Senior Design 1 Initial Project Document

January 29, 2021

Raman Spectroscopy using a Concatenated Laser System to Measure Water Content and Chemicals in Fuel

Department of Electrical Engineering and Computer Science

College of Optics and Photonics

University of Central Florida

Dr. Lei Wei, Dr. Samuel Richie, Dr. Aravinda Kar

Sponsors: Ocean Insight

Group 1

Yaelle Olivier	*PSE*	*yaelleolivier@knights.ucf.edu*
Tyler Morris	*CPE*	*tmorris24@knights.ucf.edu*
Austin Collins	*CPE*	*austincollins37@knights.ucf.edu*

Project Narrative

Water contamination is the silent and often overlooked disease for engines using any petroleum fuel source. In an emergency using fuel reserves, the number one issue for equipment failure is due to the fuel being contaminated. This is because the government and fuel companies will buy and store large amounts of fuel and store it for a long time in case emergencies happen. However, the tanks often go unchecked and the fuel fails in such an emergency. Fuel just isn't what it used to be, it has been modified through refineries to produce more fuel for less crude oil.

This means that that the diesel you get now has a much shorter shelf life of 90 days compared to the shelf life in the 1960s in which the shelf life was 10 years. It has been shown that diesel will degrade 26% in the first month and will degrade to 95% in the same time frame if there is any water present in it. Another change to diesel fuel was the move towards ultra-low sulfur diesel (ULSD) to prevent sulfur pollution in the environment. Sulfur is a known anti-microbial, so today's diesel fuels are much more likely to easily be affected by microbes and water due to the minimizing of sulfur.

Although microbes in a fuel tank do not sound very dangerous, microbes start growing due to water in the fuel tanks and feed off the partially degraded fuel and any additives. Given enough time the microbes soon turn to slime and sludge. This microbial sludge destroys surface coatings, corrosion, clogging of fuel filtration, blockage of fuel supply, and malfunctioning fuel gauges. Organisms growing in fuel have been recorded since 1895 and were reported on aviation fuel since the early 1950s. One of the first known microbial attacks was in the wing tank of a Lockheed Electra aircraft in 1961. Since then there have been hundreds of reports touching on the correlation between microbes in fuel and corrosion, engine failure, and pipe fouling to name some.

There are many tests and labs used to find the microbes in fuel and evaluate how to eliminate them which includes very harsh chemicals or disposing of the contaminated fuel entirely. Using Raman Spectroscopy with a concatenated laser system, we could preemptively test fuel for water content before the microbes have a chance to grow. This would cut down on time, money, chemicals, and wasted fuel.

Through Raman spectroscopy we can find a chemical fingerprint of the sample by the wavelengths it emits without damaging the sample. It has already been used to find the chemical fingerprint of fuel through a single laser system this provided a way to correctly characterize and quantify the adulterant and chemical compositions in fuel. Usually, quality control on fuel was done by measuring the physical properties like density, vapor pressure, and boiling points rather than accurate chemical characterizations. It was tested and proven that

Raman Spectroscopy with a laser (785nm) was able to and quantify the adulterant in each fuel sample with low errors. Water concentration can be measured with the Raman system by expanding the measurement spectral range into molecular stretch regions. To do this we must add a second laser system to see spectral regions where stretch regions are prevalent. Not to mention, we can also do this in reverse. We can use this same system to detect fuel contamination in water sources. We could track pollution in the oceans, or even see if there are traces of leaked fuel in our drinking water.

Currently, on the market, there are ways to test for water content in fuel. However, these are usually qualitative measurements using chemicals or dyes and heavy manipulation of the fuel sample, this means that once the fuel has been sampled it is no longer good to use. These kits often also take a certain amount of time before giving you the results in the form of a visual separation or color. This is not very accurate and would not be able to tell you exactly how much water is present or if there are any other chemicals in the sample.

Specifications

- Input
  - Will be two lasers overlapping onto the sample.
  - Wavelength Range 600-800 nm for lasers.
  - Controlled by a computer that also communicates to the spectrometer.
- Output
  - The device will read the chemical fingerprint from the fuel sample.
  - The device will read water concentration in the fuel sample.
  - The device will be accurate reading the chemical and water content levels.
  - The device will be fast with a processing time under 5 minutes.
  - The device will output quantitative data.
- Artificial Intelligence
  - Create a sub-routine that will automatically go through the entire analysis process upon being powered on, aside from human required interaction; I.e. start an analysis, store data, produce recipe.
  - Create an algorithm that takes data collected from the spectrometer and creates a “recipe” for treatment.
  - Automatically processes user inputs without the need to manually run programs.
  - Automatically stores data for future potential analysis.
- Graphical User Interface
  - Create a custom user interface to display options, data, and commands to help and refine analytical tests.

- Display the GUI on a touch screen, which can be interacted with by users.
- Display data in a readable, user-friendly manner.

Constraints

Time is a constraint as we only have about 25 weeks to have a fully researched and well thought out design as well as physically building the system. Every week we must provide a significant amount to our part of the project.

The environmental constraint is that we are doing this during a pandemic. This means that our classes and meetings are all online. Products may not be as available as they would be outside of the pandemic due to shutdowns.

Also, our group size and members is a constraint we have one optics engineer and two computer engineers. We will have to go out of our comfort zone and learn how to do the work missing electrical engineer. This will make it, so it is possible to connect the optical system to the computer. The other

Run time is a constraint, as we want to be able to beat out most test kits available on the common market. Five minutes is an ideal target from the start of analysis to the end of the processes. This will give a large enough of an advantage, along-side the reusability, to use our device over common test kits.

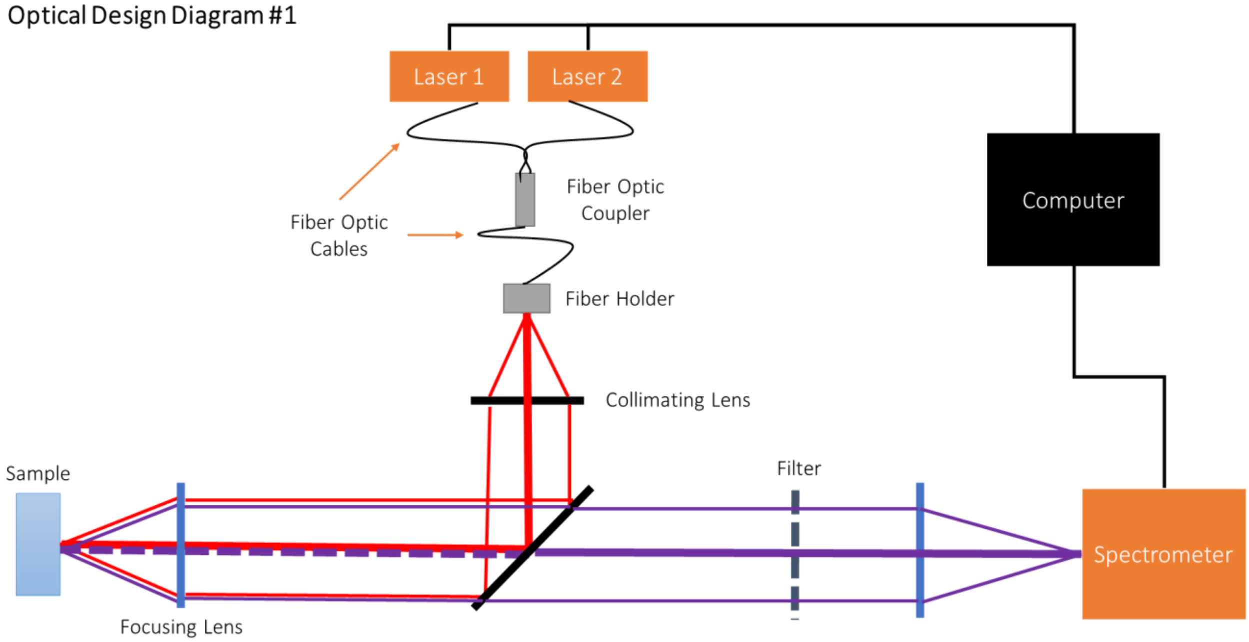
Code size is a constraint because the device's internal computers should be low scale to keep costs, power consumption, and heat generated at a low. This will allow the device to be used safely and avoid damaging other components, as well as be more usable in a field setting, where temperatures can vary.

Block Diagrams

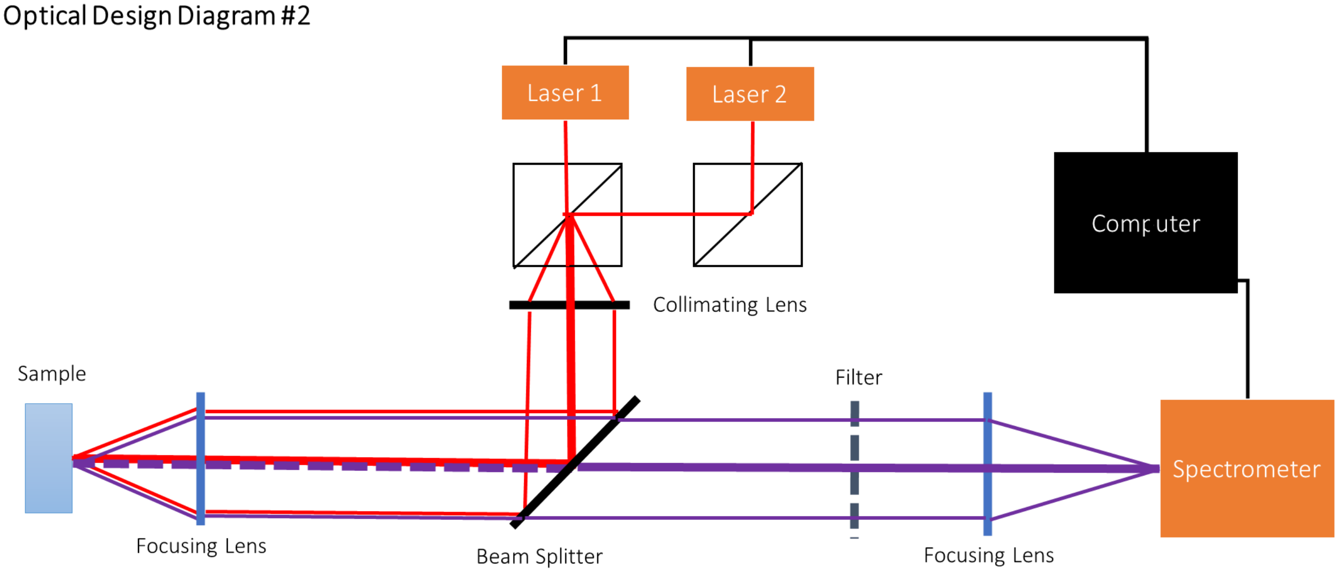
Optical Diagram

Yaelle Olivier

Optical Design Diagram #1

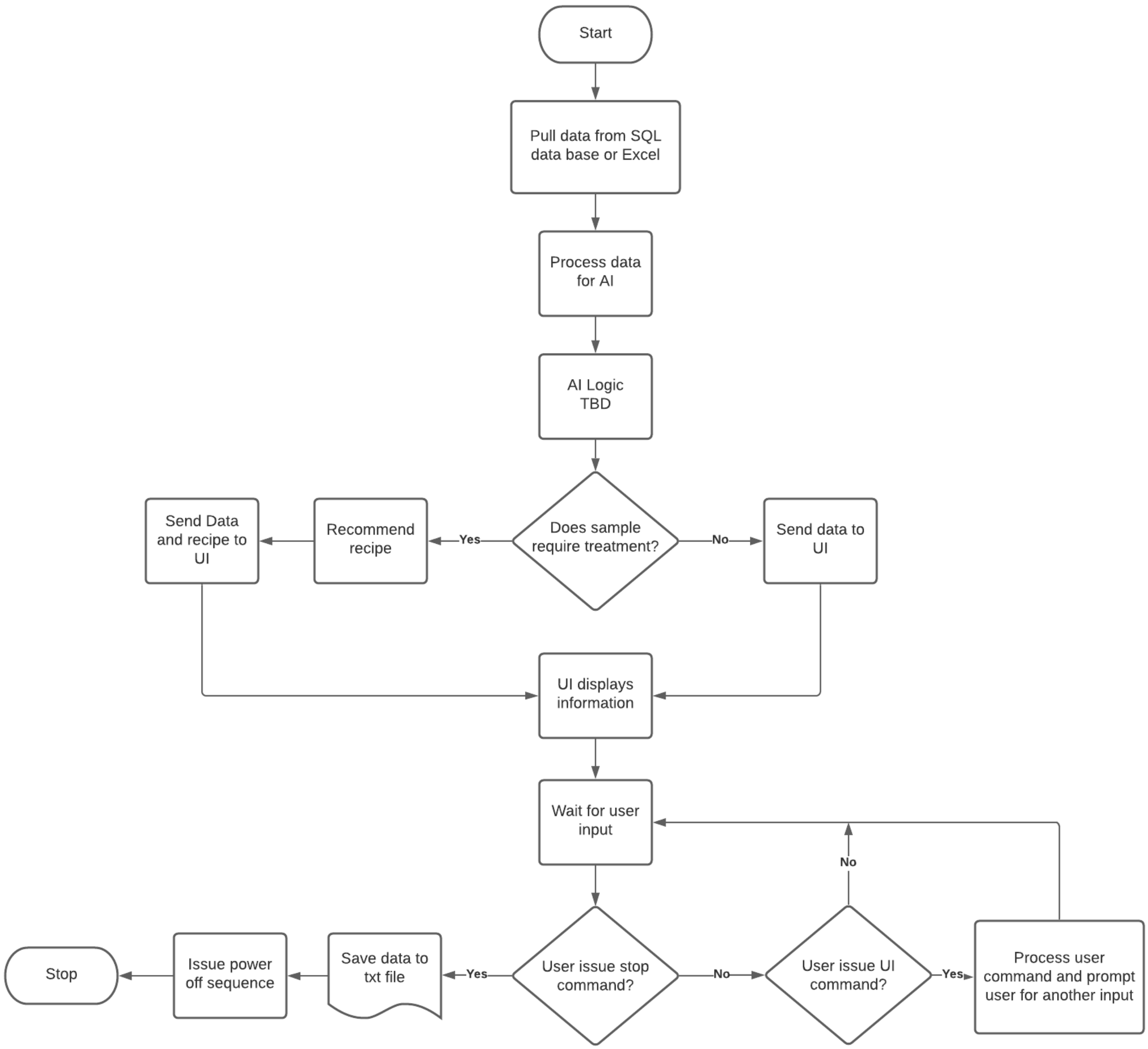


Optical Design Diagram #2



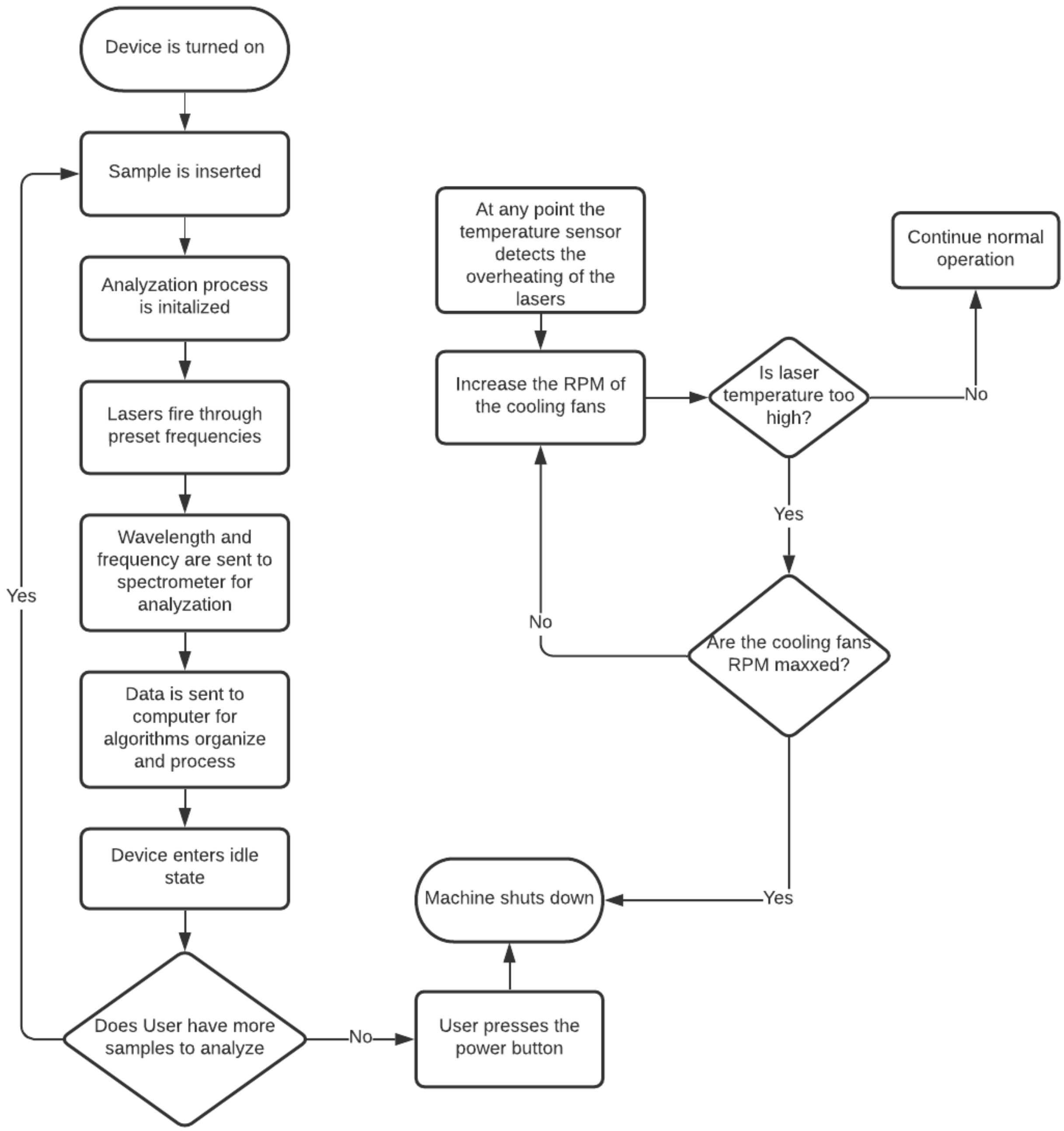
Software Diagram

Tyler Morris



Hardware Diagram

Austin Collins



Milestones

Week	Date	Description	Status
		Senior Design 1	
1	1/11/2021	Project Idea / Meeting group members	Done
2	1/18/2021	Talking with Sponsor / Project Idea	Done
3	1/25/2021	Initial project documentation	Done
4	2/1/2021	Start ordering parts	In Process
5	2/8/2021	Updated D&C	In Process
6	2/15/2021	Initial Design Stage	In Process
7	2/22/2021	Testing spectrometer and software	In Process
8	3/1/2021		In Process
9	3/8/2021	Hardware Testing	In Process
10	3/15/2021		In Process
11	3/22/2021	Prototype Planning	In Process
12	3/29/2021	60-page draft	In Process
13	4/5/2021	Prototype Planning	In Process
14	4/12/2021	Final Draft	In Process
15	4/19/2021	Final Document	In Process
		Senior Design 2	
16	5/17/2021	Building Prototype	In Process
17	5/24/2021		In Process
18	5/31/2021		In Process
19	6/7/2021	Testing and Redesign	In Process
20	6/14/2021		In Process
21	6/21/2021		In Process
22	6/28/2021	Finalizing Prototype	In Process
23	7/5/2021		In Process
24	7/12/2021		In Process
25	7/19/2021	Peer Presentation	In Process
26	7/26/2021	Final Report	In Process
27	8/2/2021	Final Presentation	In Process

Budget

Description	Quantity	Cost / Unit	Total Cost
Raman Spectrometer	1	$15,000.00	$15,000.00
Laser (600-700nm)	1	$8,000.00	$8,000.00
Laser (700-800nm)	1	$8,000.00	$8,000.00
Optical Fiber	3	$350.00	$1,050.00
Fiber Coupler	1	$100.00	$100.00
Collimating Lens	1	$150.00	$150.00
Fiber Holder	2	$100.00	$200.00
Focusing Lens	2	$150.00	$300.00
Filter	2	$500.00	$1,000.00
Computer / Software	1	$800.00	$800.00
Power Converter	1	$50.00	$50.00
Samples	1	$2.38	$2.38
Cuvettes	1	$100.00	$100.00
Box	1	$400.00	$400.00
Total Cost			**$35,152.38**

References

Hill, T. (2003). Microbial growth in aviation fuel. Aircraft Engineering and Aerospace Technology, 75(5), 497–502. doi:10.1108/00022660310492582

Ardila, J. A., Soares, F. L. F., dos Santos Farias, M. A., & Carneiro, R. L. (2016). Characterization of Gasoline by Raman Spectroscopy with Chemometric Analysis. Analytical Letters, 50(7), 1126–1138. doi:10.1080/00032719.2016.1210616

Arroyo, M. P., Birbeck, T. P., Baer, D. S., & Hanson, R. K. (1994). *Dual diode-laser fiber-optic diagnostic for water-vapor measurements. Optics Letters, 19(14), 1091.* doi:10.1364/ol.19.001091

https://www.bellperformance.com/fuel-and-tank-services/diesel-fuel-contamination

https://www.cenex.com/about/cenex-information/cenexperts-blog-page/agriculture-and-farming/water-contaminated-diesel

http://www.sourcena.com/sourceline/know-enemies-common-types-fuel-contamination/

https://digitalcommons.usu.edu/cgi/viewcontent.cgi?referer=&httpsredir=1&article=1543&context=extension_curall

https://aem.asm.org/content/aem/15/2/411.full.pdf