NDnano Summer Undergraduate Research

2018 Project Summary

1. Student name & home university:

Mark Etzelmueller, University of Notre Dame

Stephen Bauer, Purdue University

2. ND faculty name & department:

Dr. Thomas O'Sullivan, Electrical Engineering

3. Summer project title:

Development of Microimplants for Deep Tissue Optical Sensing

4. Briefly describe new skills you acquired during your summer research:

This summer, we demonstrated an initial proof-of-concept test of a micro-implantable tissue sensor and proved that our device is capable of measuring the surrounding optical properties of a tissue-simulating phantom in a precise and stable manner. This involved designing and fabricating and integrating circuits capable of powering the laser and amplifying a photodetector, programming a microcontroller to orchestrate sensing, and communicating with the microcontroller. Specifically, we became familiar with the RSL10 microcontroller firmware, and used C++ to code our device. Finally, we gained a deeper understanding of tissue optics, embedded programming, and wireless communication.

5. Briefly share a practical application/end use of your research:

This device, when fully developed, will be used in the human body to continuously monitor deep tissues and organs, such as disease progression and treatment, in real time. Monitoring tissue response through real time feedback will allow for more personalized treatment, while the deeper depth of measurements (> 1 cm) is an improvement over previous devices. This device is designed to be placed anywhere in the human body, such as vital organs or tumors, while still being able to fit inside of a needle to allow for injection into a tumor.

6. 50- to 75-word abstract of your project:

Abstract:
We are developing a micro-implantable monitoring system that provides real-time feedback to cancer therapy. The device proposed here will be capable of monitoring deep tissue (> 1 cm) whilst being small enough to fit into a needle to be injected directly into the tumor. The device uses light to assess the molecular properties of the tumor microenvironment, utilizing one or more laser diodes, a photodiode, a radio-frequency power-harvesting circuit, and a Bluetooth microcontroller to do so.

Project Summary:

<u>Introduction:</u>

Although treating cancer using a personalized medicine approach is widely discussed with great excitement, treatments for cancer are still largely based on broad cancer categories such as stage, grade, and molecular subtype. Monitoring tumor response to guide therapy in real-time is one way of delivering a personalized treatment. This summer we worked toward developing a micro-implantable monitoring system that provides real-time feedback from the tumor microenvironment. The final design will monitor deep tissue (> 1 cm) wirelessly whilst being small enough to fit into a needle to be injected directly into the tumor.

<u>Design:</u>

This device is meant to determine the optical properties of the tissue surrounding it to evaluate the condition of that tissue. To date we have created a prototype optical sensor platform that is directed via microcontroller. The design and successful implementation of simple circuits to power the laser and to read the detector signal has also been completed. The design can be seen in Figure 1.

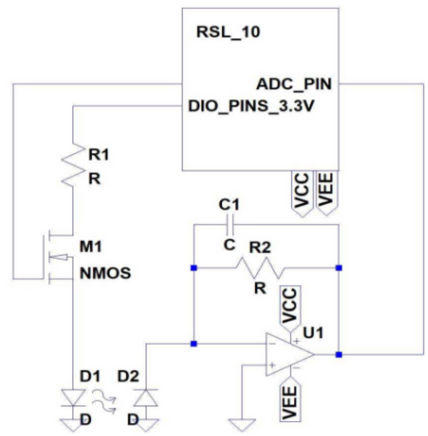

Figure 1: Circuit Diagram

<u>Process:</u>

To begin, the microcontroller triggers a measurement. This causes light rays from the laser to interrogate the tissue (or phantom) and then be received by the photodetector. Next the photodetector current is amplified in a transimpedance amplifier. This signal then is processed by an analog to digital converter. Finally, the microcontroller receives detector signal. These voltage measurements are then transmitted wirelessly via Bluetooth to a peripheral device for analysis.

<u>Conclusion</u>

This summer we have shown an initial proof-of-concept and demonstration of the feasibility for the above mentioned system. The team programmed the RSL10 in C++ to orchestrate sensing. The device took stable and accurate measurements that were sensitive to the surrounding optical properties of a tissue-simulating phantom. The system demonstrated a 0.29 % coefficient of variation when taking measurements over a fifteen minute time period. Thus we can safely conclude that the device is very stable. Finally we achieved wireless communication of the data between the microcontroller and a cellphone.

While we are proud of the progress we have made, there are many improvements and innovations yet to make. Future improvements include using the RSL10 to supply all necessary voltages, wirelessly powering the device, and maintaining a completely self-contained device while remaining small enough to allow for injection into a tumor.