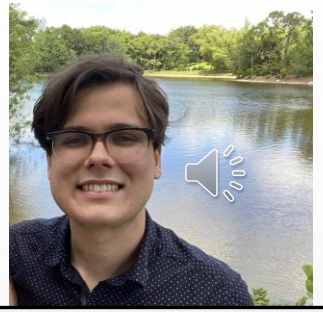
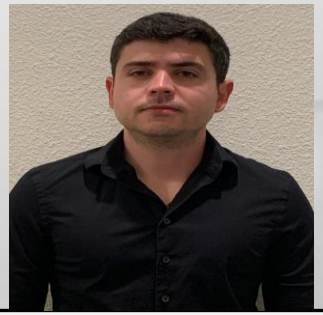
Smarter-Portable Water Bacterial Detector

Group 11



ETHAN SHEPHERD – PSE

DYLAN BRANCATO – PSE



PASCUAL SIRACUSA - EE

Project Description & Motivation

- Provide a simple testing method for bacteria in water
- Millions lack access to safe drinking water
- Existing testing methods are impractical
- Utilizes fluorescence spectroscopy to detect bacteria with a staining process
  - Typical staining process has limitations
  - Utilizing DAPI stain
- MCU for data analysis
- Aims to comply with EPA drinking water quality standards

ETHAN SHEPHERD – PSE

Overall Project Goals & Objectives

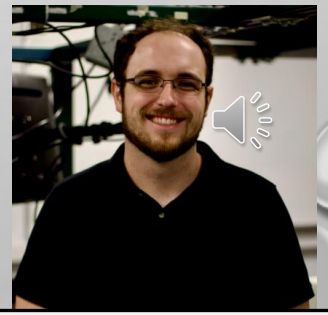
Goals Table
Basic Goals
Identify presence and approximate concentration of bacteria in water
Detect DAPI stained bacteria
Portable device
Advanced Goals
Attach a UV cleaning light that activates based on spectrometer results
Energy efficient system, multiple hours battery life
Stretch Goals
Detect multiple fluorophores
User-friendly UI

Objectives Table
Excitation Light
At least 1mW of power to ensure fluorescence
Testing various concentration with power meter
Spectrometry and Detection
Diffraction separating wavelengths by approximately 6 mm
Send sterilization information based on results.
Processing Algorithm to interpolate concentrations.
Portability
Weight of 8 pounds
Rechargeable within 1 hour
Able to power for 2 hours.

ETHAN SHEPHERD – PSE

Requirements and Specifications

Component	Parameter	Specification
Excitation Source	Power	2mW
Excitation Source	Wavelength	365nm
Water Sample	Sample Volume	3.5ml
Water Sample	Operating Wavelength	340nm - 700nm
Fluorescent Source	Power	1mW
Fluorescent Source	Wavelength	460nm +/- 30nm
Microcontroller	Detection + Display time	<1 sec.
Grating	Grooves/mm	600 grooves/mm
Photodiode	Responsitivity	0.3A/W
Spectrometer	Spectral Range Collected	460nm +/- 30 nm
Spectrometer	Focusing Size	1.2 mm x 1.2 mm
Battery	Power time	>1 hour
Entire System	Weight	<10 lbs.
Entire System	Time	<1.5 minute



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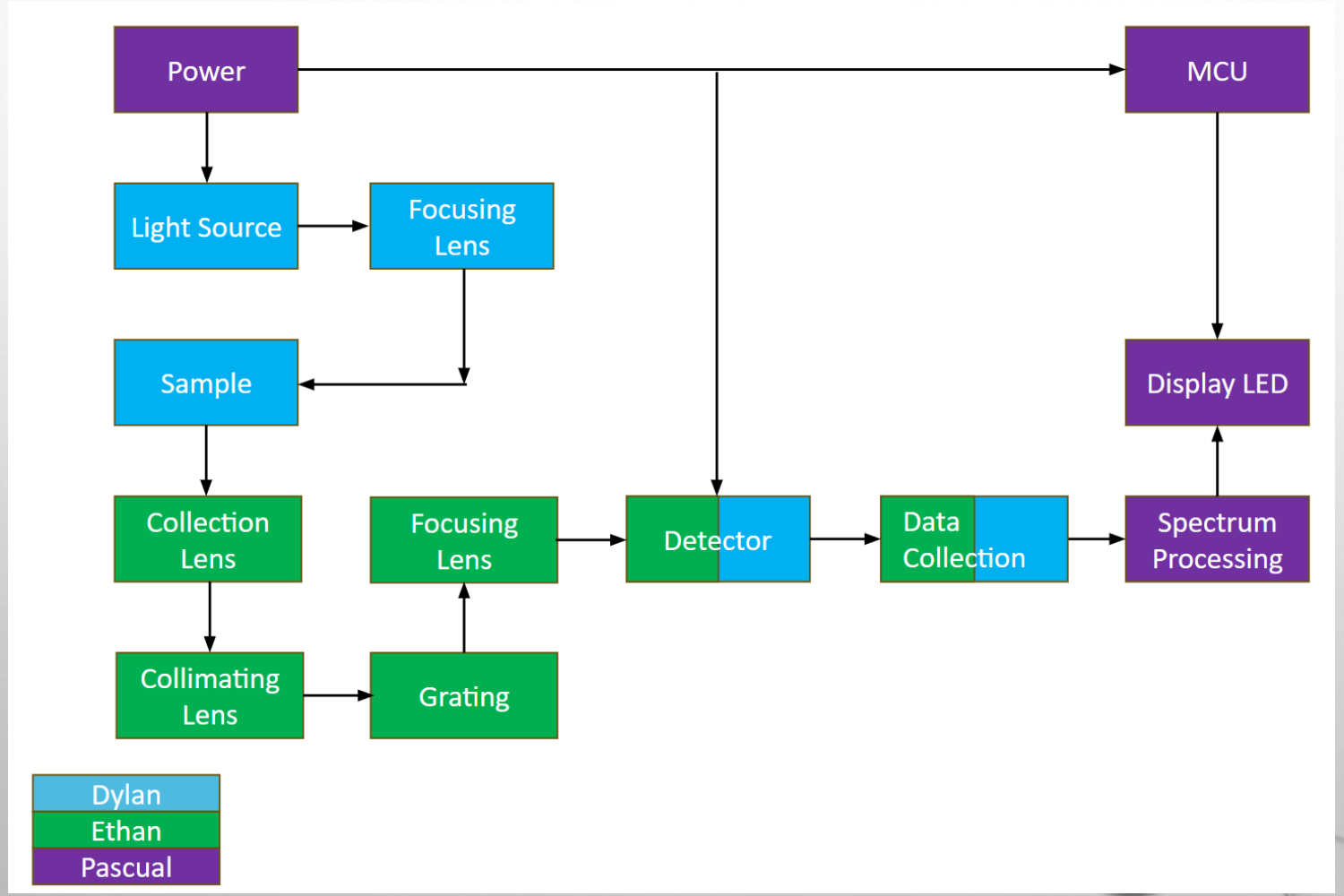
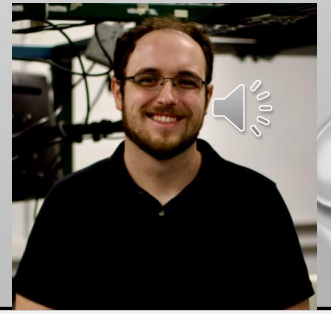
Project Block Diagram





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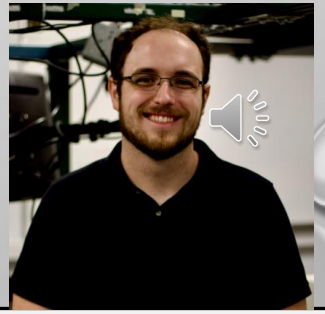
Sample Prep and Notable Chemistry

- Grow sample using vial of E.Coli intended for student use
- Each dot is 1CFU, seeing 1 dot is considered undrinkable
  - Typically, concentration is measured in molarity, but we will be using CFU as this is the typical guideline for EPA standards
- Move colonies to cuvette by counting the dots, try to use dots of similar size
- Add stain for 2 drops/ml, was the best seen in concentration testing.



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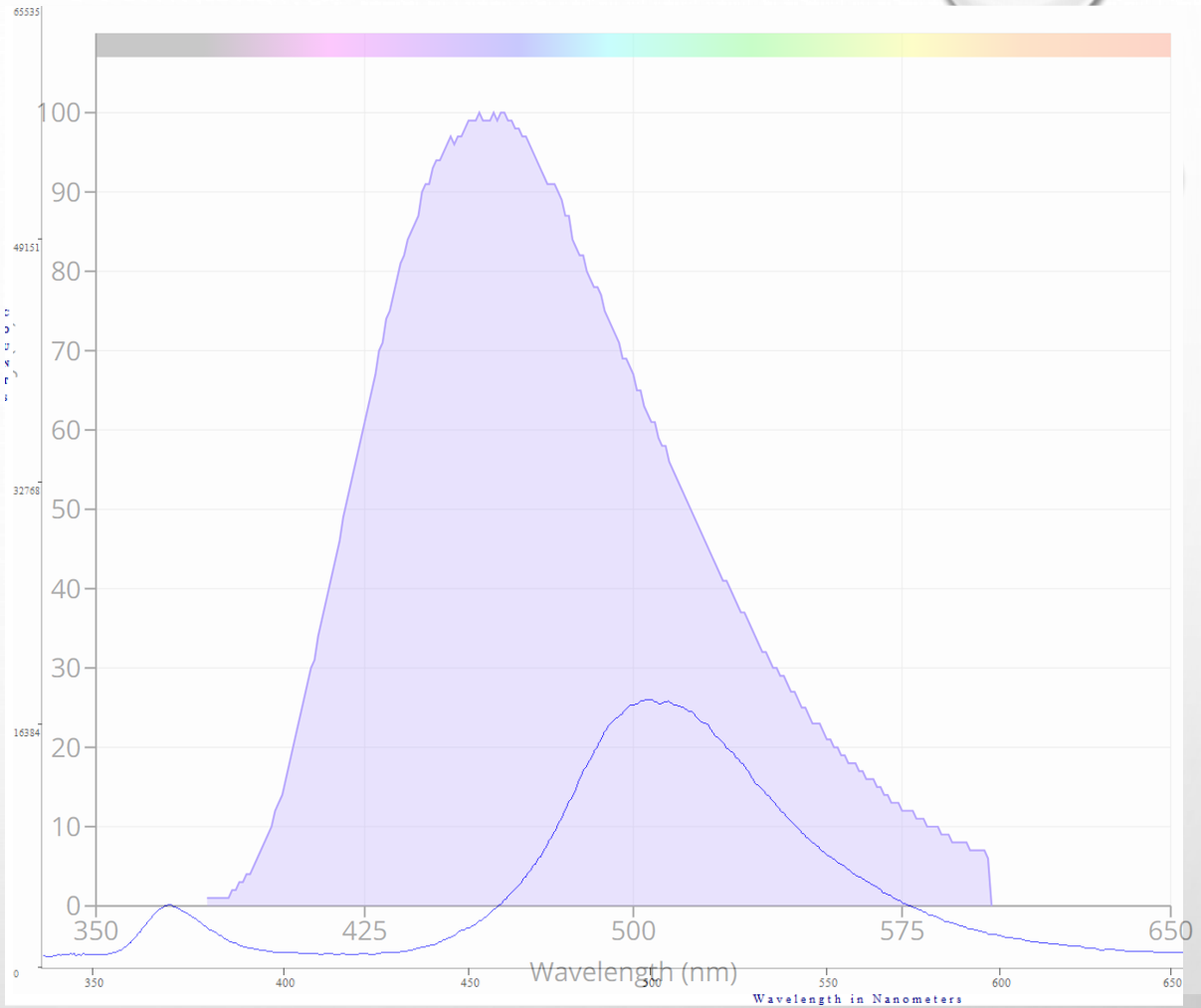
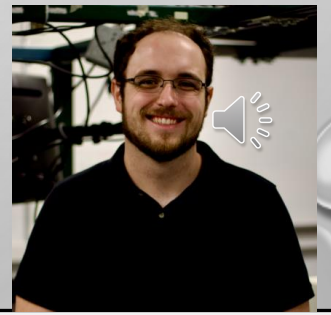
DAPI Fluorescence

- Quantum Yield = 0.04 unbound, 0.92 bound
- Fluorescence did have a shift from theoretical approximation
  - Purple line → theoretical
  - Blue line → experimental
  - Likely from change in solvent or binding to RNA.
- Fluorescence is a linear relationship
  - $Concentration = M \cdot Voltage + b$





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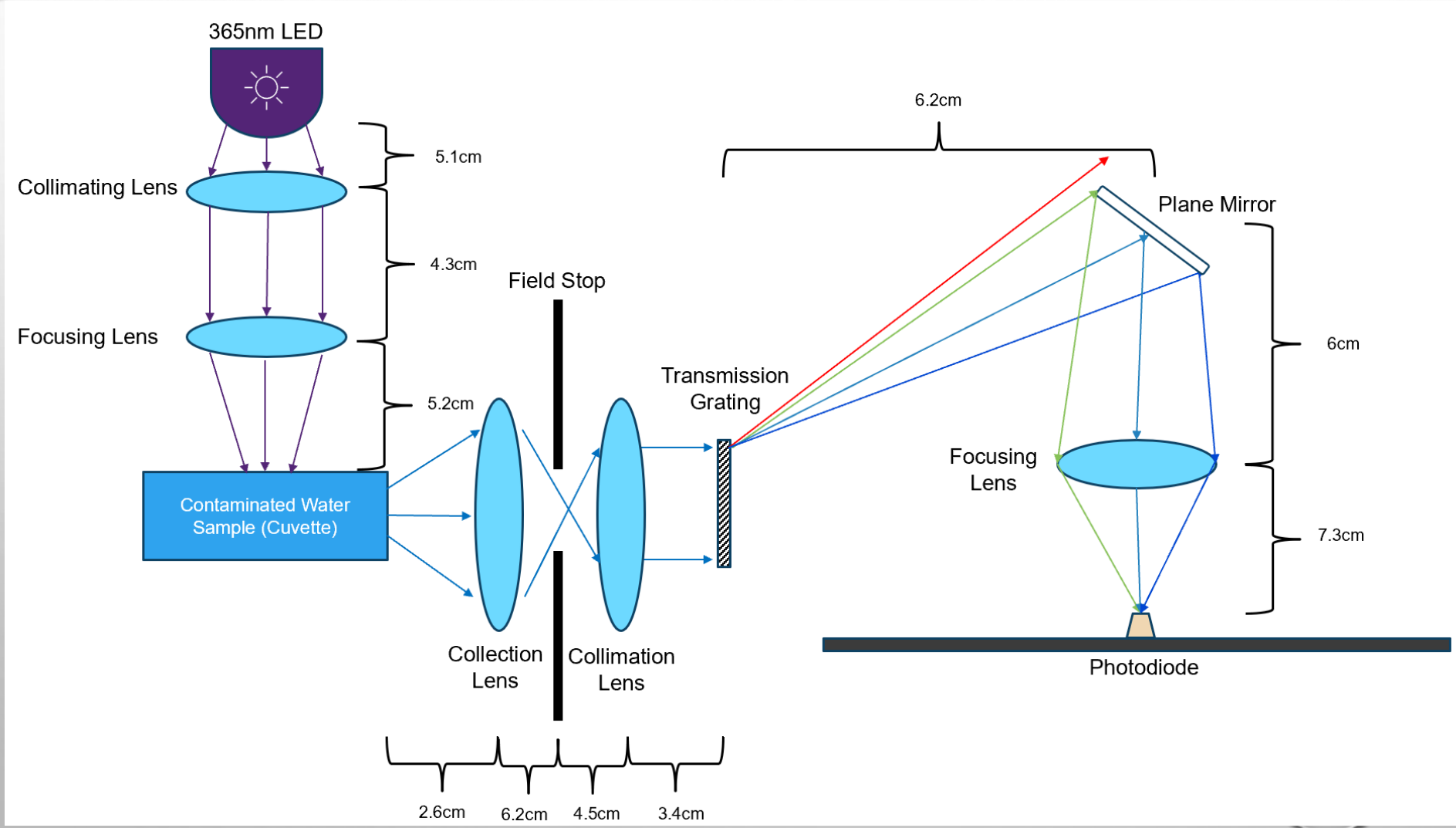
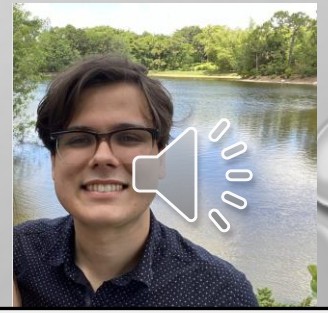
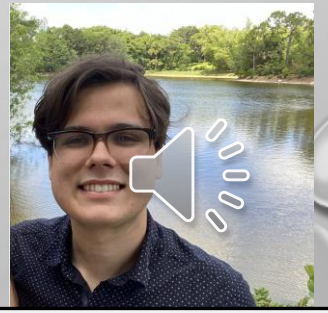
Overall Optical Design





ETHAN SHEPHERD – PSE

Overall Optical Design



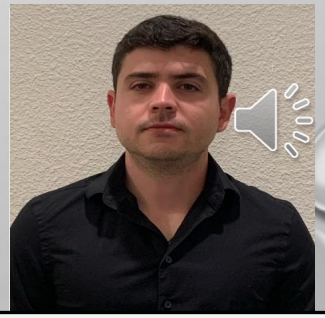
ETHAN SHEPHERD – PSE

Microcontroller Comparison and Selection

Criteria for Selection:

1. Communication Interfaces
2. I/O Pins
3. Power Requirements
4. Development Environment and Tools
5. Cost
6. Memory
7. Processing Power
8. Analog Inputs

	Arduino Uno Rev3	*Raspberry Pi Pico*	*MSP430FR6989*
Clock's speed (MHz)	16	133	16
Communication interfaces	UART, I2C, SPI, USB	UART, I2C, SPI, PIO	UART, I2C, SPI, USI
Memory	32 KB Flash, 2 KB SRAM	264 KB RAM, 2 MB Flash	128 KB Flash, 2 KB SRAM
Operating voltage (V)	7 to 12	3.3	1.8 to 3.6
Cost ($)	27	4	20



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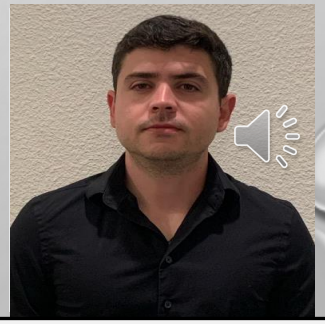
Power Supply Research and Selection

	Wall adapter	*Disposable batteries*	*Rechargeable batteries*
Portable	No	Yes	Yes
Long run cost-effective	Yes	No	Yes
Easy to use	Yes	Yes	Yes
Environmentally friendly	Yes	No	Yes

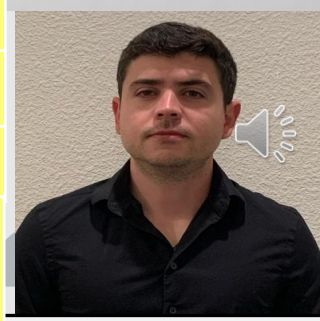


PASCUAL SIRACUSA – EE

Rechargeable battery Comparison and Selection

	Voltage	*Current*
UV LED	3.2 V	20 mA
Red LED	2 V	15 mA
Green LED	3.2 V	15 mA
Microcontroller	7 to 12 V	50 mA
Op-Amp	±4 V to ±18 V	

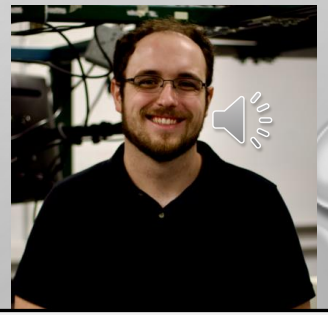
	Lead-Acid	***Nickel-Cadmium***	***Lithium-ion***	***Nickel Metal Hydride***	***Lithium-ion Polymer***
Manufacturer	Miady	Exell Battery	AOLIKES	Gecoty	Blomiky
Dimensions (in)	2.68 x 1.77 x 3.86	2 x 2 x 1.25	2.68 x 1.46 x 0.75	4.21 x 2.99 x 1.93	2.8 x 1.3 x 0.9
Weight (lbs)	0.2	0.56	0.22	0.2	0.23
Voltage (V)	6	12	7.4	7.2	11.1
Current (Ah)	5	1	2.6	2.4	1.5
Price ($)	16.99	23.95	15.82	15.99	14.99
Reason for selection	Not suitable due to size constraints	Not suitable due to memory effect and environmental concerns	Safety concerns	Suffers memory effect and shorter lifespan	high voltage, compact size, lightweight, cost-effective



Excitation Source

- Not many options for excitation
  - Lasers too large and expensive
  - Laser diodes do not exist cheaply in this wavelength range
  - LEDs are essentially the only option.
- Most important factors are power and 365nm center wavelength

Component	Center Wvl	Spectral Width	Viewing Angle (deg)	Power	Cost
JIATONG UVLED	365nm	25nm	20	1.1mW	$20 x20
TCY UVLED	365nm	30nm	35	2mW	$3.50 x10
LST1-01G01-UV01-00	365nm	40nm	130	875mW	$21.80 x1



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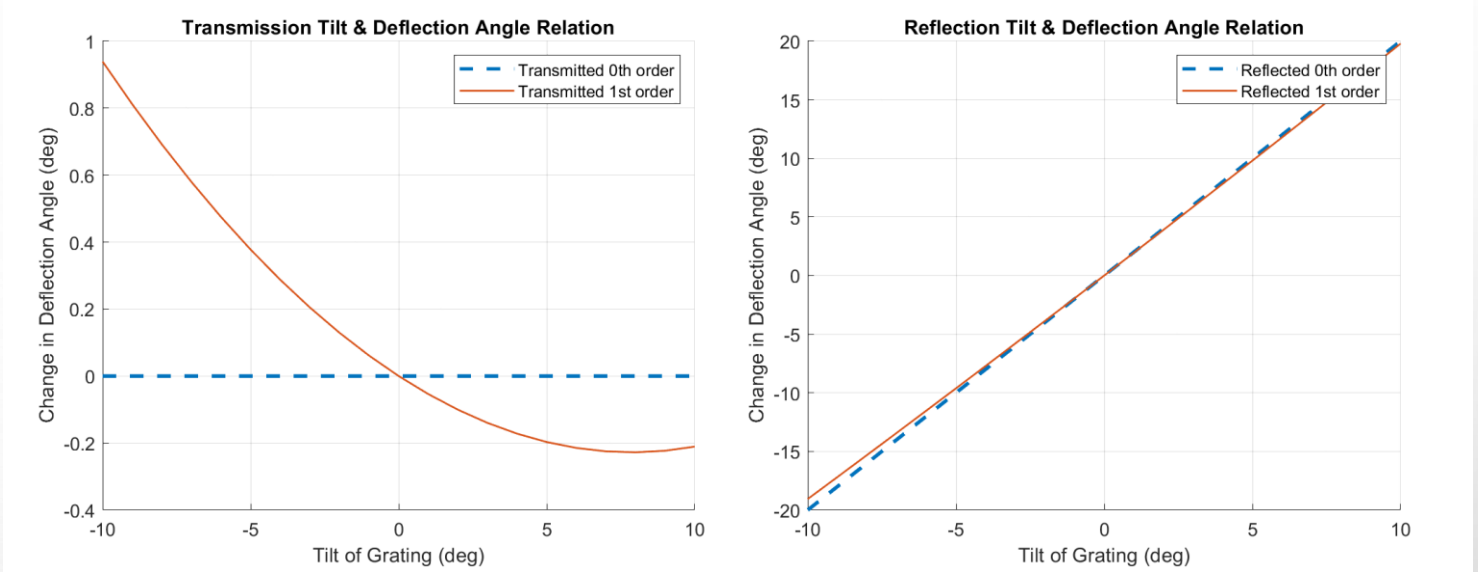
Diffraction Grating

- Transmission vs Reflection grating
- Need high efficiency at 465 nm
- Need high diffraction period
- Selected is middle of both needs



Component	Blaze Wvl	Transmission @ 465 nm	Diffraction Period	Dim.	Cost
Edmund Optics 85-290	290nm	25%	1200	12.7 mm x 12.7 mm	$110
Thorlabs GTY13-06	365nm	55%	600	12.7 mm x 12.7 mm	$106
Thorlabs GT13-03	525nm	65%	300	12.7 mm x 12.7 mm	$91

ETHAN SHEPHERD – PSE

Technology	Powering	Signal Readability	Cost
Photodiode	No	Easy	Low - High
CCD Camera	Yes	Hard	High

Photodiode

- Main Factors:
  - Responsitivity --> Better SNR
  - Cost --> Lower is better

- Detecting Area not as important
  - Will need to focus with lens for best signal

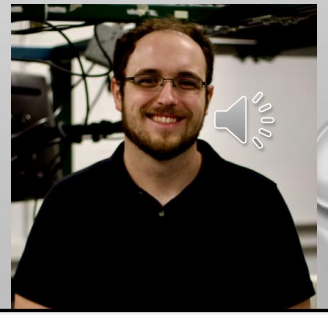
$$I = 100\mu A, R = 0.33 A/W$$

$$P_{in} = R \cdot I$$

$$P_{in} = 0.33 \cdot 100 \cdot 10^{-6}$$

$$P_{in} = 330\mu W$$

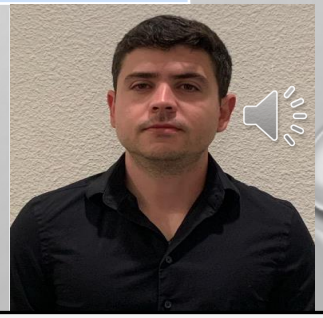
Component	Detecting Area	Responsitivity (A/W)	Cost
BPW21-O	2.73mm x 2.73mm	0.27	$13.08
MT03-023	1.1mm x 1.1mm	0.33	$16.75
FD11A	1.1mm x 1.1mm	0.28	$16.00
ODD-5WB	2.52mm diameter	0.25	$9.01



DYLAN BRANCATO – PSE

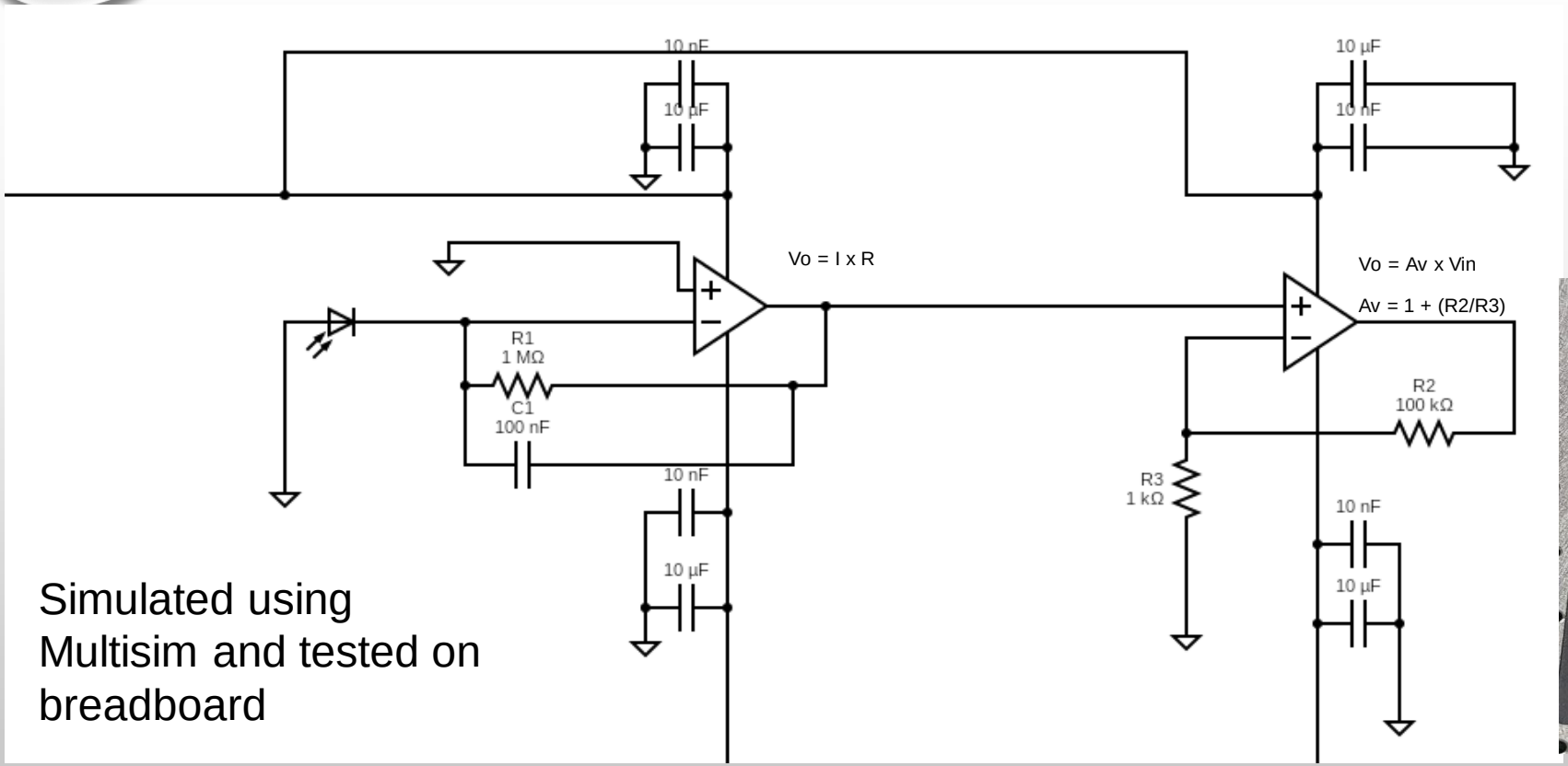
Operational Amplifier Comparison and Selection

	OP27GPZ	*TL084I*
Voltage Supply Range	±4 V to ±18 V	±2.25 V to ±20 V
Input Offset Current	12 nA	5 pA
Input Bias Current	15 nA	30 pA
Input Offset Voltage	30μV	3 mV
Input Voltage Noise	3nV/√Hz	18 nV/√Hz
CMRR	120 dB	86 dB
Cost	$5.80	$0.9

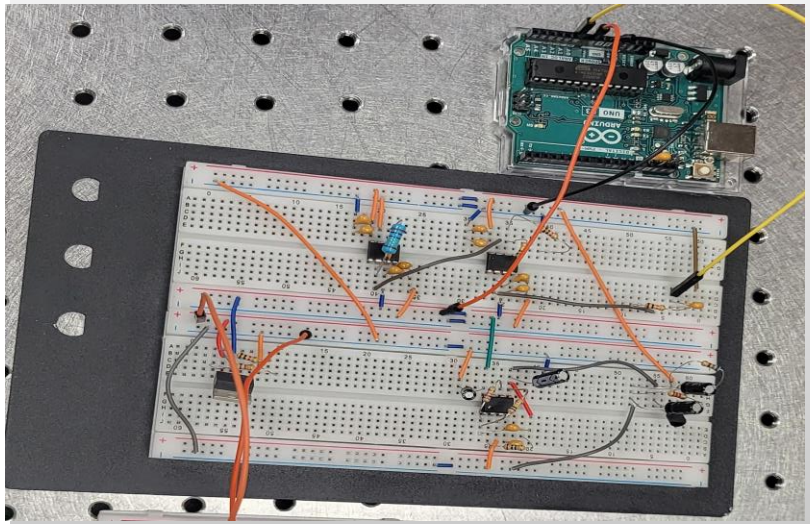


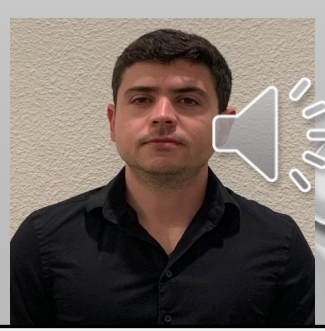
PASCUAL SIRACUSA – EE

OPERATIONAL AMPLIFIER CIRCUIT DIAGRAM



Simulated using Multisim and tested on breadboard





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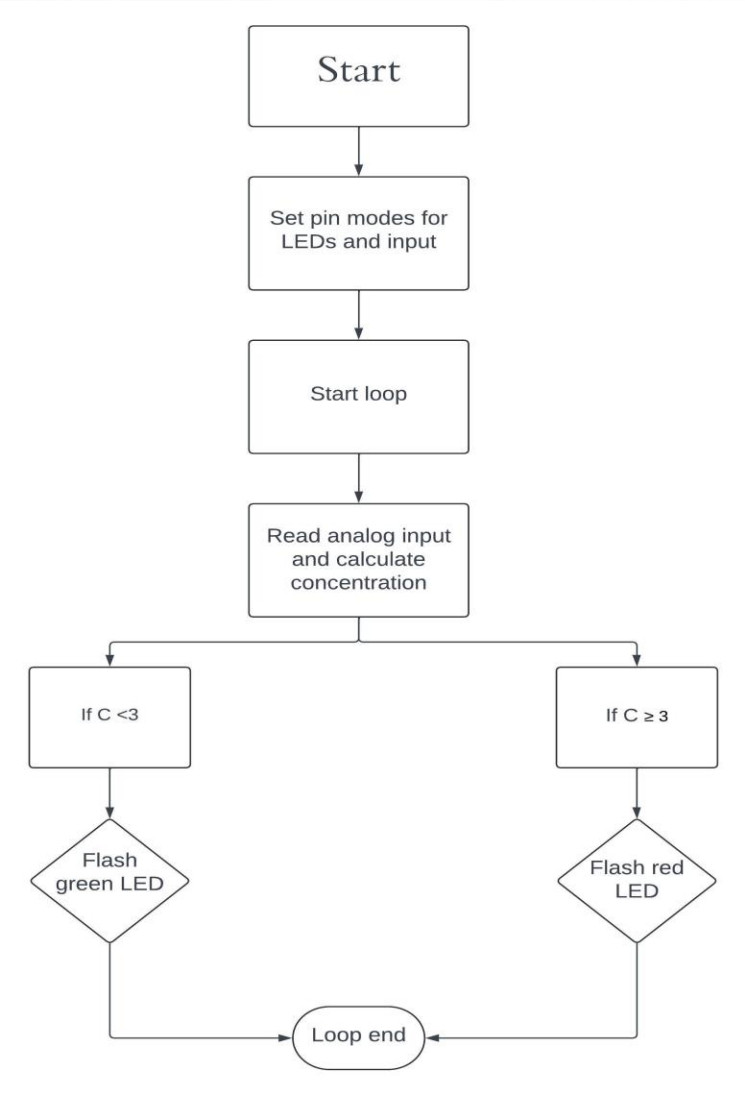
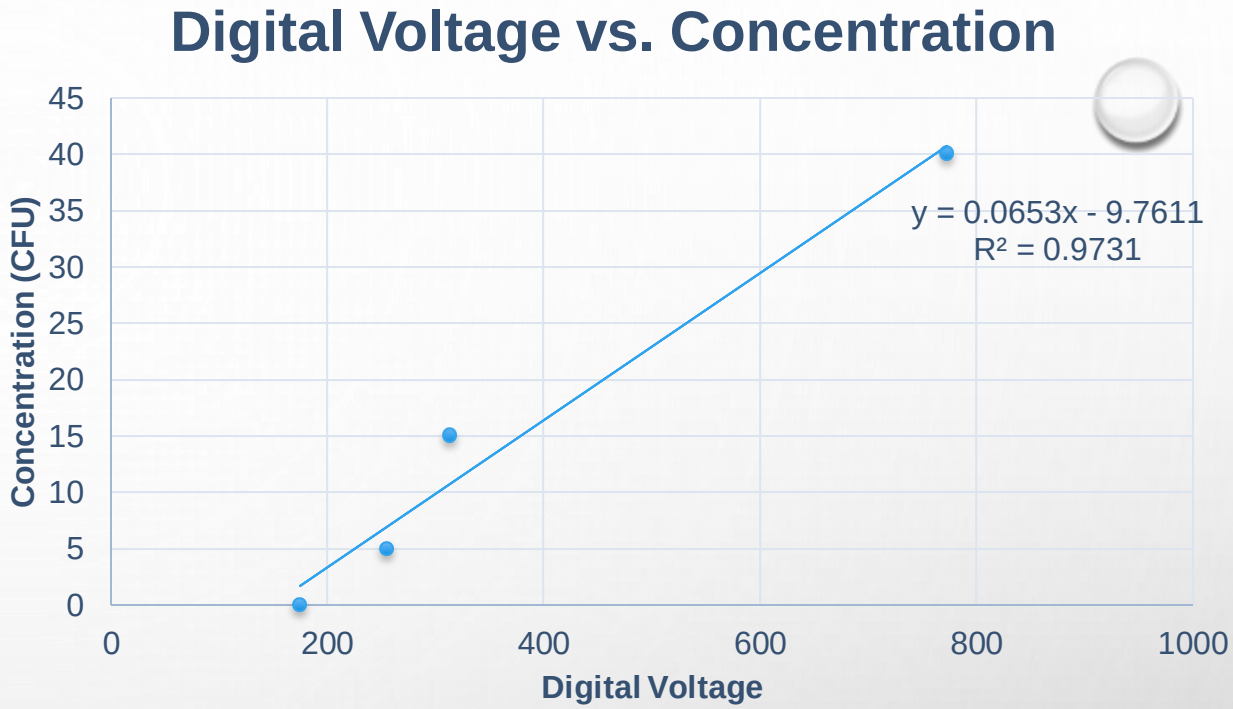
Software Flowchart





PASCUAL SIRACUSA – EE

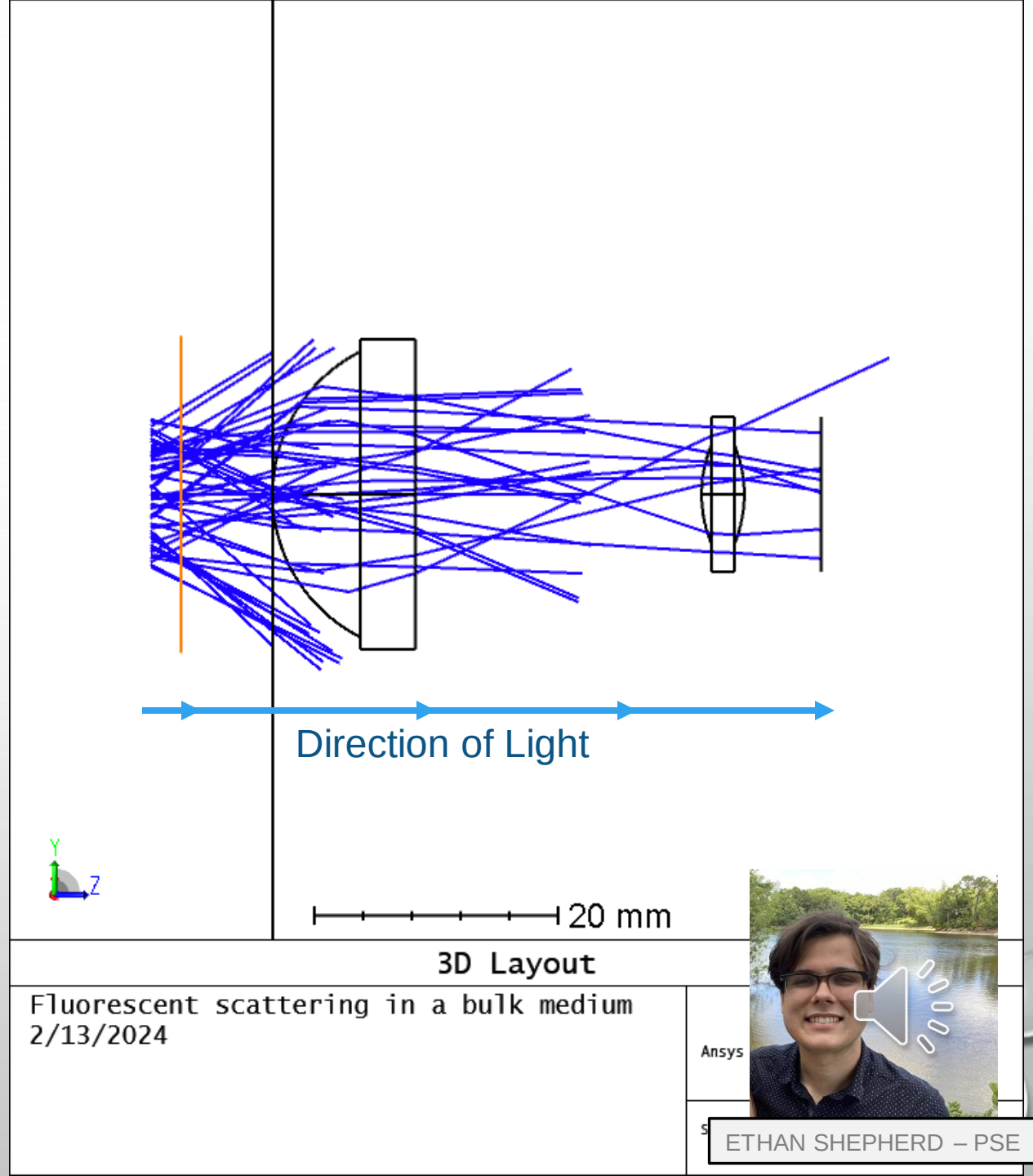
Lenses

- Three major lenses needed:
  - Exclusion of photodiode lens

1) Sample collection lens
   - High power, high NA

2) Spectrometer collimation lens
   - Lower power, 1/2” diameter

3) Spectrometer focusing lens
   - Lower Power

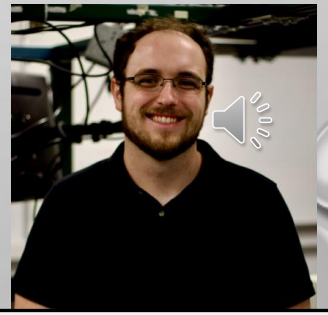


ETHAN SHEPHERD – PSE

LOD and LOQ

	Digital Voltage Reading (avg)	Concentration (CFU, avg)	Standard Deviation
Pure Water	174	1.56	0.0346
Pure Water + DAPI (2drops/ml)	188	2.517	0.0651
Water + Bacteria (40CFU)	196.294	3.057	0.0552
Water + Bacteria (40CFU) + DAPI	756.67	39.656	0.077

- For 99% confidence interval, an LOD of:
  - 1.649CFU for pure water
  - 2.685CFU for pure water +DAPI
- For LOQ using the 10 times rule:
  - 1.906CFU for pure water
  - 3.168CFU for pure water + DAPI
- Manufacturer recommendation is wait 20 minutes for stain
  - Results max out at about 2.139 ± 0.3385 minutes for concentration of 40CFU



DYLAN BRANCATO – PSE

Work Distribution

Ethan Shepherd	Dylan Brancato	Pascual Siracusa
• Light collection from sample • Detection method • Spectrometer design • Housing	• Sample Preparation • Fluorescence emission • Spectrometer Design	• Power Distribution • Data Processing • Signal Amplification

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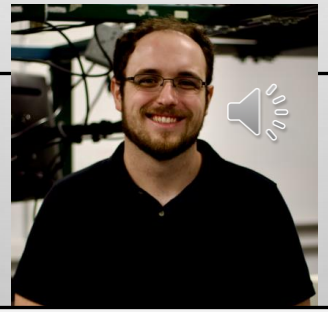

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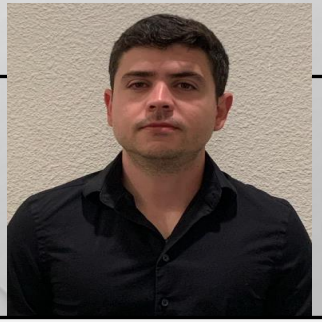
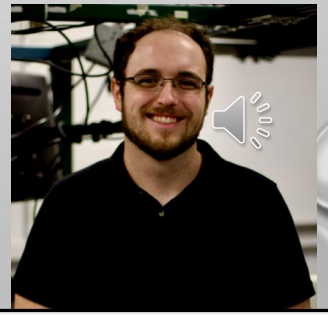


PASCUAL SIRACUSA – EE

Bill of Materials vs Budget

Item	Quantity	Budget	Cost
Excitation Source	1	$15	$21.50
Cuvette	4	$40	$37.66
Bacteria Culture	2	$50	$42.15
Lenses	5	$120	$109.62
Diffraction Grating	1	$110	$106.84
Photodiode	2	$10	$16.75
Microcontroller	1	$30	$27.60
Battery	2	$20	$29.98
Various EE Parts	X	$20	$22.85
DAPI Stain	1	$100	$158.65
Housing materials	X	$70	$85.37
Total		$585	$658.97



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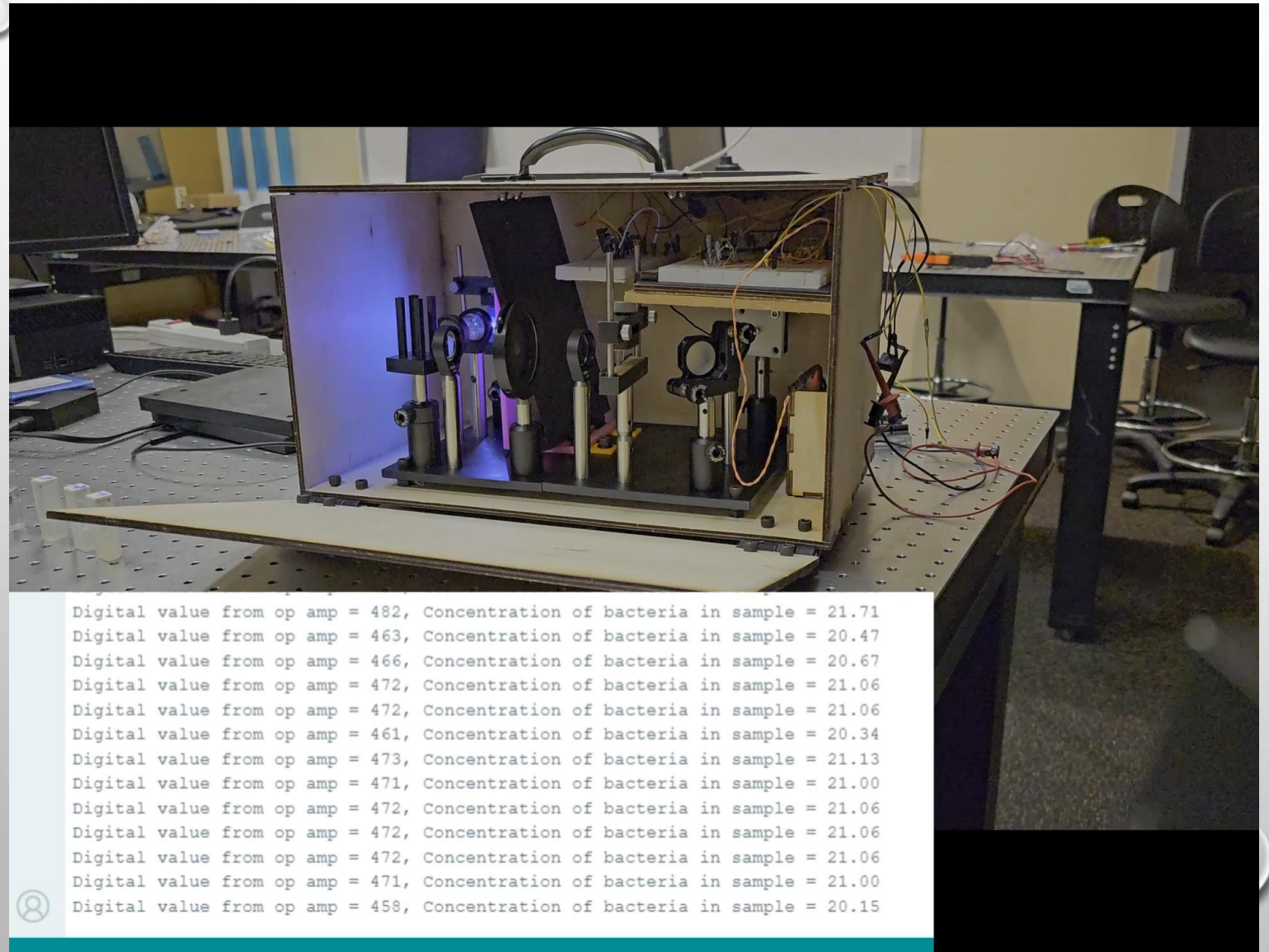
Device Functionality



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Digital value from op amp = 482, Concentration of bacteria in sample = 21.71
Digital value from op amp = 463, Concentration of bacteria in sample = 20.47
Digital value from op amp = 466, Concentration of bacteria in sample = 20.67
Digital value from op amp = 472, Concentration of bacteria in sample = 21.06
Digital value from op amp = 472, Concentration of bacteria in sample = 21.06
Digital value from op amp = 461, Concentration of bacteria in sample = 20.34
Digital value from op amp = 473, Concentration of bacteria in sample = 21.13
Digital value from op amp = 471, Concentration of bacteria in sample = 21.00
Digital value from op amp = 472, Concentration of bacteria in sample = 21.06
Digital value from op amp = 472, Concentration of bacteria in sample = 21.06
Digital value from op amp = 472, Concentration of bacteria in sample = 21.06
Digital value from op amp = 471, Concentration of bacteria in sample = 21.00
Digital value from op amp = 458, Concentration of bacteria in sample = 20.15
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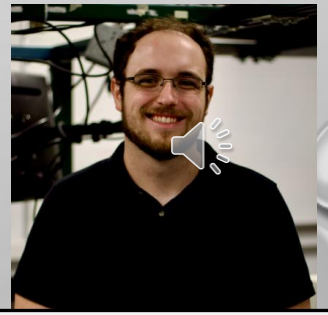

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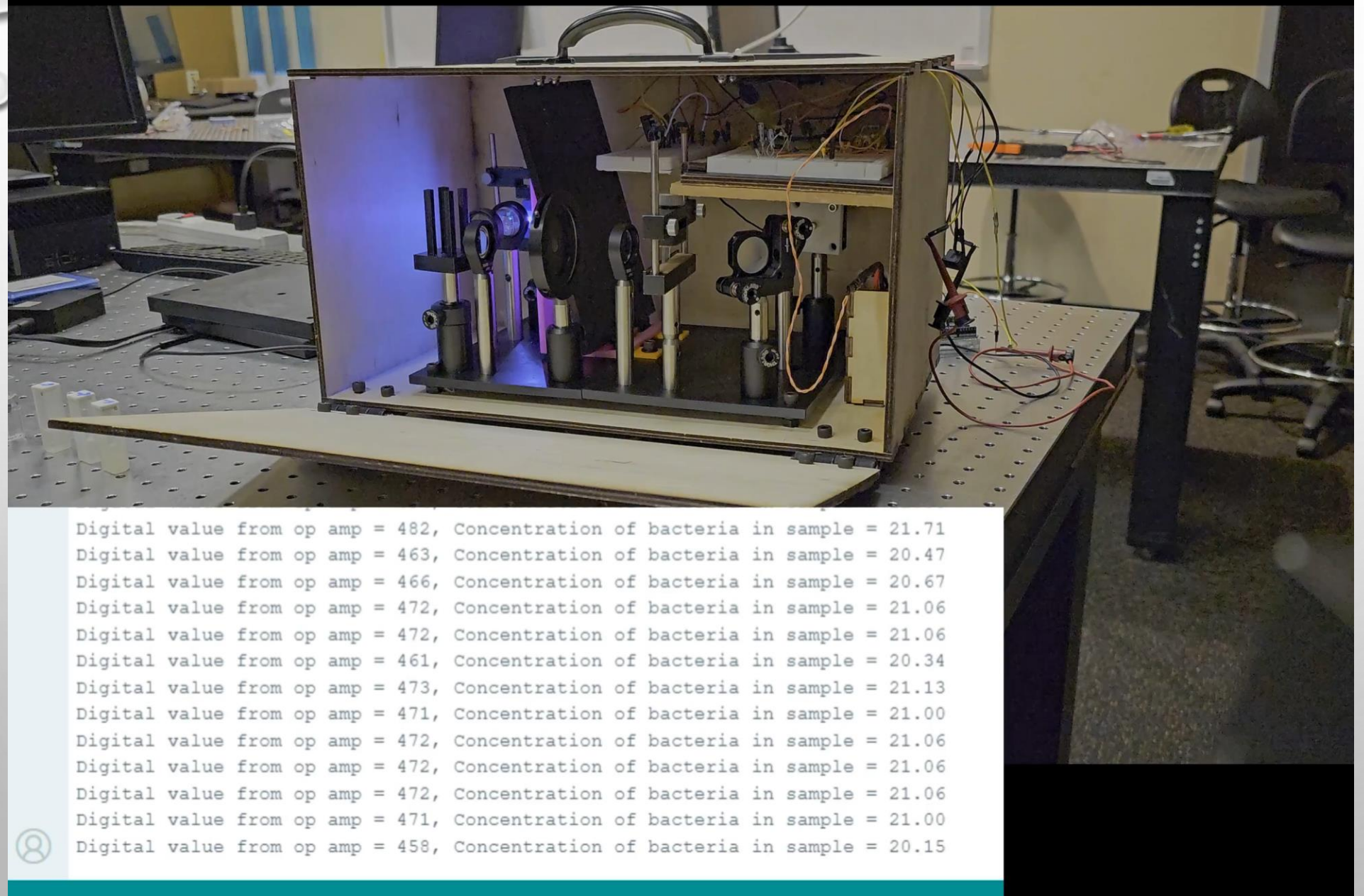

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Digital value from op amp = 472, Concentration of bacteria in sample = 21.06
Digital value from op amp = 471, Concentration of bacteria in sample = 21.00
Digital value from op amp = 458, Concentration of bacteria in sample = 20.15
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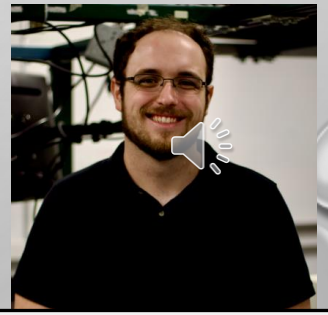
Note:

- Some concentration is shown for pure water samples, this is due to scattered light off the cuvette and fluorescence of unbound stain. The concentration is 0.



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