July 26, 2020

Dr. Craig Scratchley
School of Engineering Science
Simon Fraser University
British Columbia, V5A 1S6

RE: ENSC 405W/440 Proposal for SpecTro

Dear Dr. Scatchley,

The team at photonicEyes has prepared a Proposal Document for Spectro. We aim to create an air particle detector that can analyze the shape, size and concentration of particles within a space. This will be accomplished by using Silicon Photomultipliers (SiPM) detectors to capture light scattered off particles. SpecTro is intended to be used by industrial manufacturing companies, cleanrooms, and medical facilities to aid in the pursuit of monitoring particulates in their rooms.

This document is intended to show an overview of SpecTro. PhotonicEyes will explain the projects background, implementation plan, and brief overview of the components. We will also go further into who we intend to use SpecTro, and the market and competition, the risks, and the budget associated with the engineering prototype.

Our diligent team consists of five senior engineering students in the SFU program: Raheem Mian, Kurtis Raymond, Amirsaman Fazelipour, Ahnaf Tahmid, and Sazia Tasnim. Our team come from many disciplines of engineering and thus has many different strengths, skills, and view points. We intend to make a product that is useful and that will benefit society.

Our team would like to thank you in advance for taking the time to review our proposal. If you have any questions, please feel free to contact us through GitLab or email me at rmian@sfu.ca.

Regards,

Raheem Mian
Chief Executive Officer
photonicEyes

SFU SIMON FRASER UNIVERSITY

photonicEyes

SpecTro
Project Funding Proposal

Partners

Raheem Mian

Kurtis Raymond

Ahnaf Tahmid

Sazia Tasnim

Amirsaman Fazelipour

Sponsor

Dr. Fabrice Retiere

TRIUMF

Submitted To

Dr. Craig Scratchley

ENSC 405W

School of Engineering Science

Simon Fraser University

TEAM 3

July 26, 2020

Executive Summary

A growing concern in the world is the presence of certain air particulates. Air particulates can be harmful for many reasons and these reasons depend on the industry. Electronic manufacturing facilities monitor the particles in the air to prevent a decrease in yield for their wafers. While the health industry (hospitals) wants to prevent their patients from additional harm in the form of allergies, or other diseases. Also, construction sites and housing may have unknown problems and may call for investigation of the air to find asbestos or high concentrations of microbial contamination The main theme is that air particulates are disliked among many industries and a way to monitor toxins in the air is the solution.

Our motivation is to develop a device that can solve this problem. Our product, SpecTro is an air particle detector that aims to measure particulates ranging between 0.1 and 10 microns. It analyzes the shape of the particulates to differentiate between more spherical vs non spherical particles. WE intend to use Silicon Photo-multipliers (SiPMs) for the detection of the particles. This device will provide the user with the name, concentration, size and shape of the particulates and the approximate timing the particulates were present in the space.

We have a 3-phase plan that consists of producing a Proof of Concept, Engineering Prototype, and a Finished Product. We intend to prove the concept through simulations by using tools such as Chroma, MATLAB light scattering scripts, ADDA, ANSYS, and Zemax. These tools will allow us to simulate fluid dynamics, light scattering, and create optical designs. Therefore, allowing our team to first prove our concept to our sponsor, professors and investors and formulate how we intend to proceed with the next phase of the project.

This project has many components and is very hardware oriented. The prototype will consist of an Air Inlet, Measurement Chamber, Exhaust System, Light driver, Light Source, Focusing Element, Light Dump, Data Acquisition System, and peripherals such as Wi-Fi, Bluetooth, and USB modules. The data will be collected on an FPGA SOC, here we can manage the frequency of the information and analyze and store the data.

Particles are to be collected in the measurement chamber entering through the Air Inlet. A VUV LED light will then be pulse at a high frequency towards the center of the chamber. Light scattering is the result of light bouncing off a particulate. The scattered light will then have a chance to be detected by the SiPM. The output of the SiPM will be checked at a comparator (checks the voltage coming from SiPM) which will instruct the FPGA about a particulate detection. The analysis of the data will be in the form of tables and charts and can be viewed by the user through reports sent via Wi-fi, Bluetooth, USB connection, and the physical device.

The air particle detector market is growing fast every year. The market was valued at 10.4 Billion USD in 2019 and set to register a CAGR of 7.3 from 2020 to 2027. The air particulate detectors on the market vary between daily ambient and professional use and their prices are reflected respective to their intended utility. SpecTro is a device that is intended to be used in both cases at a competitive price.

PhotonicEyes is excited to work on SpecTro to solve the problem of preventing damage from air particulates. We are a team of 5 engineers that have proven skills in hardware design and software development. We come from different disciplines of Engineering such as Physics, Computer and Systems; making us a team with wide ranging skills and views. Through our motivation and knowledge we aim to make a device that will be beneficial and provide a positive impact on the world.

Contents

List of Figures

List of Tables

Glossary

SiPM Silicon Photomultipliers. 2

VUV vacuum ultraviolet. 2

1 Introduction

The purpose of this document is to provide information regarding the product "SpecTro" for potential investors. PhotonicEyes will present the need of this product and our motivation behind this innovating idea. This document will discuss the following topics: (1) Prospective Market and Pricing Points (2) Expenses and Income and (3) Timing of Project (Gantt Chart). The Appendix will include the team's names, their roles, and personal description.

1.1 Background

Light commonly scatters off small particles in air. This is most commonly seen with our own eyes in the sky, where the sky is blue during the day, and fades to a deep red during sunset. The nature of this scattering depends on several factors, including the wavelength of light used, and the size of the particle. For particles which do not absorb the light, the light will scatter off characteristically. By using a fixed wavelength of light, we can infer the size of the particle which scattered it.

The most common parameter we will discuss in this document is the sizing parameter,

$$x = \frac{\pi D_p}{\lambda}$$

And there are three regions of interest:

1. Rayleigh scattering ($x < 1/100$)
2. Mie Scattering ($x \sim 1$)
3. Geometric Scattering ($x > 100$)

By using $x \sim 1$, and detectors directly opposite each other, we should be able to measure how asymmetric a particle is. By examining the shape a particle in this way, our device may be able to distinguish between, for example, a an asbestos particle from a small moisture particle. A basic diagram showing the basic principles of the scattering detector is shown in Figure 1. A range of indoor particles are shown in Table 1.

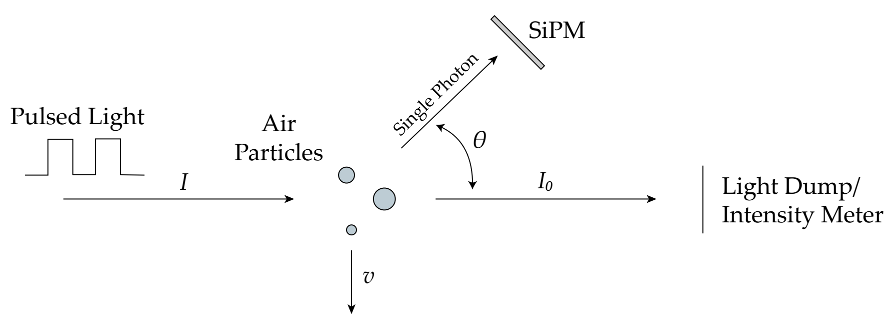

Figure 1: A conceptual diagram for scattering pulsed light off small particles in the air

The most important particles to evaluate, are those between the region of 10 nm and 10 μm. Particles smaller than 10 nm tend to coagulate into larger ones, and particles larger than 10 μm are heavy enough to deposit themselves onto surfaces in a timely fashion.

Several regions are of interest. For health and safety, inhalable particles are defined as particles with diameters smaller than 15 μm and are designated PM15. Fine particulate, which are able to penitrate deeper into the lungs, are defined as having a diameter of less than 2.5 μm, and are designated PM2.5

Particle	Size, μm	Particle	Size, μm
Skin Flakes	1-40	Asbestos	0.25-1
Visible Dust and Lint	$\geq$25	Resuspended Dust	5-25
Dust Mite	50	Tobacco Smoke	0.1-0.8
Mite Allergen	5-10	Diesel Soot	0.01-1
Mold and pollen spores	2-200	Outdoor fine particles (sulfates, metals)	0.1 - 2.5
Cat Dander	1-3		
Bacteria*	0.05 - 0.7	Fresh combustion particles	$\leq$0.1
Viruses*	$\leq$0.01-0.05	Metal Fumes	$\leq$0.1
Amoeba	8-20	Ozone- and terpene- formed aerosols	$\leq$0.1
Mineral Fibers	3-10		

*Occur in larger droplet nuclei

Table 1: Commonly found fine particulate substances indoors. Data and table was taken from Ref. [1].

2 Product Overview

In this section we will examine various aspects of the project, and justify why our instrument is in a good position to be competitive on the market.

2.1 Project Scope

This project originally began with a group of UBC student working on a capstone together with Fabrice Retière a senior research scientist at TRIUMF. Their goal was to use VUV-sensitive Silicon Photomultipliers (SiPM) designed to measure scintillation. Their original plan was to design a small, low-cost, particle sensor. However, after some advice from an anonymous company, the focus switched to building a high end particle analysis instrument.

The UBC group was able to construct a basic prototype to illustrate the concept, however, the data they obtained was swamped with parasitic light, and only measured three unique angles. Further details of the report can be found in Ref. [2]. Based on the main issues outlined in the report we collectively decided to focus on the following aspects of the project.

1. Figure out a scheme which would allow the instrument to provide some sense of particle shapes for those which are $x \sim 1$.
2. Design a sample preparation system which would allow air to flow in, but prevent the ingress of light. This system would also need to protect the internal components from contamination of the sample air.
3. Redesign the optical system which controls the light from the LED. This includes picking and choosing optical elements, as well as placing collimators (narrows a beam) and field stops, to prevent the unnecessary scatter of light.
4. Study the geometry of the measurement chamber using Monte Carlo simulations to limit the stray light from scattering off intermediate surfaces, and iterating on the previous measurement chamber.
5. Design a digital system which could be built on an FPGA, which performs the initial analysis directly from comparators connected to the output of the SiPM driver circuits.

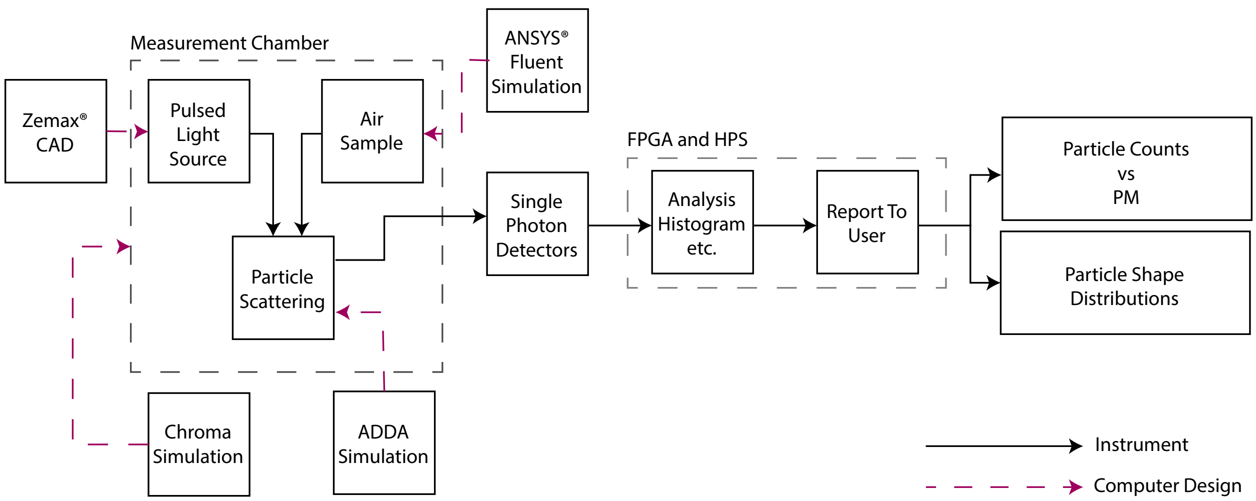

Figure 2: Basic system overview of the SpecTro device.

2.2 System Overview

For our system we are attempting to use a low cost UV LED as a pulsed light source. To compliment this low intensity light source, we are using UV sensitive SiPM's originally developed for the nEXO double beta decay experiment. The advantage of using a pulsed light source with the SiPM is a reduction in the complexity of the sensor circuitry, which leads to a great reduction in instrument cost. Figure **??** shows a very basic cloud diagram of how the device is structured. The sections below will discuss a selection of the main components which require more clarification.

Pulsed Light Source

The pulsed light source is composed of a LED pulse with a specially designed pulsing circuit. The light from the LED needs to be culminated and focused. A big challenge of this system is to limit the amount of stray light, or scattered light which is not from particle scattering. The design can be verified using the Zemax CAD software.

Air Sample

Since our device measures the particulate in the air, we need a way of collecting this sample. One requirement of inserting the air sample is to not contaminate the interior of the measurement chamber. The ANSYS fluent software will be used for the verification of this requirement.

Particle Scattering

As discussed in Section 1.1, SpecTro relies on using light scattering to measure the shape and size of particles. The software package ADDA, or a similar program, will be used to simulate the scattering of a particle of arbitrary light source. This will allow us to decide optimal SiPM positioning inside the measurement chamber.

Single Photon Detectors

Since the probability of an incident photon scattering into the a detector is very small, we can use single photon detectors to analyze the scattering intensities over many pulses.

Data Reported To User

The user may find particle concentration for specific bins, ie $PM_{2.5}$ (particles which are $\geq 2.5\,\mu$m) interesting. In particular, for cleanrooms, this allows for a automated verification of different ISO 14644-1[3] cleanroom standards on a pass fail basis. Knowing the distribution of particle shapes will also be of interest to some users.

2.3 Risks and Benefits

Risks

A large part of the project relies on the results of simulations based on CAD designs. Due to COVID-19, the amount of physical hardware testing is almost zero, thus, there is a huge reliance on CAD and simulations. Due to this, the main risk of the project is ensuring that the simulations are able to model the real physical system. And that the simulations are good enough to verify our assumptions for the project, such as being able to correlate particle scattering distributions to size and shape.

In particular, we have set stringent requirements to almost completely eliminate stray parasitic light from sources other than scattering. There is a potential that our requirements are set too stringent, and using pulsed LED light will offer not enough signal to the parasitic light noise. By using the above software, we should be able to deduce this outcome.

Benefits

The benefits of the SpecTro pulsed light design are numerous. By counting only single photons in a pulsed light system, the front end electronics can be greatly simplified, and events can be discriminated on an event by event basis. This allows us to use more photon detectors for less cost, and improve the reliability of size and shape measurements.

The intention of this is to lower the cost of the whole instrument, and allow for various types of units, from high end particle analyzers, to detectors which can be permanently installed and integrated into a HVAC system.

3 The Need, The Market, The Competition

The Need

Maintaining air quality control is relevant to a huge number of industries and fields. Most notably is the evaluation and monitoring of manufacturing environments and cleanrooms.

- General Clean rooms

  The ISO 14644-1 [3] and ISO 14698 [4] standards determine the allowed concentration of particulate of a given size for a particular ISO classed clean room. As such, instruments with a variety of capabilities will need to be used for verification and monitoring of clean room facilities.

  For an ISO 1 class clean room, an instrument must be able to measure particles which are $\geq$0.1 μm at a concentration of 10 particles/m^3. For comparison, ISO 9 (standard room air) is 3,520,000 particles/m^3 which are $\geq$0.5 μm, 832,000 particles/m^3 which are $\geq$1.0 μm, and 29,300 particles/m^3 which are $\geq$5.0 μm. This is quite a wide range, and very few air particle monitors are capable of measuring such a range of concentrations.

- Semiconductor Manufacturing

  The yield of a chip on a semi-conductor wafer is directly related to the defect density. The main driver for detect density is stray particles in the air which end up on the wafer during the manufacturing process. Modern foundries are most susceptible airborne particles which are on the order of the minimum feature size. Roughly 75% of yield losses in VLSI fabrication facilities is due to contamination of particles onto the wafer's surface during the manufacturing of a chip. Evaluating the condition of the air is critical to maintaining a high yield, and ensuring maximal profit.

- Electronics Manufacturing

  Certain manufacturers build devices sensitive components (such as cameras or night vision devices), and particle contamination can lead to devastating losses in product reliability and revenue. Being able to evaluate and maintain proper air quality is essential.

- Industrial Manufacturing

  In an industrial setting, many sources generate air born particles which can enter into a worker's lungs, and cause numerous health problems including cancer. By continuously monitoring for airborne particles, the safety of the workforce can be maintained from this invisible threat. Our instrument will be designed to be used for the verification of regulation requirements.

  Additionally, some industrial plants will benefit from evaluating the amount of contamination due to airborne particles, especially those which care for the longevity of their equipment, and the items they produce.

- Pharmaceutical Manufacturing

  Stray airborne particles have a direct impact on the shelf-life, safety, and effectiveness of a pharmaceutical drug. Understanding the state of the air inside the manufacturing plant is crucial to maintaining regulation approved drugs.

- Ambient air monitoring

  Outside air is regularly monitored for so-called fugitive dust, which is dust suspended from the air produced by some source. Examples include particles on a surface swept up by turbulent currents, or dust generated from abrasions.

An application of this would be the monitoring the ambient air for fugitive dust outside or inside a hospital, which is crucial for the health of the patients within.

- Specialty Indoor air Quality Monitoring (IAQ)

  If an IAQ investigation warrants knowing more about the shapes of particles in the air, such as those commonly found indoors, then utilizing an instrument which can differentiate shape is important. For instance, a building with unknown water damage may have much higher concentrations of microbial contamination, which will not resemble other forms of airborne dust. Due to the different types of particles commonly present outside vs inside, it may be possible to determine if the affected air quality is mostly due to an inside or outside source.

The Market

SpecTro is a particulate detecting device designed to be used by Industrial or commercial stakeholders with influence on manufacturing devices accountable for air-quality diagnostics and demonstrations like particulate sensor, air filtration, air purifier, etc. The market analysis will be based on these factors along with some competitors in this arena.

The dramatic rise in the air quality demonstration across the world is the main reason for the growth of the particulate detection market. The health issues arising due to the poor-quality detection and filtering method is also one of the factors assisting the market growth. The governments of different countries are taking severe steps to combat pollution by conducting tests with the help of air quality monitoring systems and impose restrictions from exceeding the prescribed limits [5]. This will catalyze the demand for the particulate matter detection which would be used in air quality monitoring systems. The availability of cheap and counterfeit materials in the market to measure the air quality is said to be a major restraint for the market growth of this products [5]. Nevertheless, the growing use of this detectors by various end use industries is expected to present significant growth opportunities for the market.

The global industrial air filtration market size was valued at USD 10.4 billion in 2019 and is expected to register a CAGR of 7.3 from 2020 to 2027 [6]. The need to control industrial air quality across a range of end use industries is a key factor anticipated to drive market growth over the forecast period. Additionally, the rising need to reduce energy consumption across several industrial applications may elevate the demand for an effective industrial air filtration system. Growing concerns regarding environmental health coupled with reducing raw material resources and natural depositories are primarily expected to fuel industry growth over the forecast period [6].

There are 3 main technologies in the current market that are used for detecting particulate matter in the air, and they all operate on a similar principle. They are infrared, Beta attenuation mass monitoring and Laser diffraction [7]. Some air purifiers have an “air quality monitor” built in. These are almost always taking advantage of an infrared detector. Most of the more affordable household-grade particle detectors on the market use infrared. Most famously used one is Beta attenuation mass monitoring system. They are big and expensive, so they are very uncommon. They are mostly used for regular monitoring over long periods of time and are appropriate for measuring ambient air. Professional handheld devices such as the Dylos Corporation or IQAir ParticleScan use laser diffraction to count particles and determine their size [7]. This method works in lots of scientific settings, and you can use it in air, liquid, or vacuum but not in your daily life living room.

The Competition

The global particulate detection market has been segmented based on measuring range, end use industry and geography. Based on the measuring range, the market is divided into 0.3-2.5 μm, 0.3-5.0 μm, 0.3-10 μm, and others [5]. In end use industry, the market is isolated into consumer electronics, industrial, power generation, medical, chemical, etc. As per geography, the particulate sensor market competition has been sub-divided into:

- North America (U.S. and Canada)
- Latin America (Mexico, Brazil, Peru, Chile, and others)
- Western Europe (Germany, U.K., France, Spain, Italy, Nordic countries, Belgium, Netherlands, and Luxembourg)
- Eastern Europe (Poland and Russia)
- Asia Pacific (China, India, Japan, ASEAN, Australia, and New Zealand)
- Middle East and Africa (GCC, Southern Africa, and North Africa)

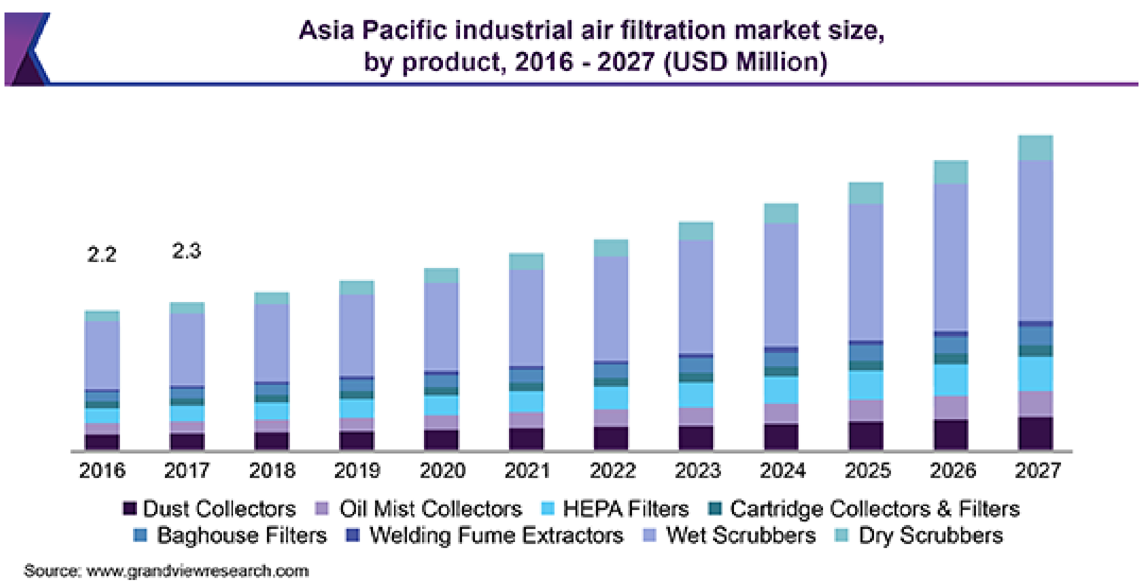

Figure 3: Market Size of Asia Pacific industrial air filtration [6]

Some of the major competitors in the air particulate sensor market includes Dylos Corporation, IQAir, Infineon Technologies AG, Sensidyne, Sensirion, AMETEK Land, Delphi Technologies, Robert Bosch GmbH, Thermo Fisher Scientific, Yokogawa Electric Corporation, Tritech, Airy Technology, Inc, Honeywell, etc [5].

A range of aerosol particle counters exist on the market. In this section, we will outline several different products which are most similar to ours with an example of one of them.

- **TSI's Aerotrack Model 9110**
- **Particulate Matter Sensor SPS30**
- **Konomax's Model 3905 & 3910**
- **Particle Measuring System's Lasair® III 110 .1 Micron Particle Counter**

Particulate Matter Sensor SPS30(for HVAC and Air Quality Applications):

With this new particulate matter sensor, Sensirion expands its range of environmental sensing solutions and innovates a new dimension in indoor and outdoor air quality applications. The MCERTS-certified SPS30 particulate matter sensor marks a new technological breakthrough in optical PM detection. Its measurement principle is based on laser diffraction and makes use of Sensirion's innovative contamination-resistance technology. This technology, together with high-quality and long-lasting components, enables precise measurements from the device's first operation and throughout its lifetime of more than ten years [8]. The SPS30 will enable the implementation of innovative air quality monitoring devices that prevent air pollution and health issue damage by reducing PM2.5 [8].

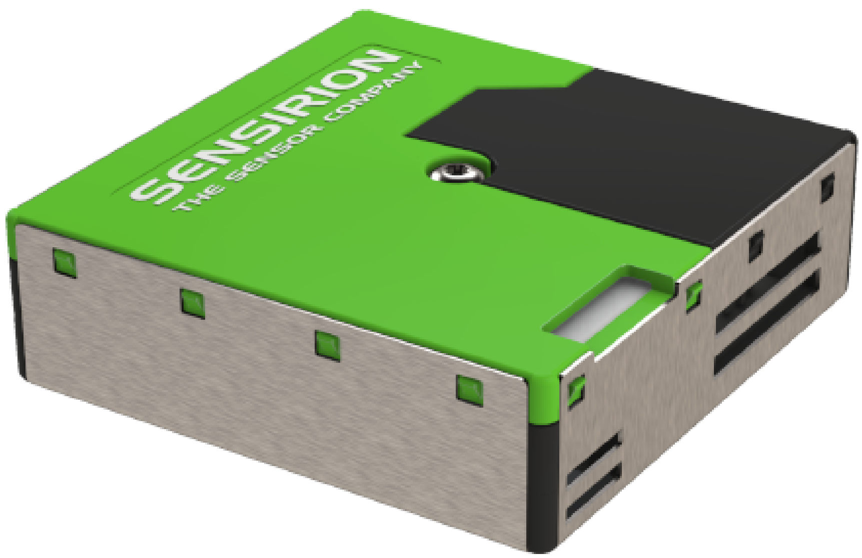

Figure 4: Particulate Matter Sensor SPS30 [8]

Part	Price / unit (CAD)	Quantity	Additional information
SiPM	20	10	TRIUMF (sponsor)
DE10 - Nano kit	0	1	Pre-owned
Button	0.95	4	Adafruit
Standard 16x2 LCD Module	9.95 - 13.28	1	Adafruit
MCP23017	1.61 - 4.00	1	Microchip
Bluetooth Module - HC06	2.67 - 6.45	1	Ebay
Wifi module - ESP8266	9.33 - 10.00	1	SparkFun
USB module	28.37 - 30.06	1	Devantech
Small High-Pressure fan	22 - 30	1	Noctua
HEPA Filter	29.15 - 88.02	1	LEVOIT, Mcmaster
Light Driver	0 - 4360.69	1	Function generator at SFU, custom driver from TRIUMF (sponsored), picoQuant
Light Source	200 - 300	1	255nm LED (CUD5GF1B), SETi/Seoul Viosys
Light Dump	58 - 340.80	1	3D printed or BT60 Beam Trap from ThorLabs (200 nm - 3um)
Measurement Chamber	77.82	2	carbon filament 1.75 mm (0.5 kg). MatterHackers
Exhaust System	77.82	1	carbon filament 1.75 mm (0.5 kg). MatterHackers
Air Pump	77.82	1	carbon filament 1.75 mm (0.5 kg). MatterHackers
Nozzle	77.82	1	carbon filament 1.75 mm (0.5 kg). MatterHackers
Lenses	100.00	4	Edmund Optics
Sub Total (Approx) Contingency Approx Total	3800.00 20% 4552.00		

Table 2: Engineering Prototype Budget

4 Cost Considerations

4.1 Cost Estimates and Budget Constraints

Table 2 on page 9 shows the complete breakdown of the parts and budget for the Engineering Prototype. The final budget is in range of: 1097.31 - 6158.53 CAD. We are more likely to use the free sources for the Light Driver; therefore the budget will be closer to the minimum.

4.2 Project Funding Sources

TRIUMF

This project is sponsored by Senior Scientist Fabrice Retière at TRIUMF. This sponsorship will assist in obtaining most of the necessary materials for the project, including components and test equipment. The SiPMs are specially fabricated for TRIUMF and are processed in house.

Engineering Science Student Endowment Fund (ESSEF)

The Engineering Science Student Endowment Fund (ESSEF) is a fund at SFU given to undergraduate student projects needing funding. Projects can be classified within 4 categories: A. Competition, B. Entrepreneurship, C. Class, D. Miscellaneous. Our project falls under 3 of these categories specifically A, B and C. Our project SpecTro will be in a competitive market against other air particle detectors, we are attempting to create a product that we can manage and gain profit, and the project was formed because of ENSC 405w. If more funding is needed this will be a great source for funding.

Wighton Development Fund

The Wighton Development Fund is managed by Dr. Andrew Rawicz. We believe that SpecTro meets the requirements of practicality and a motivation to better society. This product will help many companies with manufacturing, and hospitals to maintain clean air. This funding will be beneficial, if funding from TRIUMF is not sufficient.

5 Project Planning

5.1 Description

Our project, SpecTro, comprises of a three-stage design which includes a separate prototype completed at the end of each stage. The table below shows the number of phases along with the prototype produced at each of the three stages:

Phase	Prototype
I	Proof of Concept
II	Engineering Prototype
III	Finish Product

Table 3: Design prototype with phase number

The prototype for Phase I is Proof of Concept which intends to be completed throughout ENSC 405W during Summer 2020 term. On the other hand, the implementation of Phase II will be achieved in the subsequent semester during ENSC 440 in Fall 2020 term. After the completion of this phase, better accuracy and additional functionalities will be provided compared to the previous proof-of-concept prototype. However, further improvements on the design of SpecTro will be achieved during Phase III and is expected to be finished at the end of ENSC 440 in Fall 2020.

5.2 Time schedule

The figures below outline the time schedule for SpecTro over the two phases of the design prototype. Items in bold represent significant milestones in the project, whereas items beneath the milestones represent the sub tasks which are required to complete the milestone.

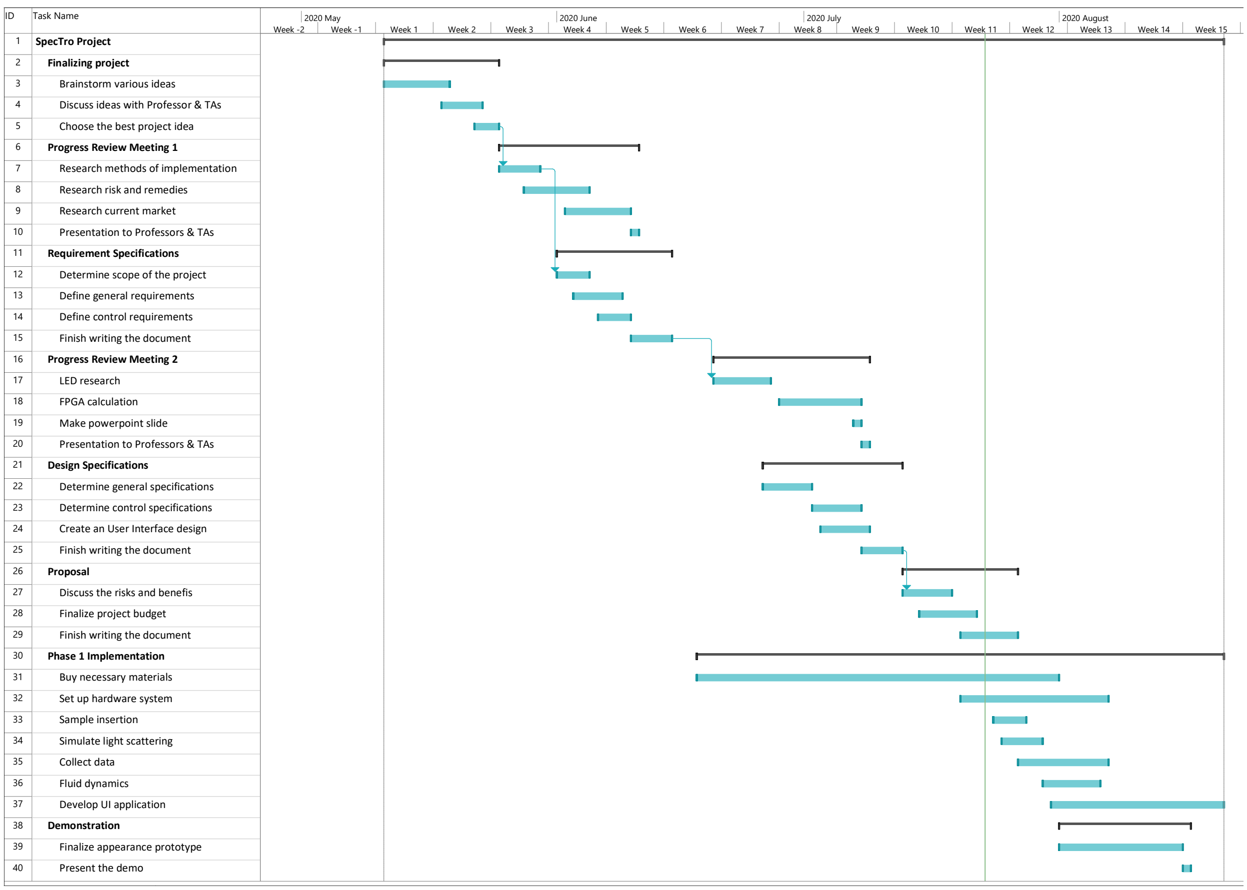

Figure 5: Gantt chart for Semester 1 of project SpecTro

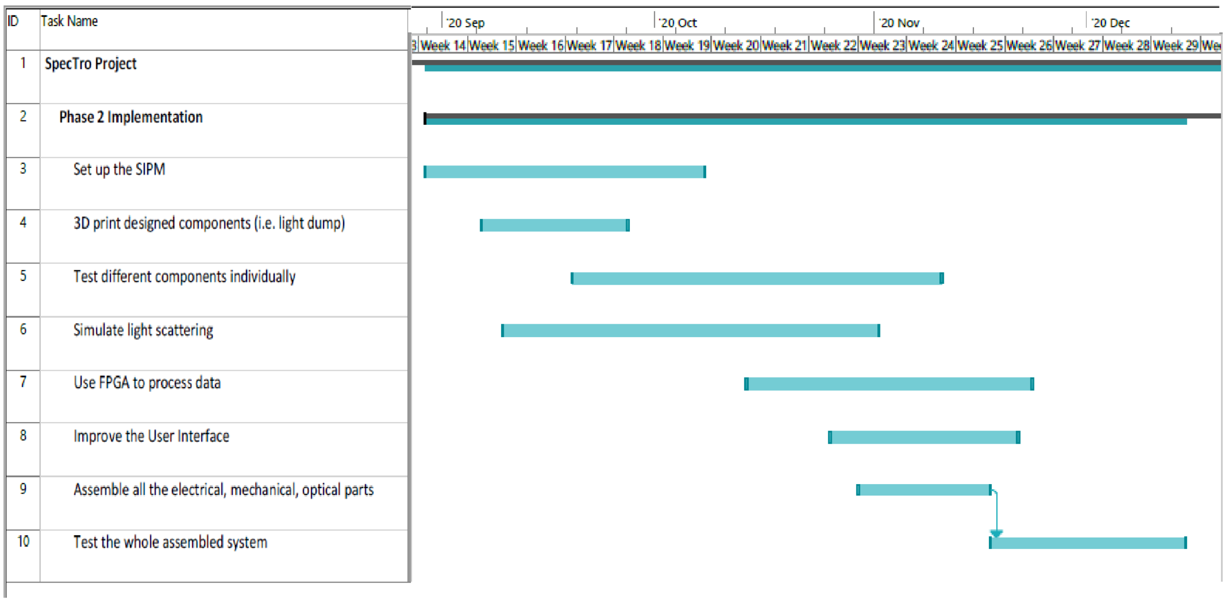

Figure 6: Gantt chart for Semester 2 of project SpecTro

6 Description of Team and Roles

Fabrice Retière - (Project Sponsor)

Fabrice is a Senior Research Scientist at TRIUMF. His specialty is in designing particle detectors for use in searching for dark matter, and detecting neutrinos. He worked on the STAR experiment at Lawrence Berkeley National Laboratory before coming to TRIUMF in 2004. Fabrice is able to leverage his 20 years of experience in experimental physics by offering expert guidance to the members of PhotonicEyes.

PhontonicEyes

PhotonicEyes is a company started by five Senior engineering science students at SFU. A breakdown of each member is given below.

Raheem Mian - CEO (Chief Executive Officer)

Raheem Mian is a fifth year Computer Engineering student. He has worked as a Software Tester at Gatekeeper Systems testing mechanical devices and websites. He also worked as a Image Processing Engineer at BORG for Dr. Marinko Sarunics. This is where he developed a 3D registration code to correct for movement in mouse eye data. He is interested in pursuing a career in image processing and digital design after he graduates in the next semester. Raheem is eager to learn more about particle physics and uses his knowledge of FPGA's and computer science to aid in hardware and software components of the project.

Kurtis Raymond - CTO (Chief Technology Officer)

Kurtis is a fifth year Engineering-Physics honors student set to graduate at the end of 2020. He has a strong interest in radiation detectors, physics, and electronics. He has spent a co-op designing a high temperature vacuum furnace using ANSYS at TRIUMF, assisted in the design of a β-tagging array at TRIUMF, and several co-ops writing software for the analysis of nuclear science experiments. Kurtis applies his engineering and physics experience to the project to assist in the mechanical design, as well as coordinating the technical aspects of the project.

Ahnaf Tahmid - CFO (Chief Financial Officer)

Ahnaf Tahmid is a fourth year Systems Engineering student attempting to graduate on Spring 2021. He has worked for Operational Engineer under Algo Communication where he learned to test their products under various embedded systems. He also has an experience in Software Development under Change Healthcare where he acquired knowledge of bug fixing of various functional elements of their designated software and writing test cases accordingly. He has a strong interest in particle physics in which he would love to learn more from this particle detection system.

Sazia Tasnim - CMO (Chief Marketing Officer)

Sazia Tasnim is a fifth-year Systems Engineering student at Simon Fraser University. She finished her first co-op working as a Quality Assurance Hardware Engineer at Icron Technologies where she learned hardware troubleshooting skills as well as operating various types of lab equipment. She also has an eight month of co-op experience working as a Software Engineer at CounterPath Corporations where she acquired programming and regression testing skills. She has a strong passion in quantum physics and Sazia will apply her knowledge to ensure that the functionality of SpecTro works as expected.

Amirsaman Fazelipour - CKO (Chief Knowledge Officer)

Amir is a fifth year Computer Engineering student graduating in December 2020. He has considerable experience in embedded software development from his past co-op positions namely, Software Test Engineer as well as Software Development Engineer both at Sierra Wireless Inc. For the past year, Amir has been working part-time as the Lead Developer and presenter for M2M Tech Inc. where he has created numerous projects and presented at 10 workshops to over 100 students. He has recently started a position at SFU, where he will be creating benchmarks in SystemVerilog for the taiga project, a RISC-V core developed at SFU. He hopes to be able to apply his expertise to the development of SpecTro in both software and hardware areas.

7 Conclusion

In this document, the project scope, system overview, the risks and benefits as well as a high-level market analysis, cost considerations and project planning have been discussed in detail. Some commonly found particulates along with specific regions of interest in terms of particulate size where SpecTro will be competitive have been specified in detail. In the overview, the system has been broken down as follows. Pulsed light source, air sample, particle scattering, single photon detectors, and data reported to the user. Moreover, one of the main advantages of SpecTro over its competitors, is its lower cost in the market, which has been demonstrated in the risks and benefits section of this document. Finally, project planning has been illustrated in the form of a Gantt chart.

References

[1] B. McDonald and M. Ouyang. "AIR CLEANING—PARTICLES". In: *Indoor Air Quality Handbook.* Ed. by John D. Spengler, Jonathan M. Samet, and John F. McCarthy. McGraw-Hill, 2001. Chap. 9.

[2] Q.Klassen W. Lin I. Beckie. "Single Photon Air Quality Analyser". Engineering Physics Project Laboratory, UBC, Vancouver, British Columbia. January 6, 2020.

[3] *ISO 14644-1:2015: Cleanrooms and associated controlled environments — Part 1: Classification of air cleanliness by particle concentration.* Standard. Geneva, CH: International Organization for Standardization, Dec. 2015.

[4] *ISO 14698-1:2003: Cleanrooms and associated controlled environments — Biocontamination control — Part 1: General principles and methods.* Standard. Geneva, CH: International Organization for Standardization, Sept. 2003.

[5] Particulate Matter Sensor Market - Global Industry Analysis Size Share Growth Trends and Forecast 2018 - 2026. *Transparency Market Research, Sep-2020.* URL: `https://www.transparencymarketresearch.com/particulate-matter-sensor-market.html`. (Accessed: 23-Jul-2020).

[6] Industrial Air Filtration Market Size: Global Industry Report 2027. *Industrial Air Filtration Market Size Global Industry Report.* URL: `https://www.grandviewresearch.com/industry-analysis/industrial-air-filtration-market`. (Accessed: 23-Jul-2020).

[7] The 3 Types of Particle Detectors: How We See the Invisible. *Kaiterra, 18-Sep-2017.* URL: `https://learn.kaiterra.com/en/air-academy/the-3-types-of-particle-detectors-how-we-see-the-invisible`. (Accessed: 23-Jul-2020).

[8] Particulate Matter Sensor SPS30. *Sensirion AG Switzerland.* URL: `https://www.sensirion.com/en/environmental-sensors/particulate-matter-sensors-pm25/`. (Accessed: 23-Jul-2020).