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Ex-vivo, remote photoacoustic sensing using speckle-analysis

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1. Motivation

The emerging hybrid imaging modality Photoacoustic Tomography (PAT) offers a lot of advantages compared to purely optical or acoustic imaging of soft tissue. At the moment, contact based ultrasound transducers are the state of the art for the detection of the acoustic signal. As they are contact-based, the field of view during the imaging process is restricted and they are not useful for special applications like wound imaging. That is why a remote, easy and robust modality for the detection of the acoustic signal would be beneficial. It has already been shown that it is in principle possible to remotely detect acoustic surface deformations which exist for PAT using speckle-sensing [1]. However this work just shows the feasibility of the approach using unrealistic hard phantoms. In this work, results for soft tissue phantoms and ex-vivo experiments are shown.

2. Materials and methods

When the acoustic wave interacts with the surface, it deforms it, which can also be seen as a tilting of the surface with the angle α. If a rough surface is illuminated with a cw-laser, a speckle pattern is generated. According to Zalevsky et al. the shift of this defocused speckle pattern on a camera is directly proportional to α [2]. In order to reconstruct α, the relative shift in pixel between the image frames of a video is extracted using a correlation method. Figure 1 displays the setup and the geometry for the soft PVCP-phantom (Polyvinylchloride-Plastisol) and ex-vivo sample (pork belly steak). The objects are excited using a short laser pulse (5 ns, 532 nm). The speckle pattern is generated with a cw-laser at 532 nm (100 mW) and is tracked with a high-speed camera (Vision Research, Phantom v1210, frame rate 824 kHz).

3. Results

The results in figure 2 show that the PVCP phantom geometry and the ex-vivo sample geometry match the detected speckle-pattern shift. The first peak of the signal at a time of 13.4 µs is due to the acoustic signal, which is generated directly when the short laser pulse hits the absorbing surface.

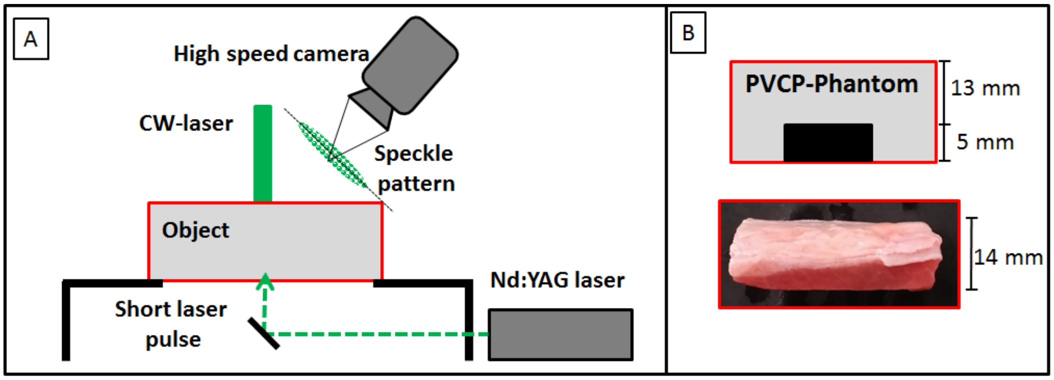

Figure 1. A: The object is excited with a short laser pulse and the speckle pattern is acquired with a high-speed camera. B: The sample geometries are shown

With a sound velocity c of 1350 $\frac{m}{s}$ for PVCP a running distance of the acoustic signal of 18 mm results, which corresponds to the phantom height. There is also a second signal peak visible which corresponds to the reflected initial signal. The results for the tissue experiments also match the sample dimensions. With an average c = 1400 $\frac{m}{s}$ for the sample, the first deflection at 10 µs corresponds to 14 mm and thus to the sample thickness. Also for this sample there is a clear second peak which belongs to the reflected initial signal. The displayed results show that with the contactless speckle vibration analysis, it would be in principle possible to detect a photoacoustic signal on tissue and derive structural information from it.

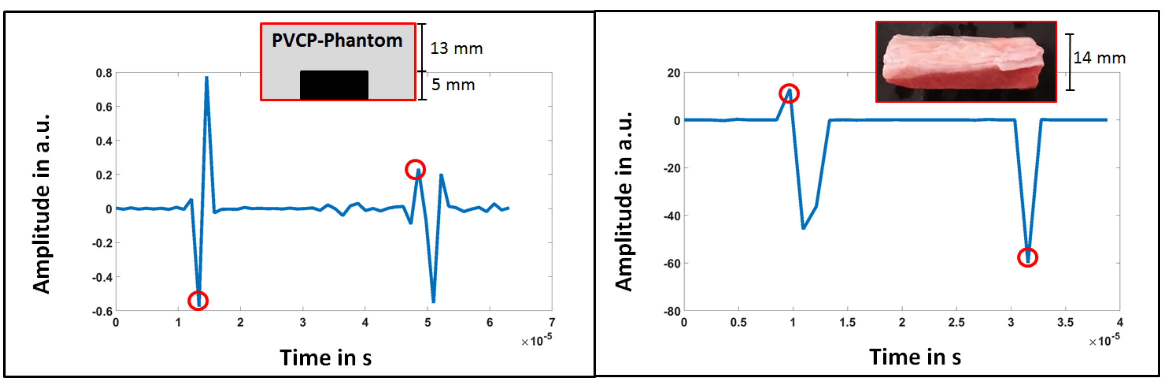

Figure 2. Results for the temporal speckle shift for the soft phantom sample and the ex-vivo sample. The initial photoacoustic signal and its reflection are marked.

References

[1] Lengenfelder, Benjamin, et al. "Remote photoacoustic tomography using speckle sensing with a high-speed camera." Optics and the Brain. Optical Society of America, 2016.

[2] Zalevsky, Zeev, et al. "Simultaneous remote extraction of multiple speech sources and heart beats from secondary speckles pattern." Optics express 17.24 (2009): 21566-21580