Photoacoustic imaging with applications in the breast

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We present the basic physics, technology and applications of photoacoustic imaging. We start with the motivation to use the method, show how image formation takes place, show examples of photoacoustic imaging configurations developed. We close with potential clinical applications, focusing on breast cancer imaging.

We present the basics of the physics, technology and applications of photoacoustic imaging. Photoacoustic (PA) imaging, is a non-invasive imaging modality that relies on optical absorption of tissue constituents for contrast. In PA, nanosecond laser pulses are used to illuminate the tissue. The light gets scattered inside the tissue getting absorbed at locations where there is especially blood present. The absorbed optical energy is converted into heat leading to thermoelastic expansion. This produces mechanical waves with frequencies lying in the ultrasound (US) frequency. The propagating US experiences relatively low scattering, allowing accurate localization of the often deeply located US sources. The method is attractive since it combines the rich optical contrast in tissue, with the ability to localize this contrast deep inside soft tissues with high resolution.

PA tomography is interesting for imaging dominantly blood vessels which is important functional and physiological information in living tissues. For example, several cancers have a higher density of blood vessels produced by the phenomenon of angiogenesis. Imaging these could help in detecting and diagnosing cancer. We will present various implementations of photoacoustic imaging instrumentation and discuss various clinical applications which are being researched. We will concentrate especially on applications involving breast cancer. Imaging the breast is important since breast cancer has the highest incidence of female cancers globally, with 2.3 million new cases and 685,000 deaths in 2020. Further, clinical breast

imaging methods suffer from drawbacks and limitations. PA imaging may have several advantages and high potential to make a clinical breakthrough in breast cancer imaging. We have recently developed a hybrid breast imaging system (PAM3) that has for the first time multi-wavelength PA imaging capability, as well as the capability to measure a full three-dimensional (3D) sound speed map of the breast through hybrid ultrasound-transmission tomography (UST). We present details of the PAM3 system, a comprehensive characterization of its capabilities on a specially-developed suite of test-objects and sophisticated phantoms, and demonstrate its performance on healthy breasts.

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