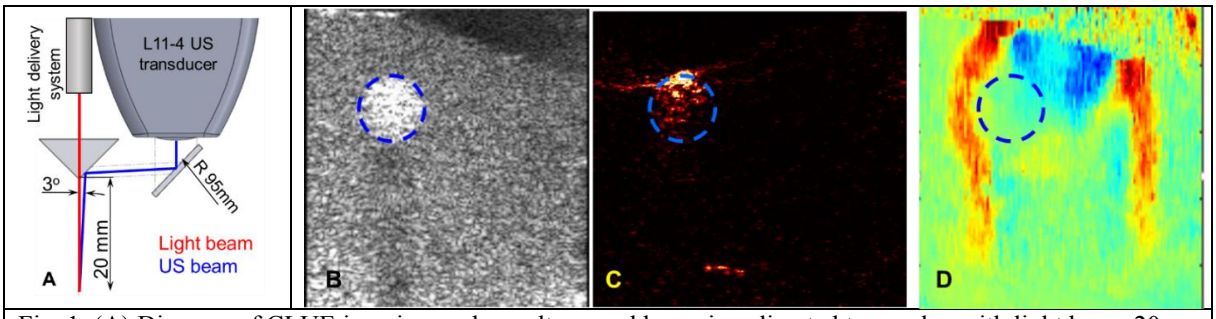

Fig. 1. (A) Diagram of CLUE imaging probe – ultrasound beam is redirected to overlap with light beam 20 mm away from a prism. Angle between ultrasound and light beams is 3°. Curved ultrasound reflector with curvature radius of 95 mm was used to adjust elevational focus of the US array such that light and ultrasound beams overlap at the same point. Co-registered (B) ultrasound image, (C) photoacoustic image, and (D) a snapshot of shear wave propagation. The shape of the left shear wave is curved because the wave already propagated through the stiffer inclusion. In all images, location of the inclusion is marked by a blue dashed circle.