A DIFFUSE OPTICAL TOMOGRAPHY SYSTEM COMBINED WITH X-RAY MAMMOGRAPHY FOR IMPROVED BREAST CANCER DETECTION

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ABSTRACT

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The central thesis of this dissertation states that optical imaging of diffuse tissues must be combined in co-registration with a recognized gold standard of mammographic screening, i.e. X-ray mammography, to gain wide acceptance in the clinical environment. This multi-modality imaging approach promises to overcome the deficiencies of both imaging modalities by drawing on the strengths of each. Functional and structural image contrast would be provided by optical and high-resolution structural contrast by X-ray. Furthermore, the structural information provided by X-ray could be used to improve the optical image reconstruction by providing boundary information and soft constraints for weakly correlated structural contrast. Ultimately, image-processing techniques could be developed to provide the radiologist with a three-dimensional image indicative of both optical and X-ray contrast that would provide much greater information content than either modality alone.

The design, characterization and optimization of a novel Time-Domain Optical Breast Imaging System are described. A comprehensive noise theory for ICCD's and laser source systems was developed to provide insight into methods for optimization of the time-domain system. The system used a mode-locked Ti:Sapphire laser source coupled to a 150-source fiber probe by a Source Fiber Multiplexer with a fiber-to-fiber switch time of under 300 μsec. This represented an improvement in switch time of more than three orders of magnitude over systems described in the literature. The unique multi-modality probe was designed with quick-release features to permit a co-registered X-Ray image to be acquired within seconds of the optical image. Massively parallel detection of 313-detector fibers was enabled by a custom designed, high performance objective, interfaced to a time-gated, image-intensified charge coupled device camera (ICCD). The time-domain system was shown to be capable of acquiring a data set with high spatial resolution in less than 3 minutes, consistent with the requirements of a clinical-level system. Recommendations as to methods of optimizing the system performance are reported.

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I recall visiting Tufts University several years ago to discuss the possibility of entering the doctoral program. I was elated to hear about a new professor that was soon to join the Electro-Optics Technology Center, coming out of the University of Pennsylvania. Although young, he was reported to be one of the leading authorities on the propagation of light in biological tissues, an area of study that piqued my interest. I asked the program director to sign me up as a student before David Boas even set foot on campus. I want to express my deep gratitude to David for taking me on early in his successful career and for all his continued patience and support over the last several years. It has truly been an honor working under the direction of one of the recognized fathers of the field of DOT.

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