Time-domain diffuse correlation tomography

Blood plays a vital role in the normal functioning of the body. It supplies oxygen and nutrients to all organs and removes metabolic residues. Abnormalities in blood perfusion are a crucial component in various conditions such as cancer, stroke, traumatic brain injury, peripheral arteries and cardiovascular diseases. Monitoring circulatory (cardiovascular system) and blood flow measurement allow for an understanding of the normal conditions of oxygen supply to the tissue and its consumption, moreover, play an important role in clinical applications. However, performing a direct and non-invasive blood flow measurement is a challenging process, especially on the brain, or similar organs, where the target medium is hidden under multiple layers of different biological tissues.

One promising non-invasive method to quantifying blood flow in the brain is diffuse optics. Diffuse correlation spectroscopy (DCS) is capable to estimate blood flow in the tissue using constant amplitude and continuous wave (CW) laser light. Near-infrared light is delivered to the sample using a fiber optic (emitter). The emitted light propagates through the sample and collected by another fiber optic, located at a distance of ρ from the emitter. The autocorrelation of the intensity fluctuations indicates the trend of detected photon decorrelation along time, and future, its decay is proportional to the blood flow of the tissue of interest. However, this method works correctly for homogenous samples; it fails for mixed dynamics and heterogeneous medium, which are more similar to the biological tissues.

In order to solve this problem in 2016, a group of scientists from Harvard Medical School developed a time-domain version of DCS (TD-DCS). In general, this method enables to study the sample dynamics at different depths, which should allow the quantification of blood flow at the different layers of the sample. However, the ideal TD-DCS technique requires pulse lasers with long coherence length (narrow spectral line), this method has not yet well developed, and the coherence length of the available systems are limited to several centimeters. For this reason, the spatial resolution of TD-DCS is insufficient, and the current instruments are incapable of quantifying the blood flow in mixed dynamics media, such as layered biological tissues.

As part of this project, we solve this problem by employing a novel approach to model the autocorrelation function of the sample. For the first time to our knowledge, we develop the standard model with additional exponential terms, which allows to distinguish different dynamic components, including static, slow and fast flows. As a result, we are able to estimate the dynamic of the sample of interest more precisely by removing the contribution of the layers hiding the target sample. This approach has already been verified on tissue-like phantoms to correctly estimate the dynamics in a medium hidden by a highly 5 mm static slab. In the next step, we will investigate whether the exclusion of static scattering components enables us to illustrate the distribution of different scattering components in multi-layer biological tissues, including skin, bones, joints, and muscles. Finally, we provide a comprehensive tool to study both the dynamics and the structure of biological tissues using diffuse optics.