In the field of medical diagnostics, biomedical photoacoustics (PA) is a non-invasive hybrid optical-ultrasonic imaging modality. Due to the unique hybrid capability of optical and acoustic imaging, PA imaging has risen to the frontiers of medical diagnostic procedures such as human breast cancer detection. While conventional PA imaging has been mainly carried out by a high-power pulsed laser, an alternative technology, the frequency domain biophotoacoustic radar (FD-PAR) is under intensive development. It utilizes a continuous wave optical source with the laser intensity modulated by a frequency-swept waveform for acoustic wave generation. The small amplitude of the generated acoustic wave is significantly compensated by increased signal-to-noise ratio (several orders of magnitude) using matched-filter and pulse compression correlation processing in a manner similar to radar systems. The current study introduces the theory of a novel FD-PAR modality for ultra-sensitive characterization of functional information for breast cancer imaging. The newly developed theory of wavelength-modulated differential PA spectroscopy (WM-DPAS) detection has been introduced to address angiogenesis and hypoxia monitoring, two well-known benchmarks of breast
tumor formation. Based on the WM-DPAS theory, this modality efficiently suppresses background absorptions and is expected to detect very small changes in total hemoglobin concentration and oxygenation levels, thereby identifying pre-malignant tumors before they are anatomically apparent. An experimental system design for the WM-DPAS is presented and preliminary single-ended laser experimental results were obtained and compared to a limiting case of the developed theoretical formalism.