PhD Thesis title: 'Optimizing ultrasound detection for sensitive 3D photoacoustic breast tomography'

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ABSTRACT:
The standard modality for breast cancer detection is X-ray imaging. Diagnosis is performed after the triple assessment of X-ray mammography assisted by ultrasonography and biopsy. Magnetic resonance imaging (MRI) is sometimes used in specific problem solving such as contradictory results obtained from X-ray and ultrasound images. X-ray mammography is capable of producing 2D projection images with a high spatial resolution. However, X-ray mammography besides posing ionizing hazards, is less sensitive in women with dense breasts. In addition, X-ray mammography has difficulties to image tumors close to the chest wall. Ultrasonography suffers from poor soft tissue contrast, inherent speckle noise, strong operator dependence and lack of standardization. MRI has high sensitivity but suffers from variable specificity, a relatively high cost and needs the use of a contrast agent. Thus, there is a great need for an alternative technology to detect and diagnose early stages of breast cancer with high sensitivity and specificity.

Photoacoustic imaging has shown great potential to visualize high optical absorption contrast based on hemoglobin absorption that can impact breast cancer detection and diagnosis. State-of-the-art photoacoustic breast imaging systems are promising but are limited either by only a 2D imaging capability or an insufficient imaging field-of-view in 3D. This thesis investigates various aspects regarding the design and development of a sensitive 3D photoacoustic tomography system for full breast imaging, focusing on the optimization of ultrasound detection, the heart of the system.

We comprehensively studied improvements in piezoelectric ultrasound detectors, developing a very sensitive detector intended for photoacoustic breast imaging. This thesis concludes with a laboratory prototype of a breast imaging system based on such a device. The system possesses a 2 mm XY plane resolution and a 6 mm vertical resolution. A vasculature-mimicking object was successfully visualized down to a depth of 40 mm in the breast phantom. Further, tumor mimicking spherical objects with diameters of 5 and 10 mm, at 20 mm and 40 mm depths are recovered, indicating high system sensitivity. The system has a 170 x 170 x 170 mm^3 FOV, which is well suited for full breast imaging. This imager forms the basis for a clinical version being developed. Various recommendations are provided for performance

improvement and to guide this laboratory prototype to a clinical version in the future.

References to author publications that relate specifically to the dissertation:

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2. **W. Xia**, D. Piras, M. Heijblom, W. Steenbergen, T. G. van Leeuwen and S. Manohar, "Poly(vinyl alcohol) gels as photoacoustic breast phantoms revisited," J. Biomed. Opt. 16(7), 075002, (2011).

3. M. Heijblom, D. Piras, **W. Xia**, J.C.G. van Hespen, J.M. Klaase, F.M. van den Engh, T.G. van Leeuwen, W. Steenbergen, and S. Manohar, "Visualizing breast cancer using the Twente photoacoustic mammoscope: What do we learn from twelve new patient measurements?," Opt. Express 20, 11582-11597, (2012)

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6. **W. Xia**, D. Piras, M. K. A. Singh, J. C. G. Van Hespen, T. G. van Leeuwen, W. Steenbergen and S. Manohar, "Design and evaluation of a laboratory prototype system for 3D photoacoustic full breast tomography," Biomed. Opt. Express 4(11) (2013).