3/5/11

Final Report for the Nicholas and Elizabeth Slezak Super Center for Cardiac Research and Biomedical Engineering at Tel Aviv University:

Blood flow mapping using Doppler Photoacoustic imaging

Prof. Avishay Eyal, School of Electrical Engineering, Faculty of Engineering
avishay@eng.tau.ac.il

Non-invasive flow mapping in blood vessels is a field of growing interest. The most common and mature techniques are Doppler Ultrasound (DU) and Laser Doppler Velocimetry (LDV). Other purely optical techniques such as Optical Coherence Tomography (OCT) and Laser Speckle Imaging (LSI) have also been utilized for blood-flow measurement. All these techniques are based on scattering of waves from a moving medium and characterization of velocity-dependent features in the scattered waves. Recently, it was proposed to use the photoacoustic Doppler (PAD) effect for in-vivo measurement of flow. Photoacoustic (PA) imaging in general is based on measurement of the acoustical waves that are generated due to the absorption of modulated light in a tested medium. When the excited region comprises a moving fluid with light-absorbing particles, such as the red blood cells (RBCs) in blood, the generated PA waves exhibit a Doppler shift proportional to the flow velocity. In previous works we have presented the use of tone-burst optical excitation for time-resolved spectral mapping of flow. In this excitation method, like in regular pulsed excitation, the mean power is dictated by the multiplication of the peak power, the pulse duration and the pulse repetition frequency (PRF). When we would like to map the axial position as well as the flow, the pulse duration is limited by the required axial resolution and the PRF is limited by the time it takes the acoustic wave to travel from the farthest imaged object to the transducer. While peak power is high enough for biomedical applications when using a Q-switched Nd:YAG laser, Optical Parametric Oscillator or a dye laser, it is significantly limited in laser diodes, in order to avoid catastrophic optical damage to the diode facet. However, the use of laser diodes is desirable due to their compact size, low cost and availability in a wide range of wavelengths in the visible and near-IR ranges which are applicable for biomedical imaging. Therefore, it is desirable to find methods to improve the SNR of the photoacoustic response under peak power limitations. In the last research year we have made a significant progress in developing methods for PA Doppler measurement of flow via a system of high frequency modulated laser diodes. In particular we have demonstrated the use of interleaved sequences of tone bursts for efficient utilization of the time and frequency domains. An adequate processing of the PA return signal enables spectral separation of the responses to the different tone burst sequences and their overlaying for obtaining images with enhanced SNR. The advantage of using such coded excitation is shown in the figure below.

The funding of the *Nicholas and Elizabeth Slezak Super Center* (together with additional funds) enabled us to obtain a Laser Diode system in the bio-compatible wavelength range of 830nm. Using this system we have been able to demonstrate SNR enhancement in vascular phantoms. We are currently working on summarizing our novel method and these results in a Journal paper where the contribution of the Slezak center will be appropriately acknowledged.