**Introduction**

Good morning. My project is the Development of a low-cost Sensor Chain for Photosynthetically Active Radiation Measurement. Before I get into the specifics of my project, I would like to provide some background information.

**Southern Ocean and Antarctic Region (background)**

The Southern Ocean and Antarctic region play a crucial role in global climate patterns. Despite this, the Antarctic region is one of the most understudied regions in the world. The consequence of this fact is that Earth System Models cannot accurately predict what is happening in the Antarctic.

Within the Antarctic, we are specifically interested in the Marginal Ice Zone. This is the interface region between the open ocean and consolidated pack ice. Ice formation in this region is seasonal and highly impacted by the extreme environmental conditions in this region.

These environmental changes not only affect ice formation, but also the entire ecosystem.

**Phytoplankton (background)**

Central to the marine life in this region is phytoplankton. These microscopic organisms not only form the base of the microbial food web, but also play a crucial role in global carbon cycling. In the figure to the right, you can see the various roles played by phytoplankton within the Antarctic region.

**Factors that affect phytoplankton growth**

Phytoplankton growth is influenced by **various factors**, including light availability, temperature, salinity, nutrient availability, and wind strength. The Marginal Ice Zone accounts for some of the highest rates of primary production in the Southern Ocean, especially during spring and summer. Conditions for phytoplankton growth become ideal as sea-ice melts. This not only allows more light to penetrate the ocean, but also releases low-salinity, nutrient rich water.

A common theory was that phytoplankton growth occurred with or after ice-melts. However, a recent study has shown that 90% of observed phytoplankton growth had occurred before the ice retreat. This indicates that phytoplankton in this area have adapted to grow in extreme low-light conditions, or light is more readily available in the under-ice environment.

**Light in the Antarctic**

Light conditions within the Antarctic vary drastically throughout the year. These graphs show the how sunlight varies within the region and show how latitude impacts the overall sunlight received throughout the year.

Sunlight is composed of ultraviolet light, visible light and infrared. This graph shows the spectral composition of sunlight. Not all light that reaches earth’s surface is suitable for the process of photosynthesis. Infrared radiation does not have enough energy to fuel the process, while ultraviolet radiation can damage photosynthetic cells.

**Phytoplankton and PAR**

The range of light used in photosynthesis is called Photosynthetically Active Radiation, or PAR. It ranges from 400nm to 700nm, which is roughly the same range as visible light. The figure shows the absorption spectra of various phytoplankton species. From this graph we can see that phytoplankton productivity is impacted not only by the amount of light it received, but also the composition of that light.

**PAR sensors**

PAR sensors, or quantum sensors, are available commercially from companies such as Apogee or LiCOR. However, these sensors have a high cost per unit, thus making them impractical for deployment in the Antarctic. Another method is the use of off-the-shelf components to develop a PAR sensor. This method allows a lower cost per unit; however, it does require careful component selection and extensive testing.

There are two main options when using off-the-shelf components. The first is a more analog approach, using photodiodes and carefully selected optical filters. This approach has been shown to give good results when measuring PAR, however optical filters can be expensive and hard to find.

The second option is the use of a digital photoelectric sensor. These include RGB/W sensors, as well as multi-channel spectral sensors. These sensors make use of photodiodes and carefully selected optical filters to determine the amount of light of a specific bandwidth. The use of a digital sensor negates the issue of sourcing optical filters, and also allows for less involved electronic design.

**Project Goal (Sensor Chain)**

This brings us to the main aim of my project. I am currently working towards the development of an optical sensor chain which can be deployed through Antarctic sea-ice. This system will need to be robust to changing environmental conditions, with a focus on power efficiency.

In addition to a sensor for quantifying PAR, the chain may also include sensors for measuring other environmental factors, such as temperature and humidity.

**Work already done**

Last year I tested two of these sensors, specifically the VEML6040, an RGBW sensor, and the AS7341, which is an 11-channel spectral sensor with 8 channels in the PAR range. Using my testing rig I performed various tests on these two sensors, in order to characterize how they respond to various light intensities, the angle of the incident light, as well as channel isolation of these sensors. These figures show the outputs of the two sensors to individual red, green, and blue LEDS, as well as the sensor response to white light created by an RGB LED.

From this work I determined that while the RGBW sensor offers a lower cost per unit, the channel isolation and spectral resolution of the AS7341 makes it the superior choice for quantifying PAR.

**Work currently being done**

This year I plan on testing an additional sensor, alongside the AS7341 tested previously. This sensor is the AS7265x chip set, which consists of three individual ICs with 6 channels each, giving a total of 18 channels. 11 of these channels fall within the PAR range.

These individual sensors will need to be integrated into a sensor chain. A problem with the sensors I have selected is the fact that they all use I2C communication and have fixed addresses, meaning that a single I2C bus cannot be used. To negate this issue, I found an I2C multiplexer. This allows multiple devices with the same addresses to be connected to the same I2C pins on the microcontroller.

I have designed a total of four PCBs. Two of these boards have arrived, while the parts for my other two boards have been ordered.

**Future Work**

Once I have all of my PCBs I will begin testing various functionalities. I will need to confirm that the I2C multiplexer works as intended, and compare the performance of the two sensors under various conditions.

Conduct simulated environmental tests and fields tests.