Fiber Optic Stress Sensor Research Proposal

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Introduction/Background:

Tissue stiffness has been correlated directly to various diseases, such as progression of cancer, heart disease and lung disease (Hudnut et al. 2018). High precision, non-destructive analysis of the mechanical characteristics of soft tissues would allow us to better diagnose some of these diseases. Recently, Dr. Harrison developed a fiber optic stress sensor that allows us to analyze the stress-strain curves for biological materials. The device has been used to distinguish stress-strain curves of salmon tissues with different numbers of collagen membranes (Hudnut et al. 2017). It has also been used to successfully re-create the structure of porcine pancreatic tissue on a macroscopic scale. By analyzing the tissue's stress-strain curves, researchers were able to 3D-print material that matched its structure (Hudnut et al. 2018). Our research aims to make the stress sensor more suitable for diagnostics. We are reworking the design into a more compact form factor and creating proprietary software to help the device run more efficiently.

Specific Goals of the Research:

The goal of the current research is to create a new, more compact version of the fiber optic stress sensor using a photonic integrated circuit (PIC) for data collection and to develop standalone software for this device. The development of the photonic integrated circuit requires us to rethink the data processing from the ground up and rework the design of the device. The development of software is required to enable communication between all of the devices that make up the stress sensor and to create a simple user experience with real-time responsive data collection.

Project Narrative:

The fiber optic stress sensor consists of several key components. Light from a laser is guided by fiber optic cable into a linear polarizer. The polarizer puts light moving through the cable into a predictable state. A sample is placed over a section of the optical fiber, and force is applied to the sample using a micrometer-controlled device. Force applied to the cable through the sample alters the polarization state of the light moving through the cable in a predictable way. This device allows us to create stress-strain curves for materials based on analysis of the way the light changes in response to force on the material.

In parallel with re-creating the original stress sensor, I am leading the development of proprietary software that will allow for easy real-time data analysis and collection. One of the main goals of this software is to enable synchronization between the micrometer-controlled tissue compression device and the polarimeter. Currently, both devices have separate proprietary software. Beginning data collection requires the user to have both software open and to manually begin data collection on the polarimeter and sample

compression device separately, which means they are slightly out of sync. This process introduces overhead with data processing, as we are required to parse through the data to find out where it becomes meaningful. Getting both devices to work in tandem and communicate through our software will eliminate this issue. Thus far, I have created a python program with a basic UI that has the capability to tell the compression device to move to a user-specified position. I have also successfully interfaced with the polarimeter. While these are steps in the right direction, there is still much work to be done on the software in this area. The current UI is rudimentary, with limited options for micrometer control and communication with the polarimeter.

The other important functionality of the software is fast and easy data processing and presentation to the user. At present, we are working on adapting Dr. Harrison's old data processing script to work in python with the new polarimeter device. Once that is achieved, we plan to implement data analysis in real time, with graphs generated as data is read from the polarimeter.

Once the photonic integrated circuit design is finalized by Dr. Harrison and manufactured (it should be delivered to us this summer), we will have to rework our data analysis and hardware communication code to work with the new device. Because of this, it's important we create software that is easily scalable.

We've taken some meaningful data using our rebuilt version of the original sensor using prepared PDMS samples. In parallel with the development of the software, we plan to do more tests with a variety of PDMS samples to establish a refined base device before we upgrade to the photonic integrated circuit, after which we will need to perform more tests.

Conclusions/Future Outlook:

By developing a new, more compact fiber optic stress sensor along with standalone software we hope to create a simple to use device with a wide range of applications. The ability to accurately and efficiently analyze stress-strain curves for biological materials will allow us to better understand disease progression and potentially re-create these materials with a high degree of accuracy. After finalizing the design with the photonic integrated circuit and finishing the development of the software, we hope to scale the device even further. Because of the small size of the PIC, we want to eventually develop a device consisting of an array of stress sensors. This will enable us to gather high precision stress-strain data over large areas. Continued testing with different materials is paramount to the furthering development of the device. Currently, we can't get good data from materials much harder than soft tissues. More experimentation with different types of fiber optic cable or different sensor and data analysis configurations could enable us to take data on more stiff materials. This would expand the use-cases of the device beyond the analysis of biological materials and into mechanical engineering. Embedding large arrays of sensors within vehicle parts or other machines would allow us to monitor their statuses efficiently and in real-time.

References:

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