SASSPR

Semi-Automated Sensor for Surface Plasmon Resonance

Group 2
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Motivation

- Viruses such as COVID-19 show the importance of rapid and accurate drug development.
- Observing molecular binding between an analyte and ligand is a crucial step in many biological research projects, including drug development.
- SPR sensors monitor the binding kinetics of the interaction between biomolecules without the need for labels, while also providing information on the on and off rates.
- However, commercial SPR sensors are very expensive, average cost $40,000.
- Affordable SPR sensors would provide biochemistry labs across the world with more accurate data on biomolecular interactions.

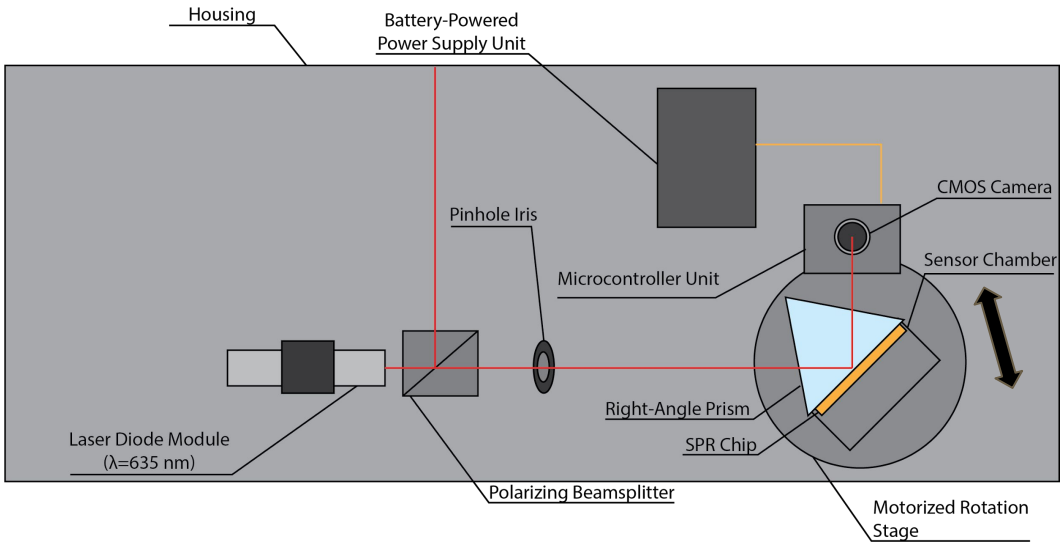
Goals and Objectives

- Design a more affordable SPR sensor compared to commercial SPR sensors on the market.
- SPR sensor will detect when surface plasmon excitation occurs and display the information to the consumer in a graphical representation.
- Sensor location will be easy to clean and reusable for future experiments.
- Experiments will be easily repeatable.

Design Description

Step 1: Determine Initial SPR Angle

- SPR chip is placed onto base of prism by user, affixed to surface using index matching gel.
- Software application fully controls camera and MCU. Laser and motorized rotation stage powered and controlled externally.
- Using Kinesis software, user rotates the motorized rotation stage from range 44-48° at a velocity of 0.5°/s.
- Camera captures 1 image every 0.5 s.
- Application measures the intensity profile of the captured images taken during the measurements. From data, the angle where max drop in intensity occurred is provided to user in a graphical representation in application.
- Rotation stage is rotated to angle were max drop in intensity was observed using Kinesis software.



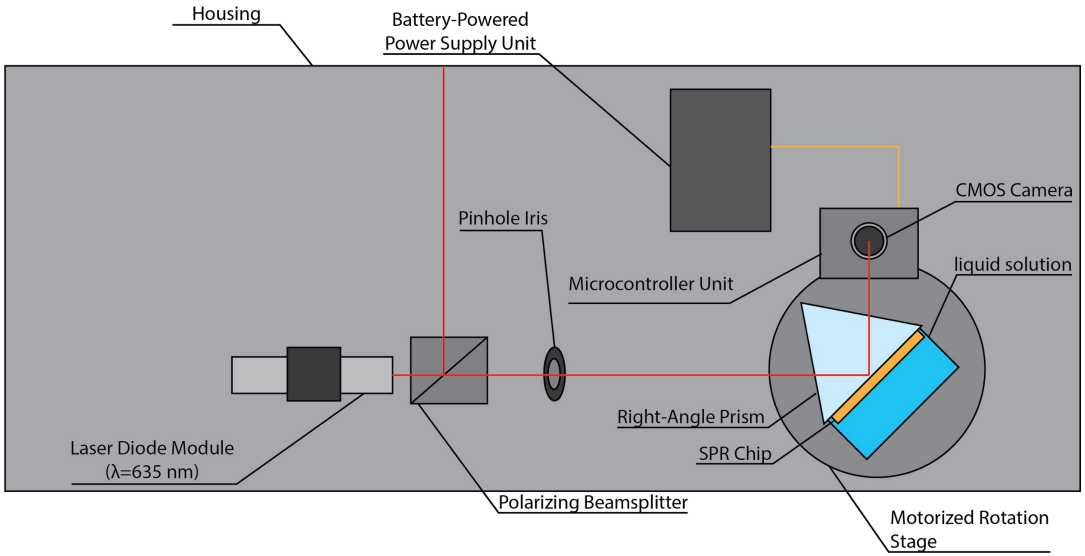
Design Description

Step 2: Observe Shift in SPR Angle

- Liquid solution to be tested is added by user to sensing chamber. The rotation stage remains fixed at angle of lowest intensity.
- Camera continues capturing 1 image every 0.5 s to create graphical representation of changes in intensity observed.

Final Results

- Software displays Reflectance vs. Time graph to user.
- Max/Min intensity data values provided for easy measurement of intensity changes during experiment.

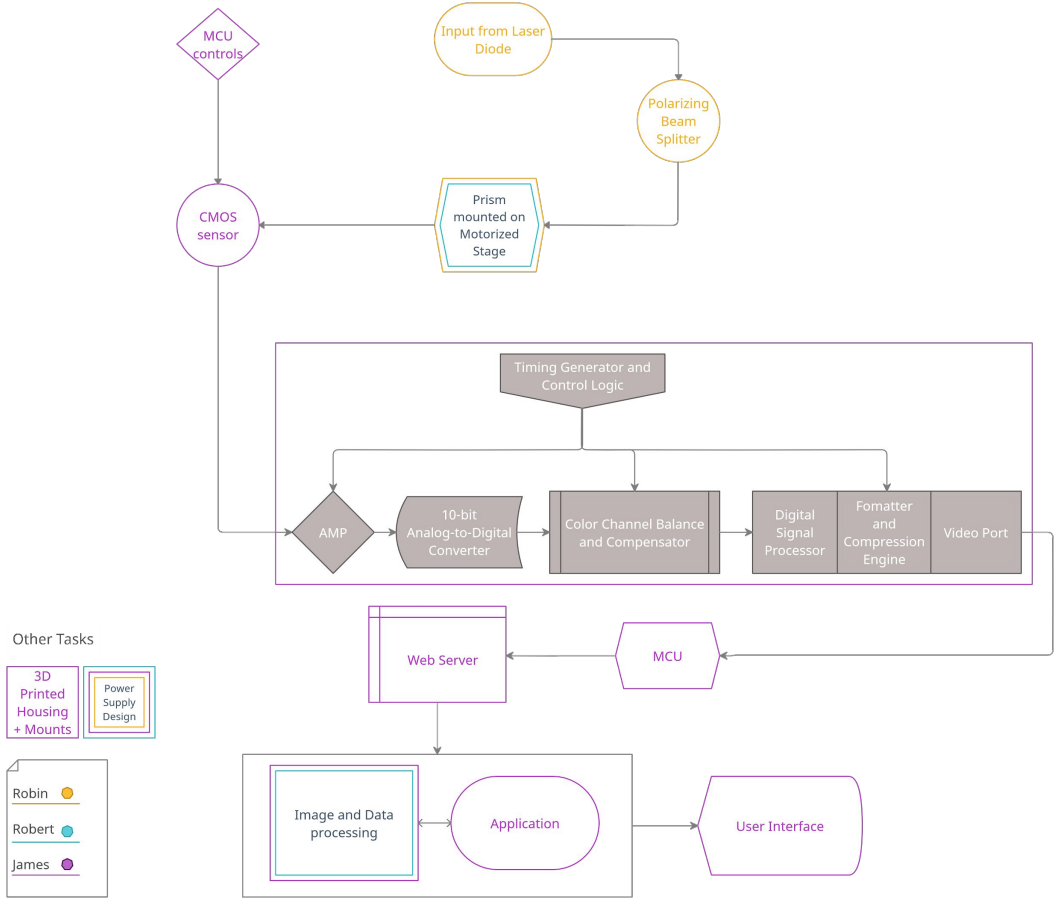


Engineering Specifications

Requirements	Units
The wavelength of laser ensures minimum broadening of SPR angular dependence.	635 nm
The CMOS camera will have a fast response time to collect necessary data.	1 image per 0.5 seconds
The motorized rotation stage provides high precision to create excitation of SPP.	25 arcsec achievable incremental motion 0.1% percentage accuracy
The software application will collect the intensity profile of images captured and process the data into graphs showing the SPR angle when molecular binding occurs within the specified time.	< 500 ms
The system shall be as compact as possible within the specified dimensions.	≤ 8” x 16” x 12”
The power draw of system will be minimal to optimize lifetime.	<10 W

Hardware Design

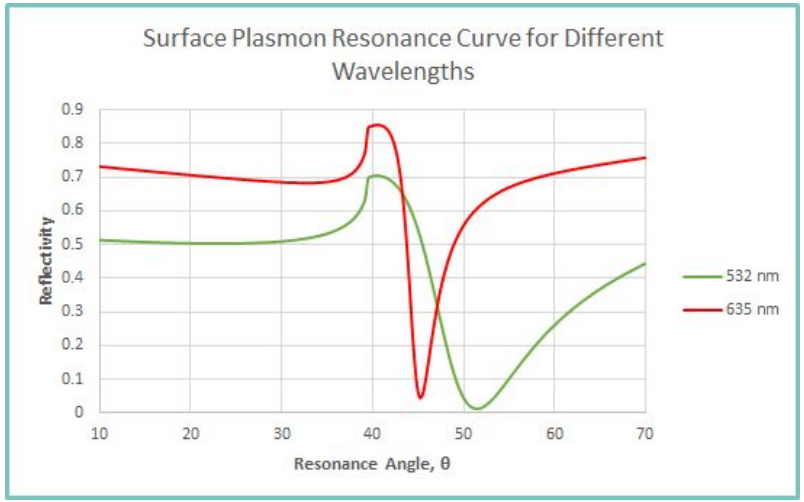
Hardware Block Diagram



Laser Diode Module

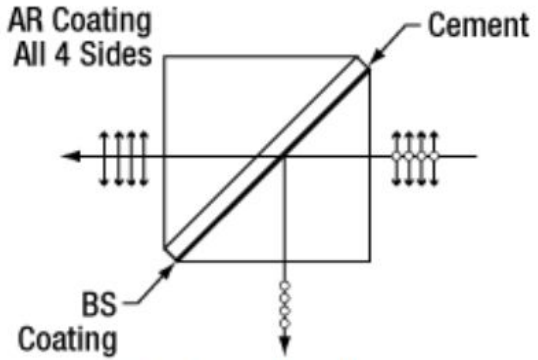
Wavelength	Manufacturer	Price	Beam divergence	Optical Output Power (CW)	Operating Voltage
532 nm	Thorlabs	$172.06	0.5 mrad	0.9 mW	4.9-5.2 V
635 nm	Thorlabs	$97.39	0.6 mrad	1.2 mW	4.9-5.2 V

Wavelength (nm)	Real Part of Dielectric Function of 50nm Gold, ε'_1	Imaginary Part of Dielectric Function of 50nm Gold, ε''_1	Length of Intensity Decay Along Direction of Propagation, L (μm)	Phase Velocity (v_p/c)
532	-4.0	1.3	0.677	0.866
635	-8.0	0.9	5.88	0.935



Polarizing Beam Splitter

Manufacturer	Thorlabs
Price	$282.44
Dimensions	16x16 mm
Extinction Ratio	T_p:T_s >1000:1
Surface Flatness	<λ/4 @ 633 nm

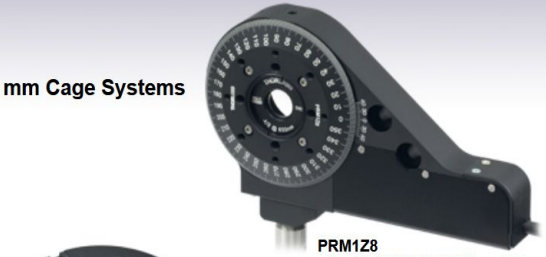


Cube Beamsplitter Diagram
(Coating and Cement Layer Not to Scale)

Motorized Precision Rotation Stage

Manufacturer	Thorlabs
Price	$1,483.58
Dimensions	131x23x83 mm
Achievable Incremental Motion (min)	25 arcsec
Percentage Accuracy	0.1%
Backlash	±0.3°
Bidirectional Repeatability	±0.1°

- Continous 360° Motorized Rotation
- 25 arcsec Minimum Incremental Motion
- Rotational Velocity: 25 Degree/Second
- Compatible with Our SM1 Lens Tubes and 30 mm Cage Systems



Surface Plasmon Sensor Material

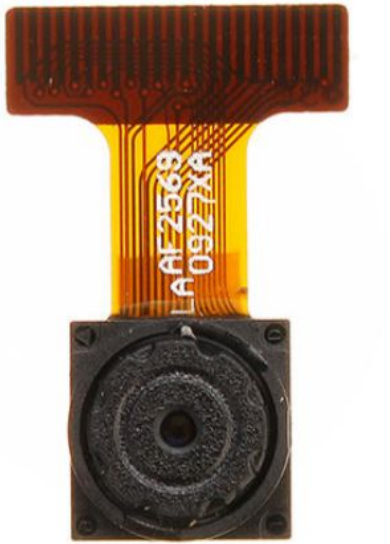
Material	Cost	Upkeep	Characteristics
Fiber Optic Cable	$8.50/meter	• Needs replacement after each use. • Metal film must be coated evenly on fiber optic core surface.	• Single mode • Operating wavelengths: 488-633 nm • Cladding diameter: 125μm • Coating diameter: 245μm
BK7 Right Angle Prism	$51.68	• Easy to clean with acetone or isopropanol. • Manufactured SPR chip can be attached to surface.	• Dimensions: 20x20x20 mm • Refractive index: 1.52 • Transmission: 93% at λ=635 nm

Microcontroller Unit

- Modified from original ESP32 to support Pseudostatic RAM and a parallel camera interface, enhancing IoT functionality
- Low-Energy Bluetooth
- Dual Wi-Fi
- Small, cheap and abundant for testing

The processing power of the ESP32 was potentially too slow for our engineering specifications but with the aforementioned qualities, we decided to work with what the device offered.

CMOS Sensor



- Omnivsion image sensor that supports up to 1600 x 1200 resolution, 15 captures per second
- Popular amongst tech giants, widely available documentation
- Onboard JPEG compression for low latency upload, removing load from MCU
- Compatible with low-end ARM microprocessors

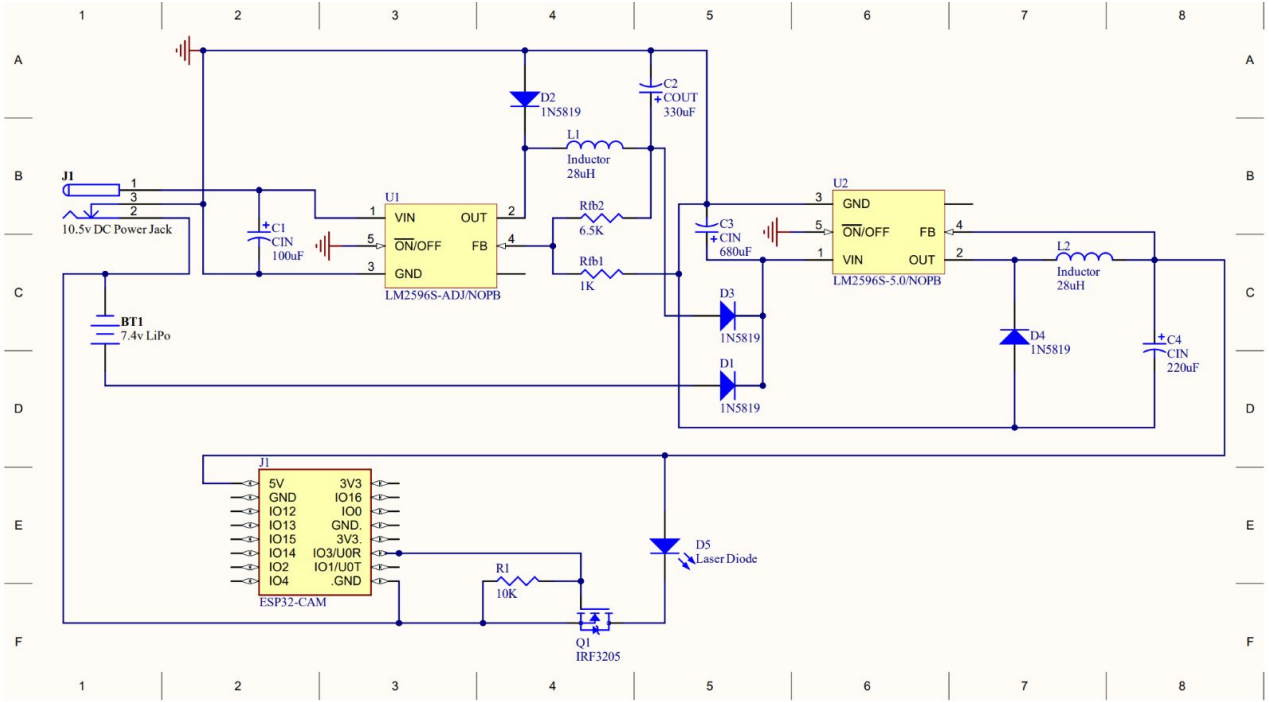
The OV2640 was a no-brainer for its similarities with smartphone cameras which is something used often for portable SPR systems.

MCU and CMOS Sensor	
Manufacturer	Xiuxin
Price	$17.99
Wireless Type	Bluetooth, 802.11bgn

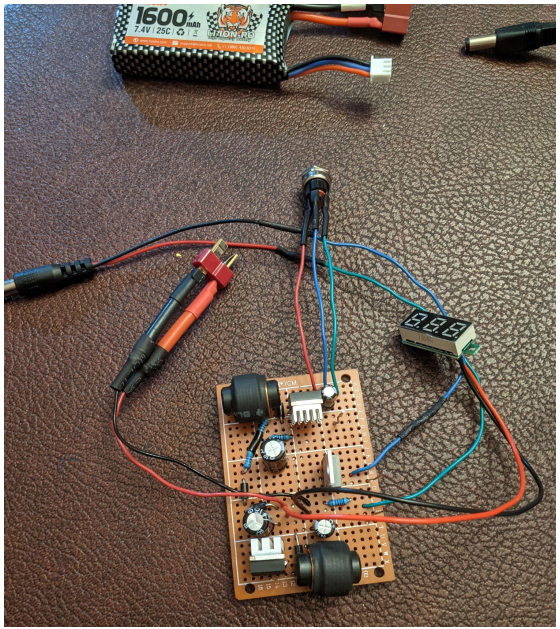
ESP32-CAM Capture vs Clock Frequency

Clock Rate	Pixel Resolution	Captures per Second	Average Processing Time	Maximum/ Minimum Processing Time
240 MHz	1600 x 1200	12.2	79 ms	209 ms/ 73 ms
240 MHz	800 x 600	25.6	40 ms	61 ms/ 38 ms
160 MHz	1600 x 1200	11.9	83 ms	162 ms/ 74 ms
160 MHz	800 x 600	27.1	39 ms	98 ms/ 42 ms
80 MHz	1600 x 1200	8.3	112 ms	185 ms/ 67 ms
80 MHz	800 x 600	25.6	39 ms	72 ms/ 34 ms

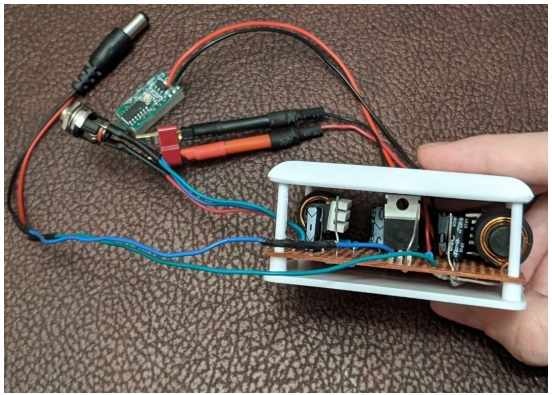
Power Design



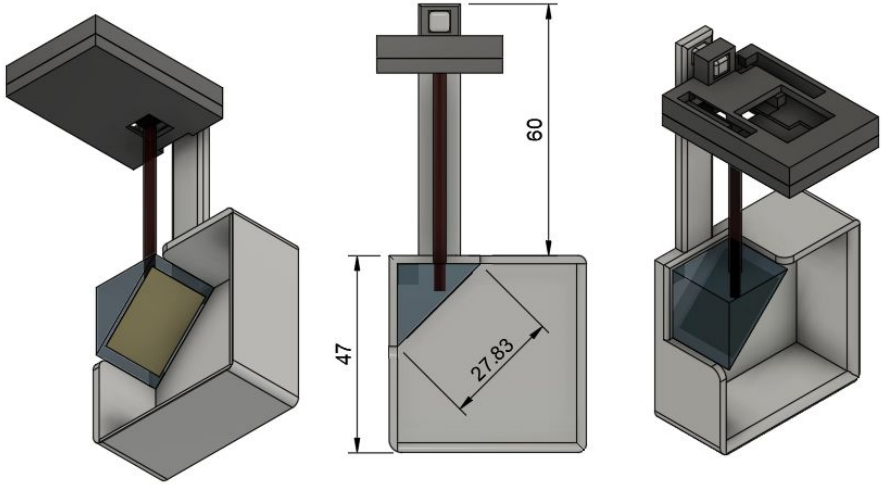
Perfboard for AC Adaptor and Battery Power Regulation

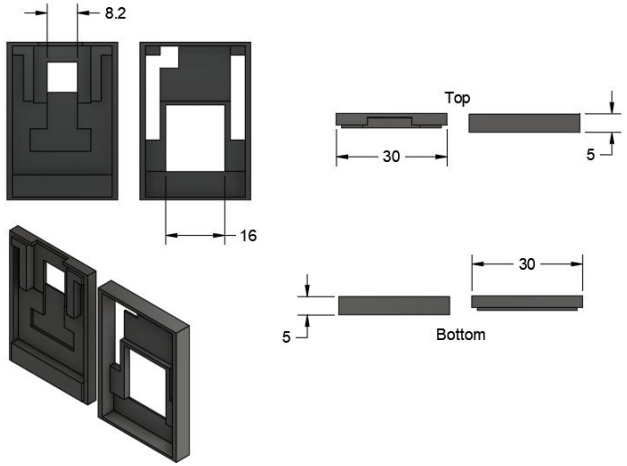


- Uses AC from a wall adaptor and DC from a LiPo battery, prioritizing AC when both are attached.
- Delivers power to microcontroller, laser diode, and rotation platform
- Uses 2 switching regulators
- Voltmeter to read battery charge level
- Houses transistor for binary control of power delivery to laser diode.



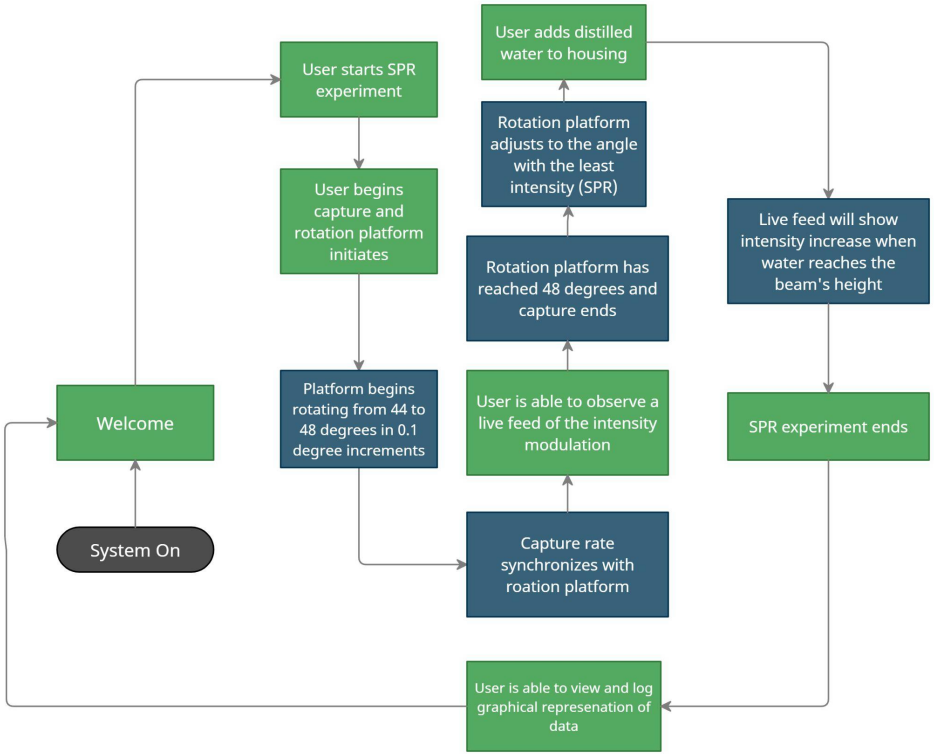
3D Printed Housing





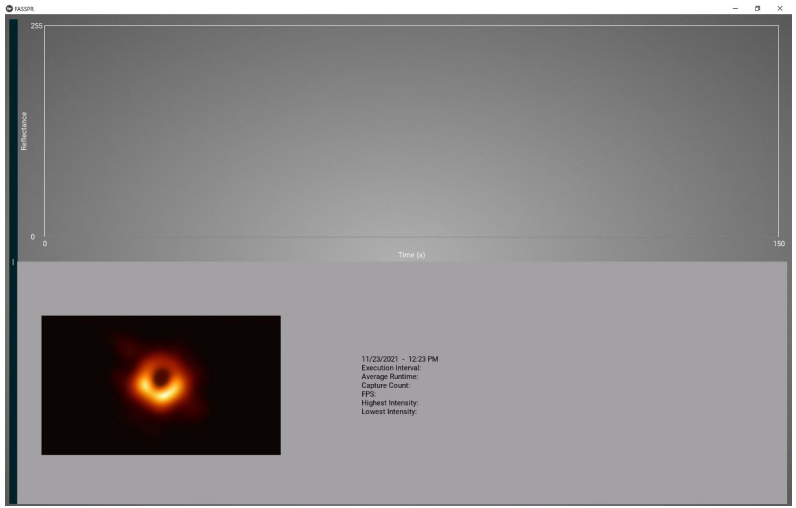
Software Design

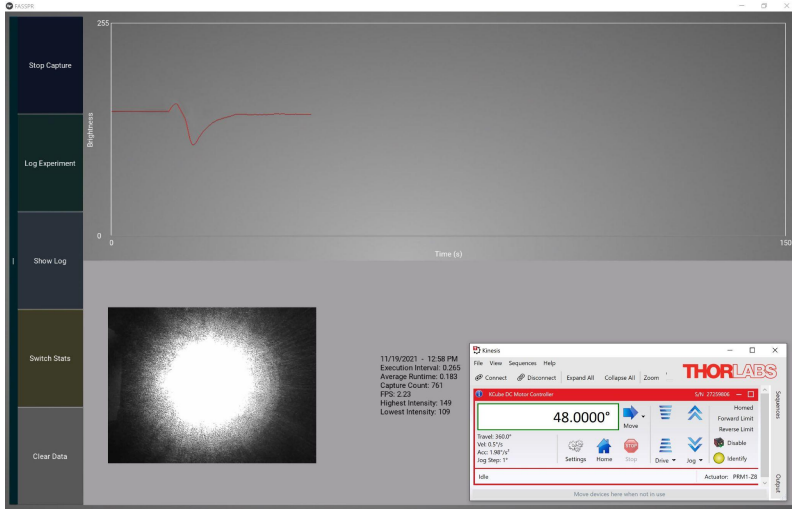
Application Block Diagram



Kivy Python Framework

- Written entirely in Python
- Fast response time to fulfill capture rate requirement
- Compatible with MacOS, iOS, Android, and Windows.
- Free and Open Source meaning wide availability of addons, libraries and documentation
- Enables rapid prototyping by building the application for all compatible systems



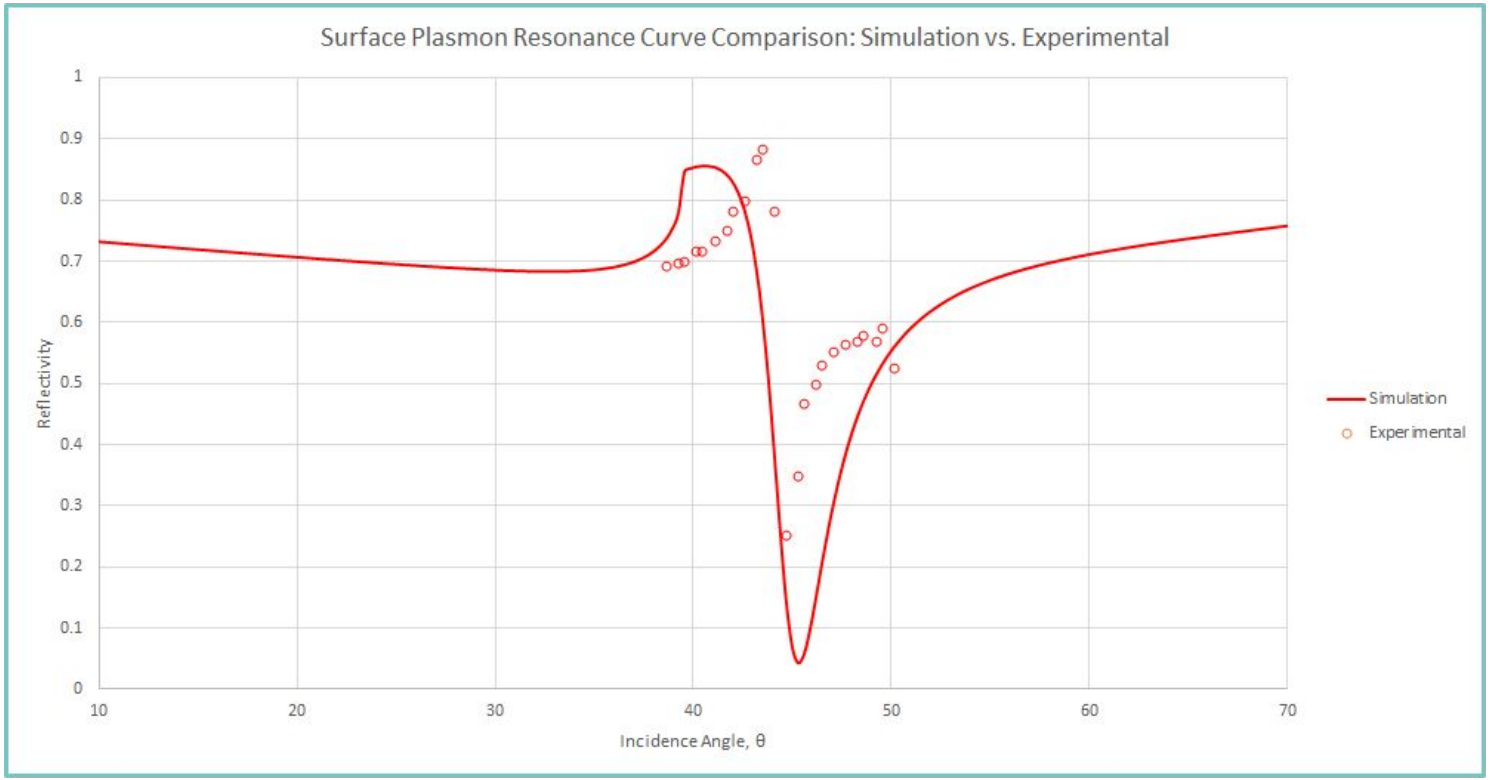


Software Solution for SASSPR

- Variable execution interval to maintain desired capture rate
- Monitor status of runtime and FPS which reveals the health status of the ESP32-CAM
- Measure and record perceived brightness of captured images and graph them over time
- View and log min / max intensity values for easier comparison
- Compatible with Windows, Android, Mac OS and iOS

Results

Simulation vs. Experimental Results



Administrative Content

Work Distribution

Member	Physical Optics	Data Analysis	Hardware	Software Application
Robert		X		
Robin	X			
James			X	X

Project Budget and Financing

Item	Quantity	Price	Out of Pocket Cost
Collimated Laser Diode Module, 635nm, 1.2mW, Round Beam	1	97.39	Covered by CREOL
Laser Diode Module Mounting Kit, 120V	1	217.51	Covered by CREOL
Motorized Precision Rotation Stage with 2.56" Platform (Imperial)	1	945.26	Covered by CREOL
K-Cube Brushed DC Servo Motor Controller	1	677.41	Covered by CREOL
15V 2.4A Power Supply Unit with 3.5mm Jack Connector for One K-Cube	1	35.36	Covered by CREOL
20mm Right-Angle Prism	1	51.68	51.68
16mm Cage-Cube-Mounted Polarizing Beamsplitter Cube, 420-680nm	1	282.44	282.44
ESP32- CAM WiFi Bluetooth Camera Module Board with OV2640 Camera	2	17.99	17.99
Distilled Water 64 oz	1	23.99	23.99
Bare gold SPR chip 20x20x0.55mm 3 pack	1	75	75
	Total Cost	2424.03	451.10

Conclusion