Outline of projects: NSERC USRA 2021 - Mermut

Outline of project 1: Multiplexed Radiochromic Dosimetry for Cancer Radiotherapy

Radiotherapy plays an important role in half of cancer patients, with an ever increasing need for quality assurance and quality control metrics. Advances such as image guidance for both external beam and brachytherapy treatment, are more widely implemented now, with radiotherapy clinics demanding more sophisticated control in radiotherapy. A low-cost, robust and real-time dosimetry system is essential to assure high quality radiation treatments regardless of resources and treatment setting.

Although patient dosimeters are currently implemented, extensive measurements are rare due to its prohibitive costs and limited resources. Our global goal is to develop a disposable real-time dosimeter probe based on a radiochromic sensor materials which we have previously demonstrated as a feasible solution. Specifically, one important aim is to conceive a design and demonstrate a new auto-calibrating feature through modification of radiochromic film. This integration of a self-calibration dye will enable a system that is easily operated and deployed. As such, in the long term, aim to spread its use in Global Health arenas and in underdeveloped regions in order enable delivery of high quality cancer radiation treatment.

In this NSERC USRA project, our research interest is to examine the question of how we can integrate into our developing formulations of radiochromic sensors with multiplexed sensing capability in a single fiber probe setup. One way to achieve this is through a liquid core fiber optic scheme. Experiments, spectroscopic analysis, and modeling of results will be closely conducted with our key collaborators (Dr. Alexandra Rink – UHN, and Dr. David Lewis). Demonstration of an automated calibration function with a dye, in concert with spatially-resolved detection, will be the ultimate goal of this study. Various radiochromic materials will be assembled in a unique, microstructured hollow core fiber optic probe. They will be optically evaluated with this configuration through quantitative absorption spectroscopy. The stability, integrity and robustness of this novel multiplexed sensor and its limits of spatial resolution will be assessed. We will benchmark to other multimodal non-fiber based configurations for spatially-resolved dose measurement used in ionizing radiation detection.

Under the guidance of our Post Doc, Dr. Chris Schruder, this NSERC USRA project principally aims to assemble this microfluidic fiber optic sensor and characterize its radiochromic properties within the context of a multiplexed sensors in series. With the research team, the student shall work on selecting suitable demonstrator dyes, fabrication of the hollow core setup, and determination of absorption spectral properties for spatially resolved detection of radiochromic fluids in a single fiber sensor. Optical probe optimizations will be investigated based on results. Variability and stability of the signal in this novel spatially-resolved configuration will be ascertained through experimental and modeling research activities.

Outline of project 2: Optical Coherence Tomography Evaluation of Oral Cancer

Structural, optical imaging within tissues is promising for the medical screening and diagnosis of various diseases, such as prevalent oral cancers. Optical coherence tomography (OCT) is an example of a non-invasive interferometry technique that allows micron scale resolution for structural determinations within complex tissues architectures. However, current imaging depth is limited to approximately 1 mm at best for most tissues (with the exception of ocular) due to absorption and scattering effects which attenuate light through oral tissues. Our aim with OCT is to resolve tissue structural properties, at high axial and lateral resolution, while concurrently enabling deep optical imaging in tissues with NIR wavelengths. One strategy is through optical clearing methods. By obtaining quantitative characterization of the structural properties of tissue lesions, (refractive index and scattering coefficient) we hope to obtain an "optical biopsy" metric for identification of abnormal tissue microstructures due to cancerous lesions. In the long term, we aim to use our OCT technique for routine clinical screening of the oral mucosa for cancer.

In this project, our specific aim is to build on our recently developed computational models to determine and discriminate optical attenuation coefficients of healthy and diseased tissues obtained from our OCT data. This will be based on elaborations of a previously established model (K. A. Vermeer et al.(2014) Biomed Optics Express, (5) as well as extension of models for more accurate determinations of scattering from our spectral domain OCT setup. A numerical model has been developed but needs to be tested and validated now with scanned pathological samples (collaborator Dr. Christina McCord, Western). These samples have been obtained from two unique Fourier domain configurations of OCT; spectral domain and swept source. Determination and discrimination of scattering coefficients obtained from these diseased tissue layers, through analysis of data using appropriate models, is our project's goal. The NSERC USRA student shall be responsible mainly for data analysis and therefrom expanding on the models based on the results. This includes testing, validating and optimizing the computational models' robustness in determination of accurate scattering coefficients and refractive index. We will also quantify the impact of application of optical clearing materials. The biophysics/physics shall be comfortable developing Matlab code. The student will benchmark results to a series of tissue-mimicking optical phantoms (tissue mimetic "model" materials) having varying and well-controlled optical properties. Statistical assessment of optical measurements obtained from a large dataset bank of diseased tissues will be required. Mainly, the student shall contribute to optimizing our models, and detailed data analyses of pathological samples.