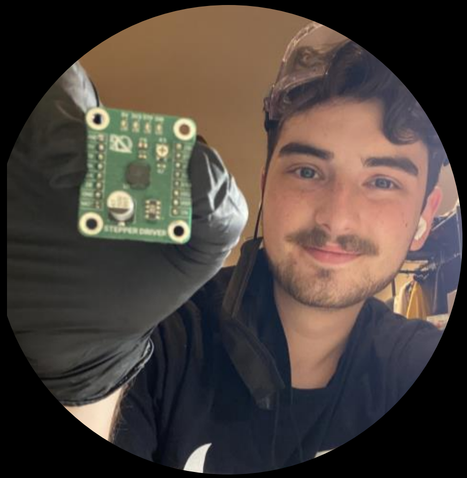
# AUTOMATED LENS METROLOGY

**Lens in, Datasheet out.**

Kiva McCracken (PSE)

Ollie Mueller (PSE)



Zachary Kassner (EE)

Daniel Gomez (CpE)

# MOTIVATION & BACKGROUND

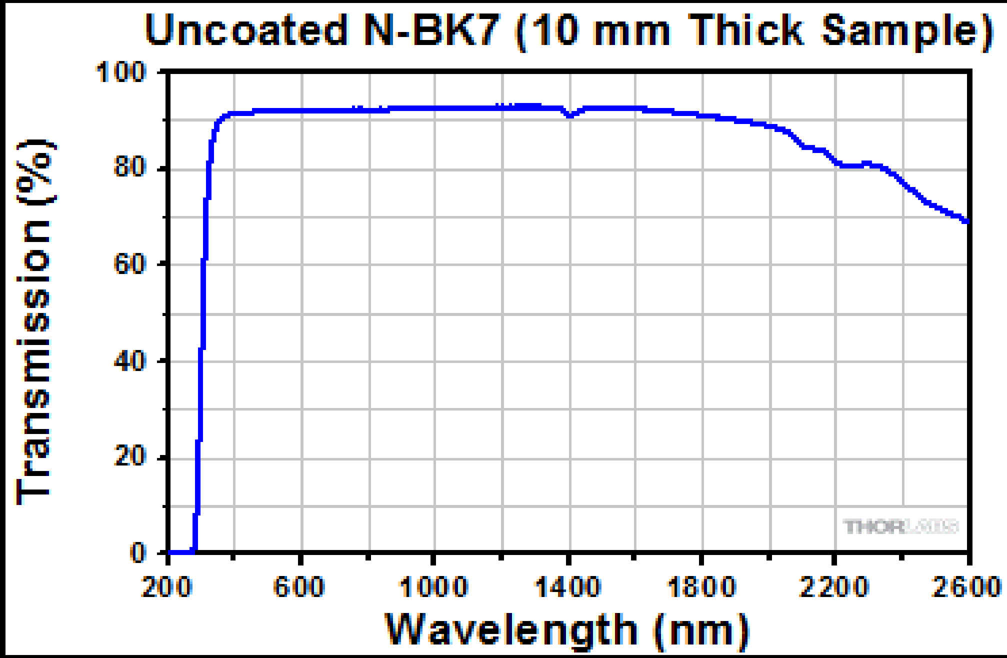


# SAMPLE DATASHEETS

## Ø9.0 mm N-BK7 Bi-Convex Lenses (Uncoated)

| Item # | Diameter | Focal Length[a] | Diopter[b] | Radius of Curvature | Center Thickness | Edge Thickness | Back Focal Length[a] | Reference Drawing |
|---|---|---|---|---|---|---|---|---|
| LB1494 | 9.0 mm | 12.0 mm | +83.3 | 11.7 mm | 3.6 mm | 1.8 mm | 10.7 mm | ⓘ |
| LB1212 | 9.0 mm | 20.0 mm | +50.0 | 20.1 mm | 2.8 mm | 1.8 mm | 19.0 mm | |

Suggested Fixed Lens Mount: LMR9(/M)

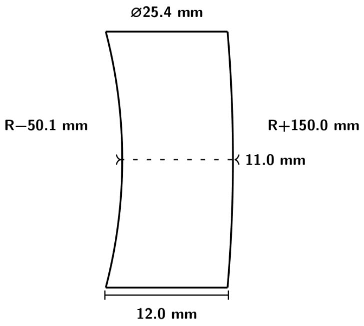



Industry (Thorlabs)

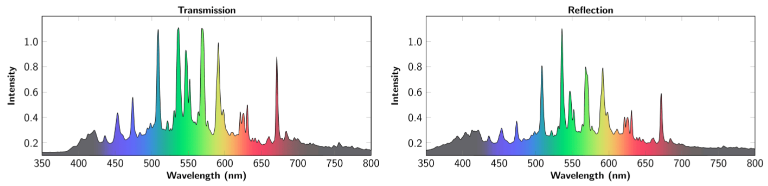
## Ø25.4 × 122.0 mm EFL Negative Meniscus Lens

**Geometry**

| | |
|---|---|
| Lens Shape | Negative Meniscus |
| Diameter (mm) | 25.4 |
| Center Thickness (mm) | 11.0 |
| Edge Thickness (mm) | 12.1 |
| Front Radius of Curvature (mm) | 150.0 |
| Back Radius of Curvature (mm) | −50.1 |




**Spectra**




**Optical**

| | $C_{656.3}$ | $D_{589.3}$ | $F_{486.1}$ |
|---|---|---|---|
| Effective Focal Length (mm) | 122.0 | **122.0** | 122.0 |
| Front Focal Length (mm) | 128.4 | **128.4** | 128.4 |
| Back Focal Length (mm) | 119.9 | **119.9** | 119.9 |
| Power ($m^{-1}$) | 8.20 | **8.20** | 8.20 |
| Index of Refraction | 1.31 | **1.31** | 1.31 |

| | |
|---|---|
| Abbe Number | 1 405 361 760 416 891.0 |
| Substrate | N-BK7 |
| Detected Coatings | AR Coated |

**Scan for .CSV File**

**Created by**

Kiva McCracken, Ollie Mueller, Zachary Kassner, and Daniel Gomez.

Ours

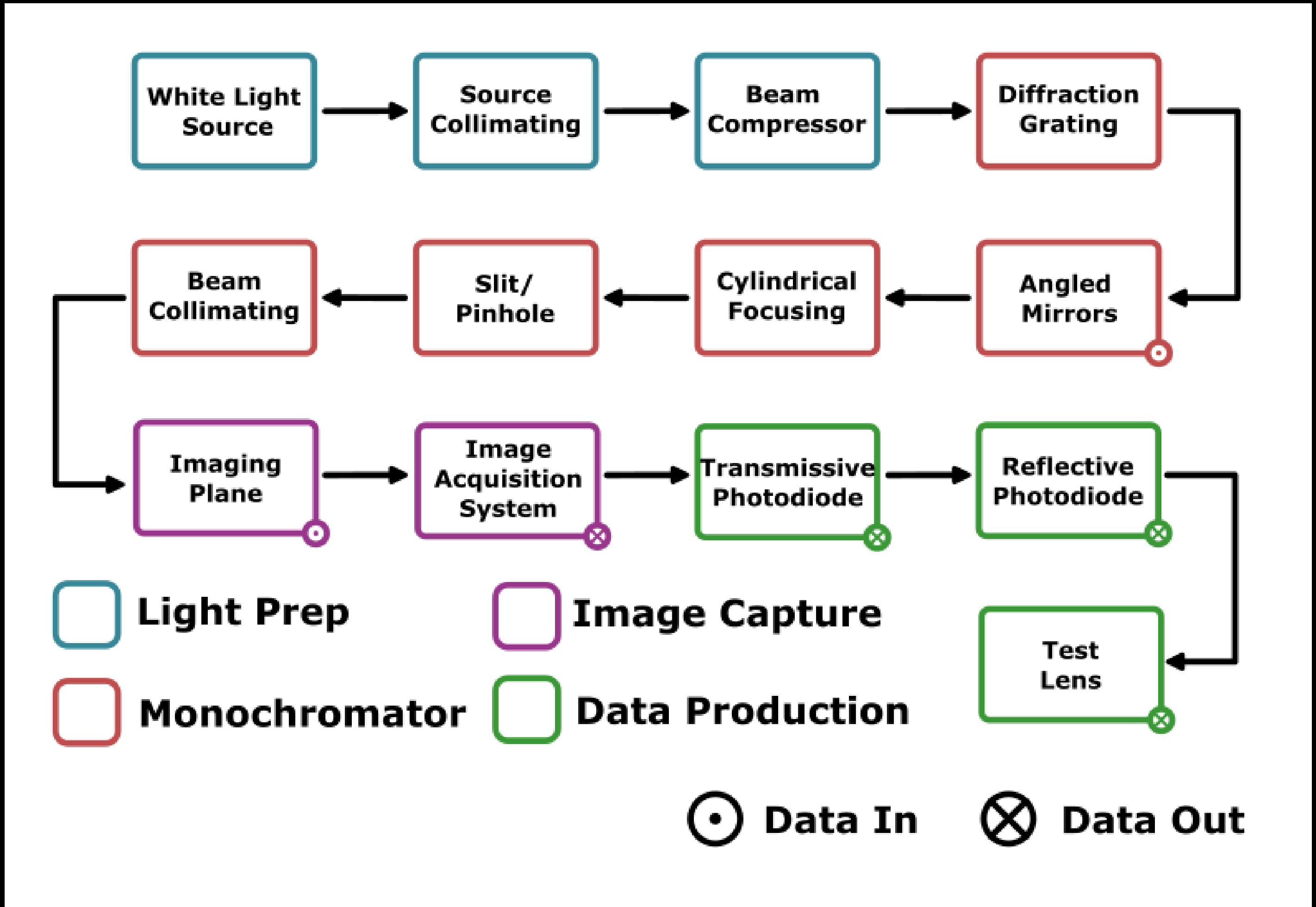
# GOALS & OBJECTIVES

| | Goals | Objectives |
|---|---|---|
| **Basic** | • Measure focal length<br>• Measure transmissive and reflective spectra<br>• Measure geometry | • WLS built<br>• WLS collimated<br>• Single monochromator<br>• IAS records an image |
| **Advanced** | • Data output in plain text format<br>• Data output recoverable via flash drive | • Calculate optical values based on measured geometry |
| **Stretch** | • System graphical touch interface<br>• Data output in a PDF<br>• Data output recoverable via QR code<br>• Lens product number estimation | • Lens product catalog lookup algorithm |

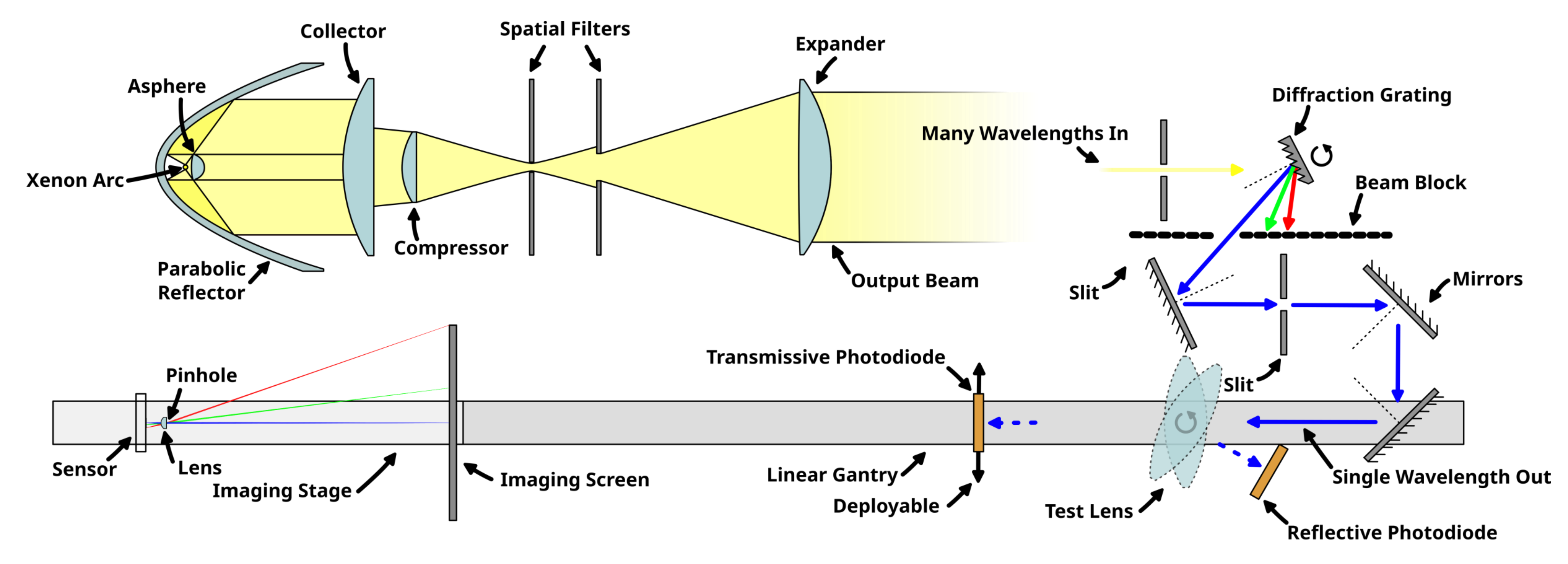
# HARDWARE DESIGN / OVERVIEW

Show the overall block diagram

# OPTICAL DESIGN OVERVIEW



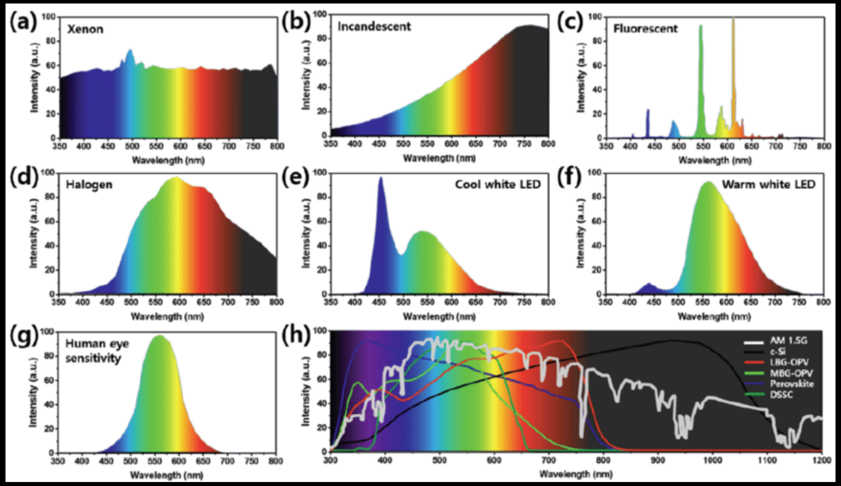
# OPTICAL DESIGN OVERVIEW



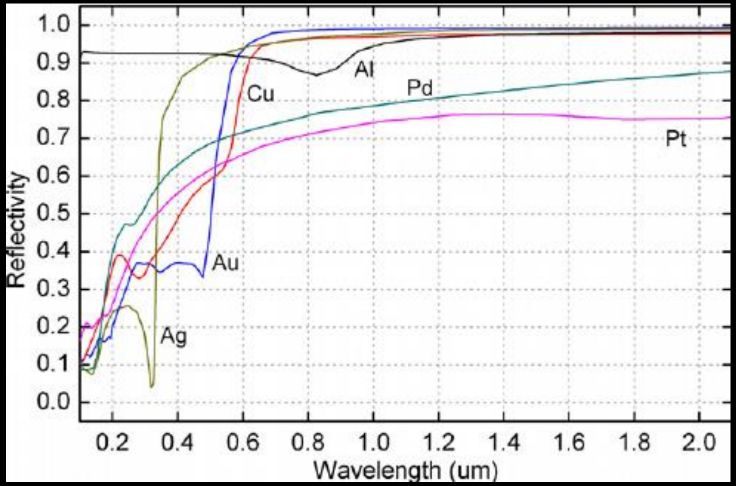
# WLS OVERVIEW/SPEC

Capture and project as much 400 to 700nm light as possible in a 10mm diameter collimated beam

# WLS COMPARISON & SELECTION




Source

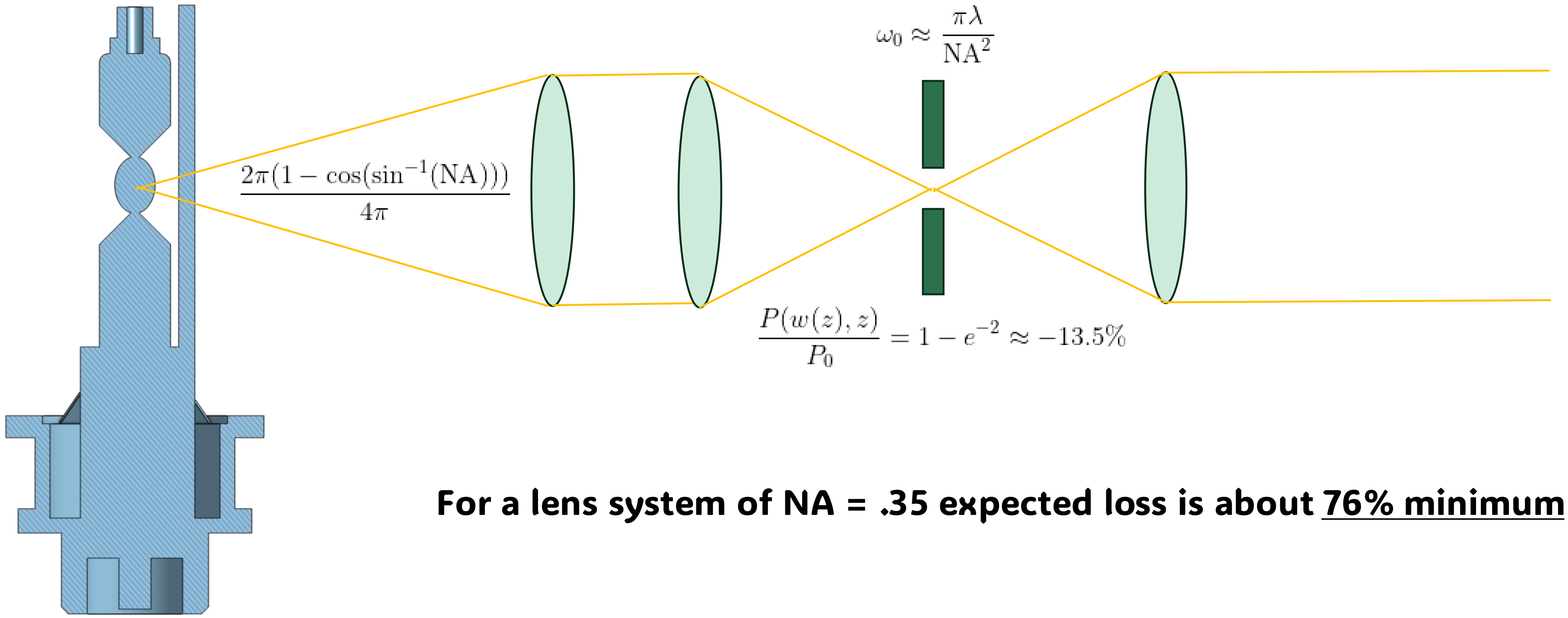



Reflector Material

- Source + Relay
- Mirror + Source + Relay
- Mirror + Source + Asphere + Relay
- Small vs. Large Reflector

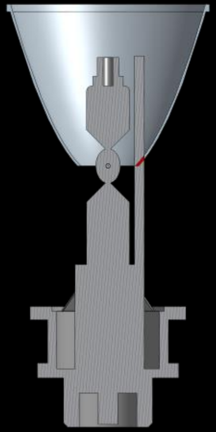
Collimation Architecture

# SOURCE + RELAY

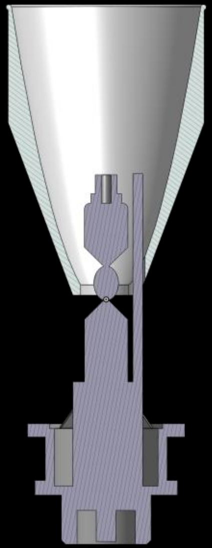



**For a lens system of NA = .35 expected loss is about <u>76% minimum</u>**

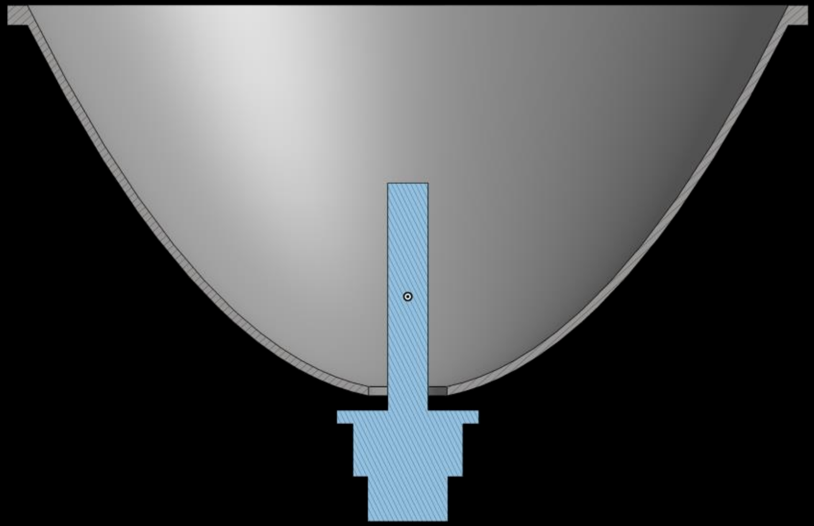
# MIRROR + SOURCE + RELAY



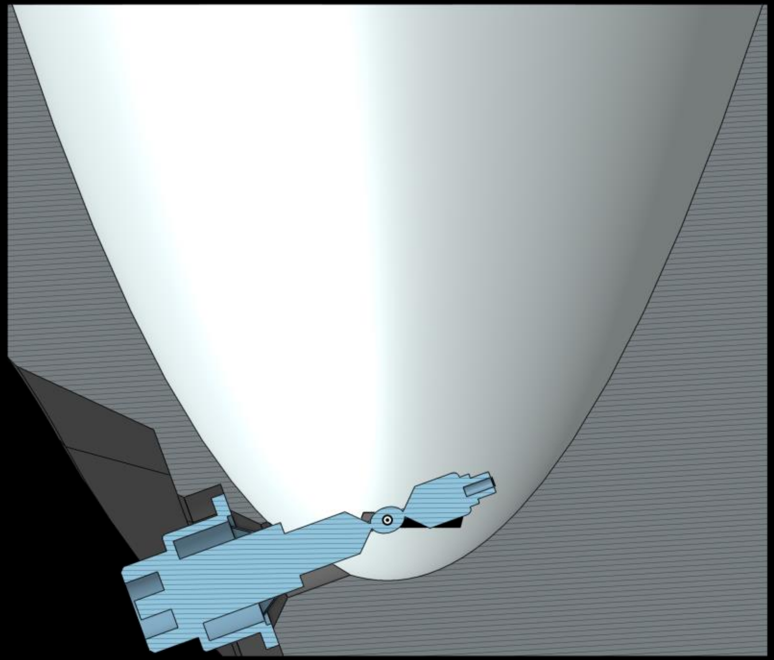
-66%



-60%

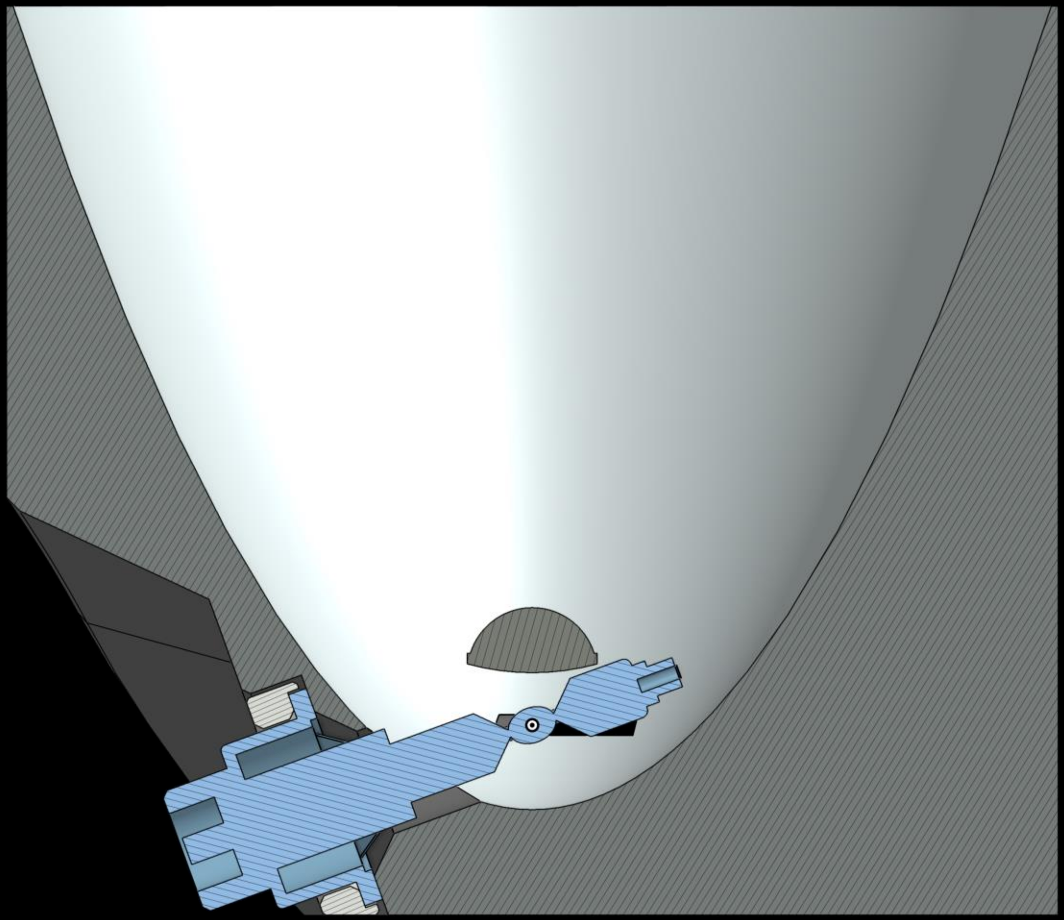


-32%



-20%

# MIRROR + SOURCE + ASPHERE + RELAY



## ~90% Collection / Collimation

# SMALL VS. LARGE REFLECTOR

Small Reflector = Very Small Focal Length = More Divergence

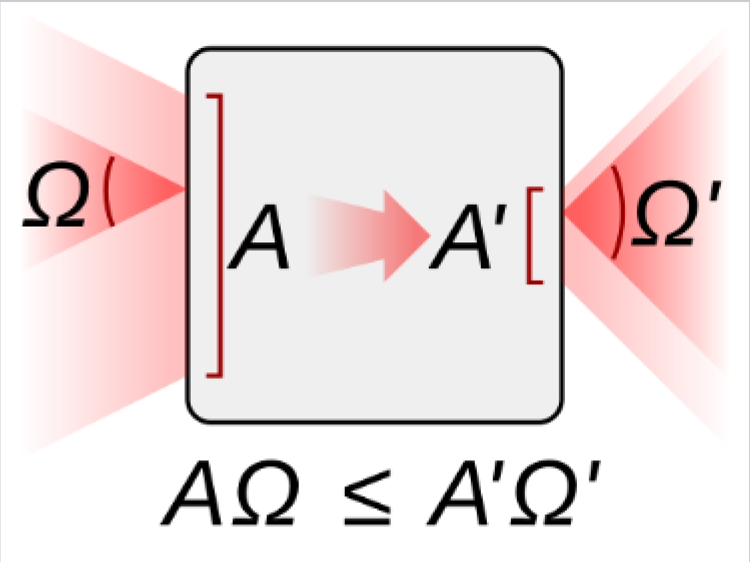
Large Reflector = Larger Focal Length = Less Divergence

Output beam size = exit aperture size → Bigger output = more compression needed = more loss

# THE HORRORS OF ENTROPY

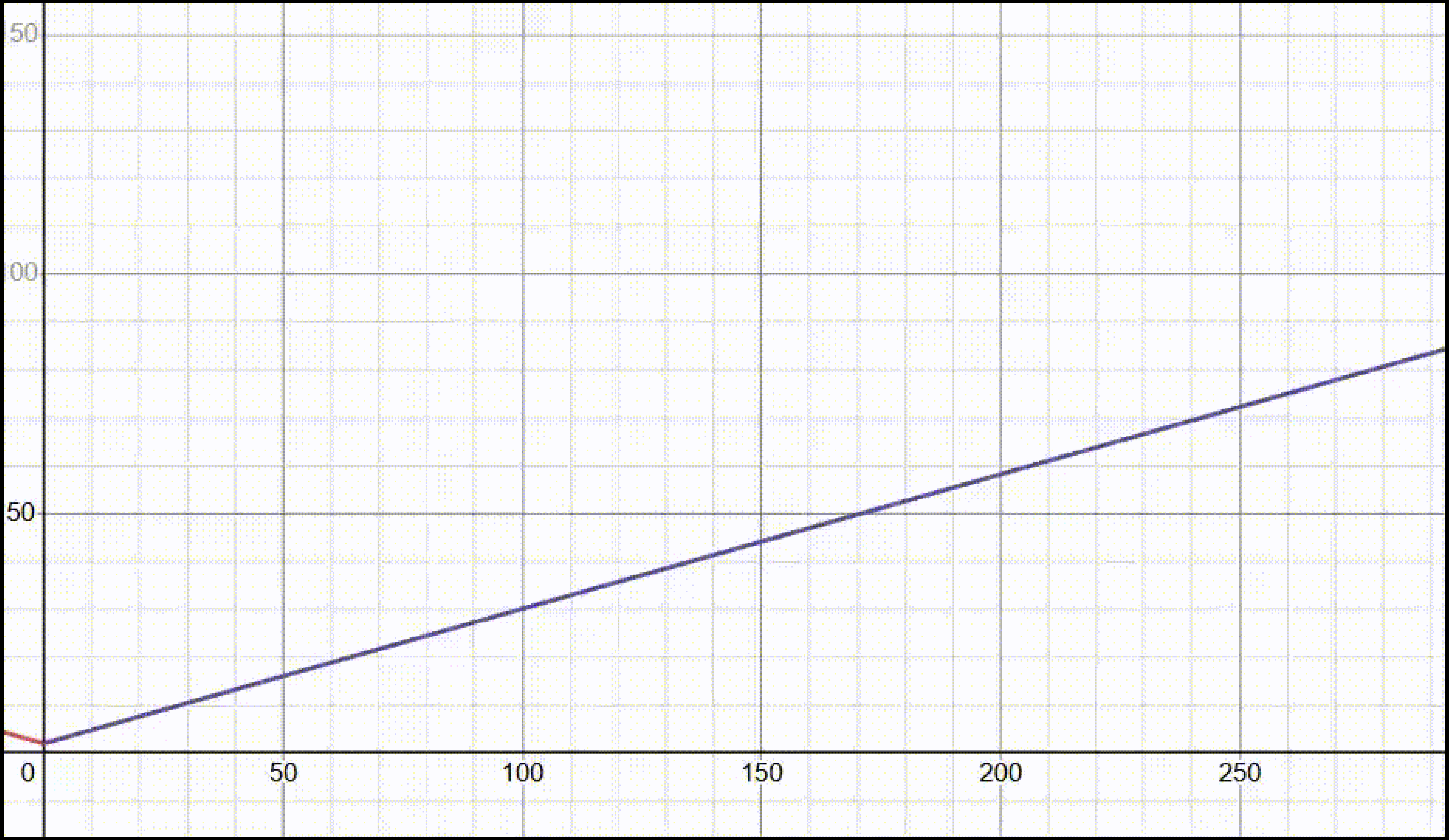
From Wikipedia, the free encyclopedia

**Etendue** or **étendue** (/ˌeɪtɒnˈduː/) is a property of light in an optical system, which characterizes how "spread out" the light is in area and angle. It corresponds to the beam parameter product (BPP) in Gaussian beam optics. Other names for etendue include **acceptance**, **throughput**, **light grasp**, **light-gathering power**, **optical extent**,[1] and the **AΩ product**. *Throughput* and *AΩ product* are especially used in radiometry and radiative transfer where it is related to the view factor (or shape factor). It is a central concept in nonimaging optics.[2][*page needed*][3][*page needed*][4][*page needed*] The term *étendue* comes from French, where it means "extent".




Conservation of etendue

# THE HOPE IN THE ~~DARKNESS~~




$$w_{out} = w_{in} \cdot m$$

$$\theta_{out} = \frac{\theta_{in}}{m}$$

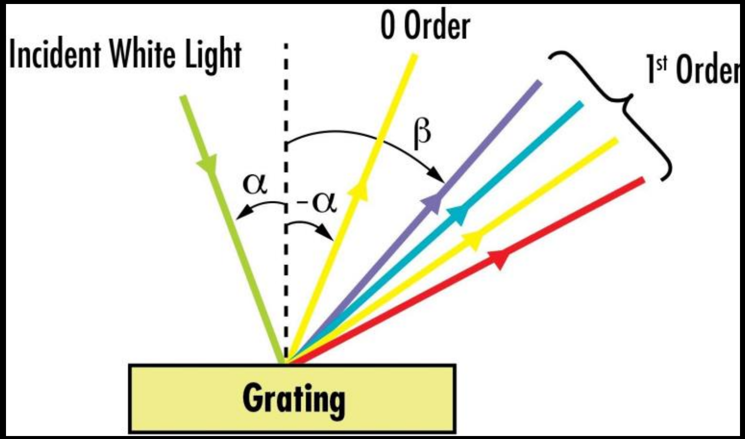
# WLS DESIGN MATRIX

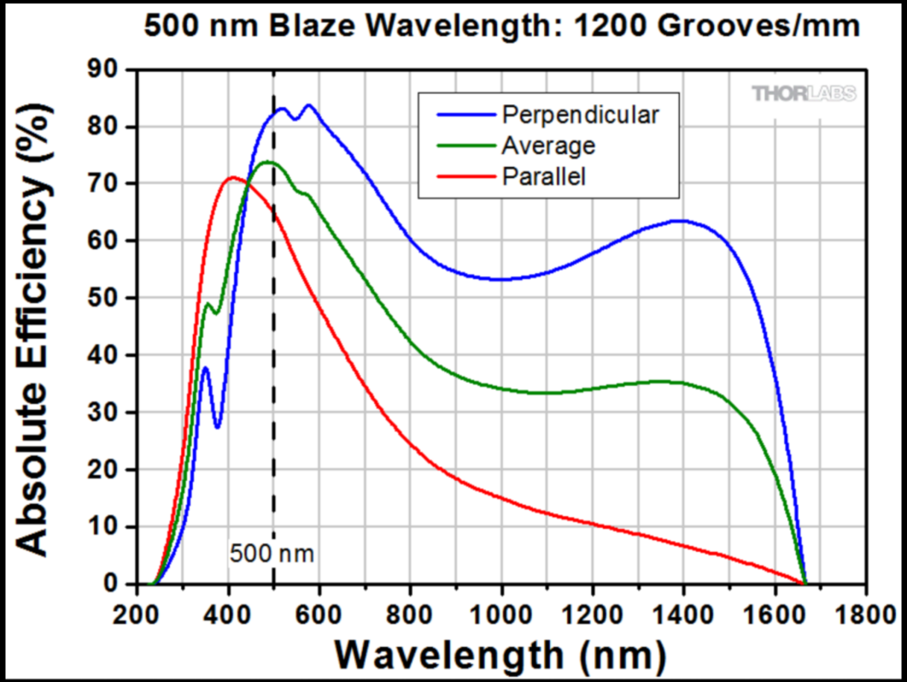
| Architecture | Efficiency | Collimation | Complexity | Score |
| --- | --- | --- | --- | --- |
| Source + Relay | LOW (+1) | HIGH (+3) | LOW (-1) | +3 |
| Mirror + Source + Relay | MID (+2) | MID (+2) | MID (-2) | +2 |
| Mirror + Source + Asphere + Relay | HIGH (+3) | HIGH (+3) | HIGH (-3) | +3 |
| Large Reflector | HIGH (+3) | HIGH (+3) | HIGH (-3) | +3 |
| Small Reflector | LOW (+1) | LOW (+1) | LOW (-1) | +1 |

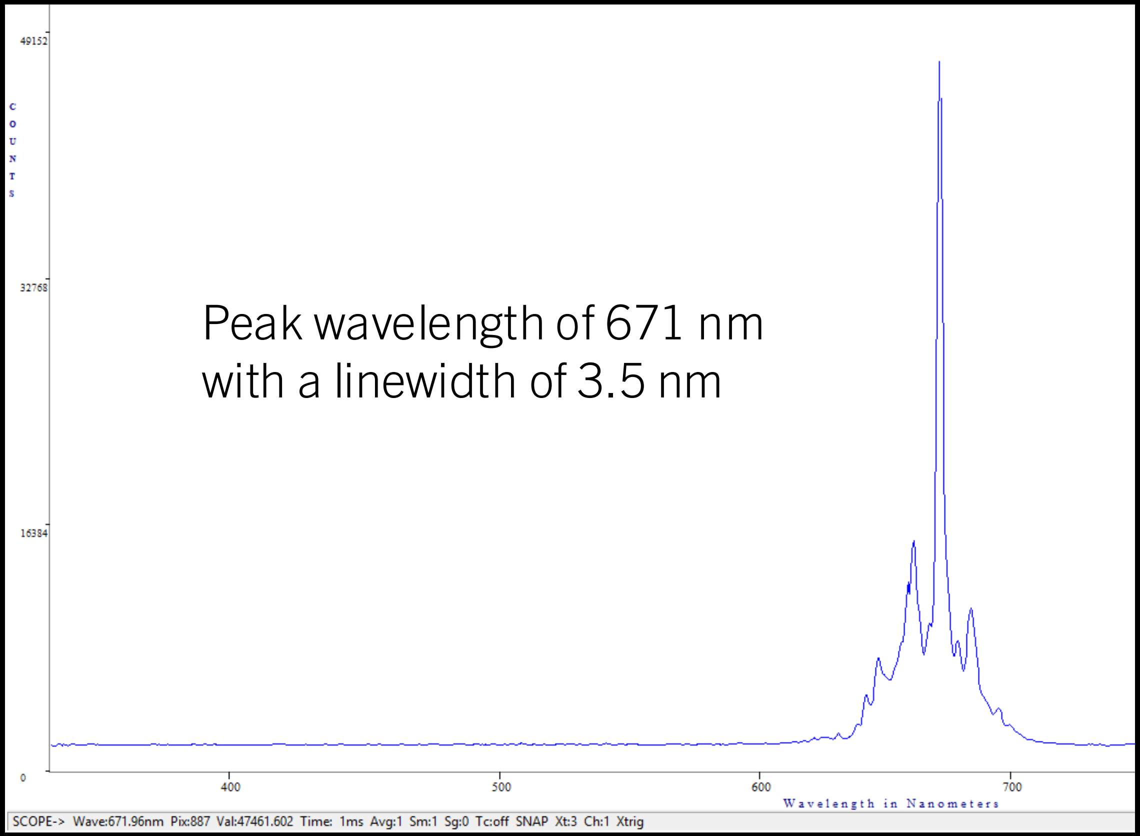
# WLS Testing

# WLS as of Feb 13th

# MONOCHROMATOR COMPARISON & SELECTION

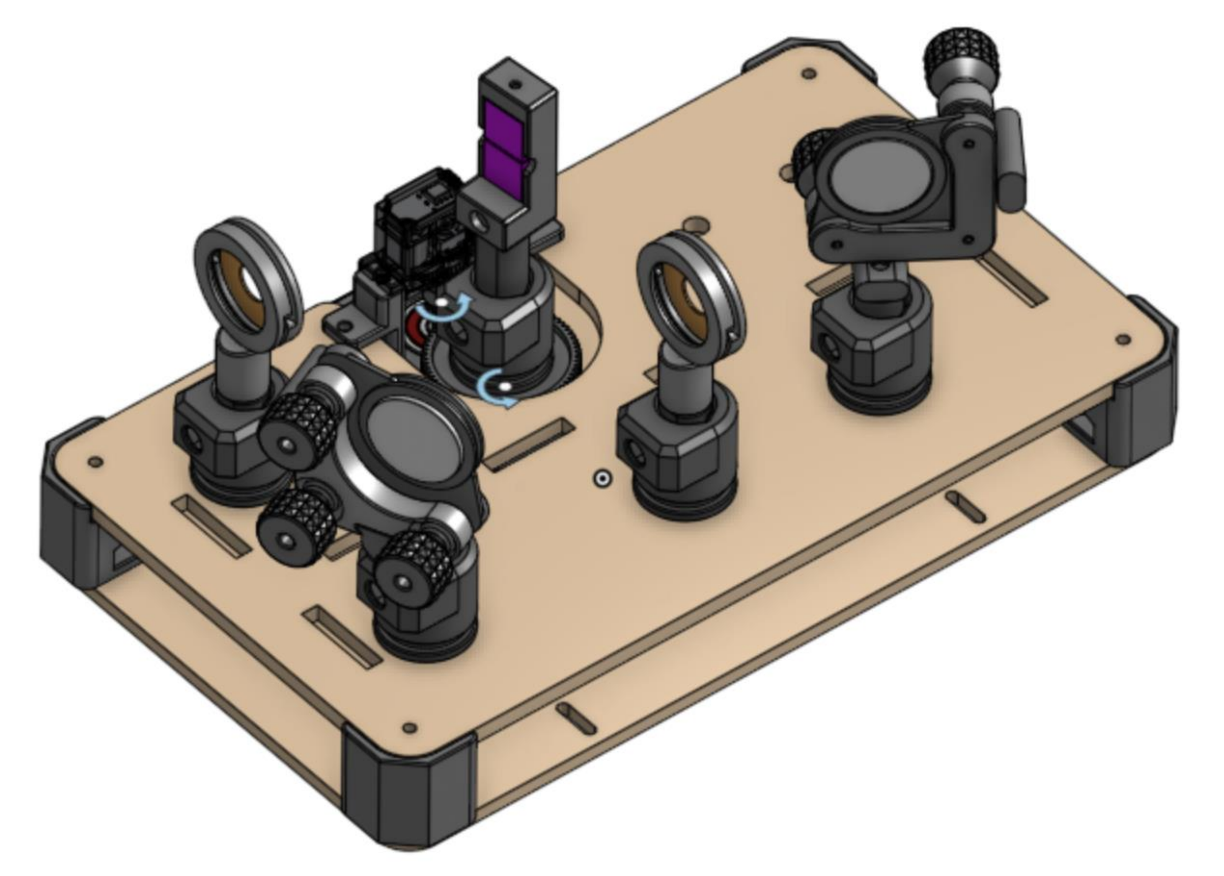


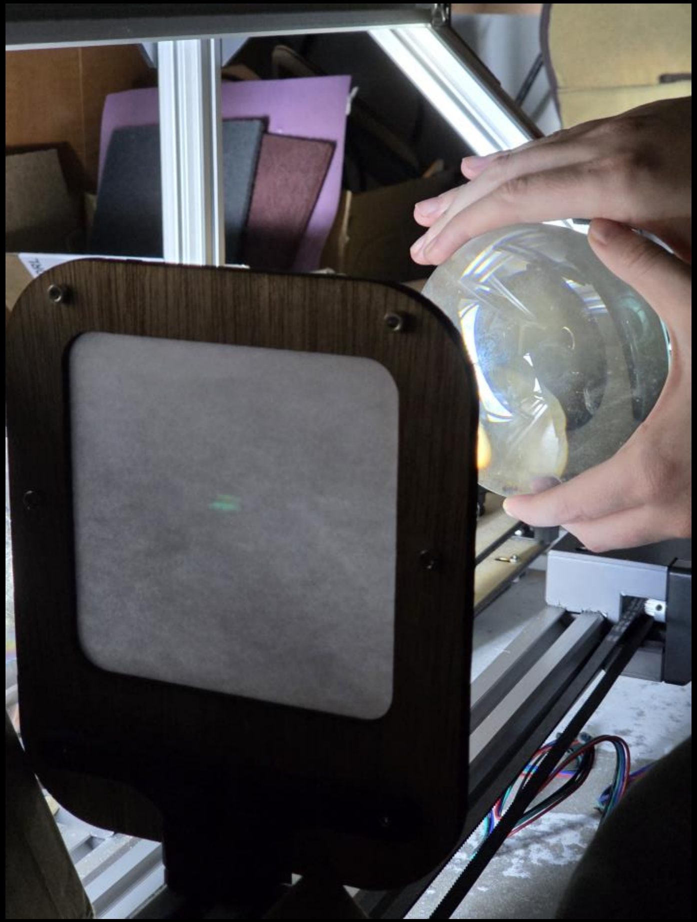




Peak wavelength of 671 nm
with a linewidth of 3.5 nm

# MONOCHROMATOR DESIGN



# MONOCHROMATOR TESTING



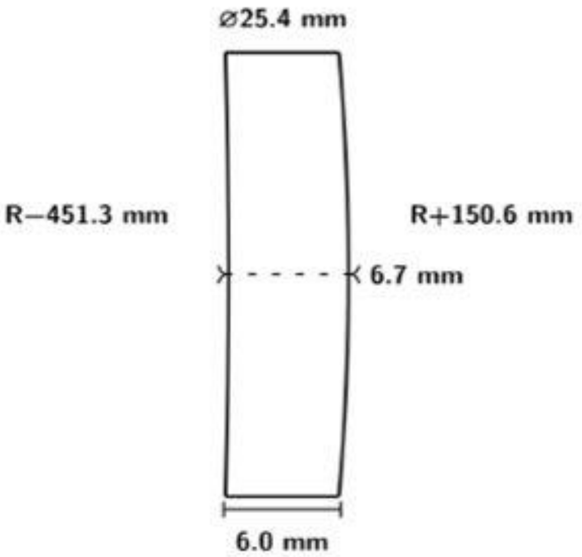
# PHOTODIODE TESTING

# DATASHEET GENERATION

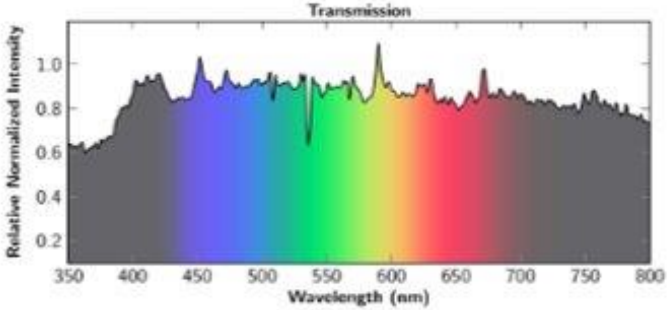
## ø25.4 × 122.0 mm EFL Positive Meniscus Lens

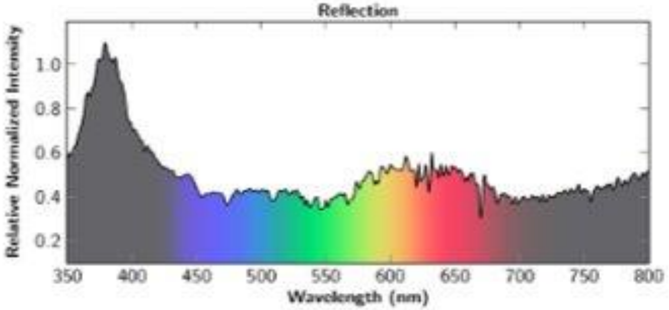
### Geometry

| | |
|---|---|
| Lens Shape | Positive Meniscus |
| Diameter (mm) | 25.4 |
| Center Thickness (mm) | 6.7 |
| Edge Thickness (mm) | 6.0 |
| Front Radius of Curvature (mm) | 150.6 |
| Back Radius of Curvature (mm) | −451.3 |




### Spectra



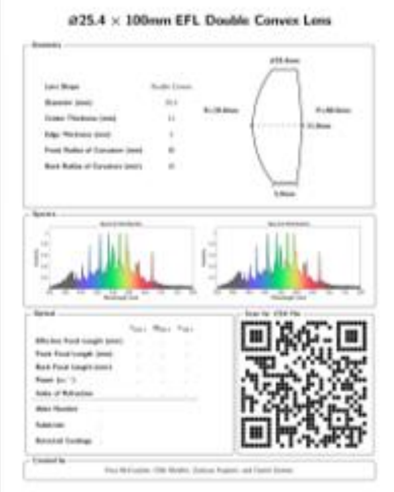



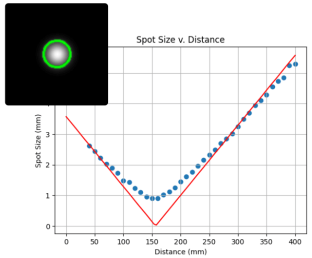

### Optical

| | $C_{656.3}$ | $D_{589.3}$ | $F_{486.1}$ |
|---|---|---|---|
| Effective Focal Length (mm) | 122.0 | **122.0** | 122.0 |
| Front Focal Length (mm) | 122.9 | **122.9** | 122.9 |
| Back Focal Length (mm) | 119.4 | **119.4** | 119.4 |
| Power ($m^{-1}$) | 8.20 | **8.20** | 8.20 |
| Index of Refraction | 1.93 | **1.93** | 1.93 |

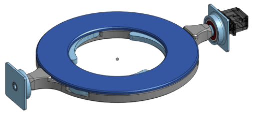
| | |
|---|---|
| Abbe Number | 1 396 736 048 075 399.8 |
| Substrate | N-BK7 |
| Detected Coatings | |

### Scan for .CSV File

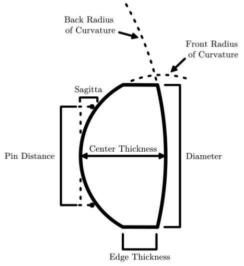





→ Focal Length



→ Diameter




Front Radius of Curvature

Back Radius of Curvature

Front Sagitta, Back Sagitta →

$$\text{Radius of Curvature} = \frac{\text{Sagitta}^2 + \frac{1}{4}(\text{Pin Separation})^2}{2 \cdot \text{Sagitta}}$$

Front Thickness, Back Thickness →

$$\text{Center Thickness} = \text{Front Thickness} + \text{Back Thickness}$$

→ Center Thickness

$$\text{Index of Refraction } (n) = \frac{fR_2 - fR_1 + 2fd + R_1R_2 \pm \sqrt{f^2R_1^2 + f^2R_2^2 - 2f^2R_1R_2 + 2fR_1R_2^2 - 2fR_1^2R_2 + 4fR_1R_2d + R_1^2R_2^2}}{2(fR_2 - fR_1 + fd)},\ f \neq 0$$

$$\text{Power} = \frac{1}{\text{Focal Length}}$$

$$\text{Edge Thickness} = \begin{cases} \text{if } R > 0, & \text{Center Thickness} - \text{Sagitta} \\ \text{if } R < 0, & \text{Center Thickness} + \text{Sagitta} \end{cases}$$

$$f_{\text{front/back}} = \frac{f - 1 \cdot (f \cdot (n-1) \cdot d_c)}{R_{\text{front/back}} \cdot n}$$

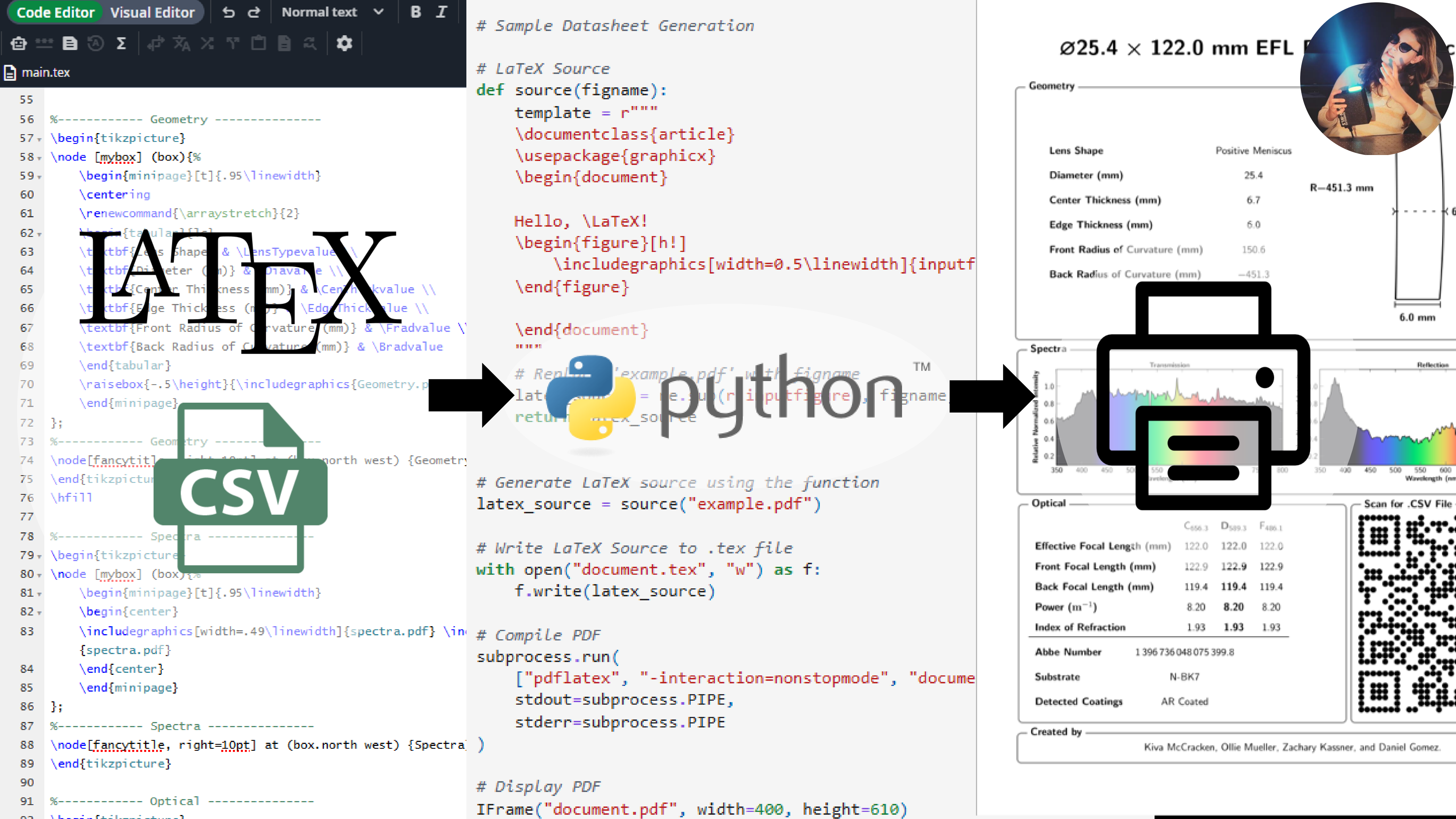
| $R_{\text{front}} > 0$ | $R_{\text{front}} < 0$ | $R_{\text{back}} > 0$ | $R_{\text{back}} < 0$ | $\geq \infty_{\text{th}}$ (front/back) | $d_{\text{center}} \gtrless d_{\text{edge}}$ | Lens Type |
|---|---|---|---|---|---|---|
| 1 | 0 | 1 | 0 | 0 | – | Double Convex |
| 0 | 1 | 0 | 1 | 0 | – | Double Concave |
| 1 | 0 | 0 | 0 | $R_{\text{back}} \geq \infty_{\text{th}}$ | – | Plano Convex |
| 0 | 0 | 1 | 0 | $R_{\text{front}} \geq \infty_{\text{th}}$ | – | Plano Convex |
| 0 | 1 | 0 | 0 | $R_{\text{back}} \geq \infty_{\text{th}}$ | – | Plano Concave |
| 0 | 0 | 0 | 1 | $R_{\text{front}} \geq \infty_{\text{th}}$ | – | Plano Concave |
| 1 | 0 | 0 | 1 | 0 | $d_{\text{center}} > d_{\text{edge}}$ | Positive Meniscus |
| 0 | 1 | 1 | 0 | 0 | $d_{\text{center}} > d_{\text{edge}}$ | Positive Meniscus |
| 1 | 0 | 0 | 1 | 0 | $d_{\text{center}} < d_{\text{edge}}$ | Negative Meniscus |
| 0 | 1 | 1 | 0 | 0 | $d_{\text{center}} < d_{\text{edge}}$ | Negative Meniscus |

$$\text{Abbe Number } (\nu) = \frac{n_D - 1}{n_F - n_C}$$

$$\begin{cases} n_D & \text{Sodium Yellow} & 589.3\text{nm} \\ n_F & \text{Hydrogen Blue} & 486.1\text{nm} \\ n_C & \text{Hydrogen Red} & 656.3\text{nm} \end{cases}$$

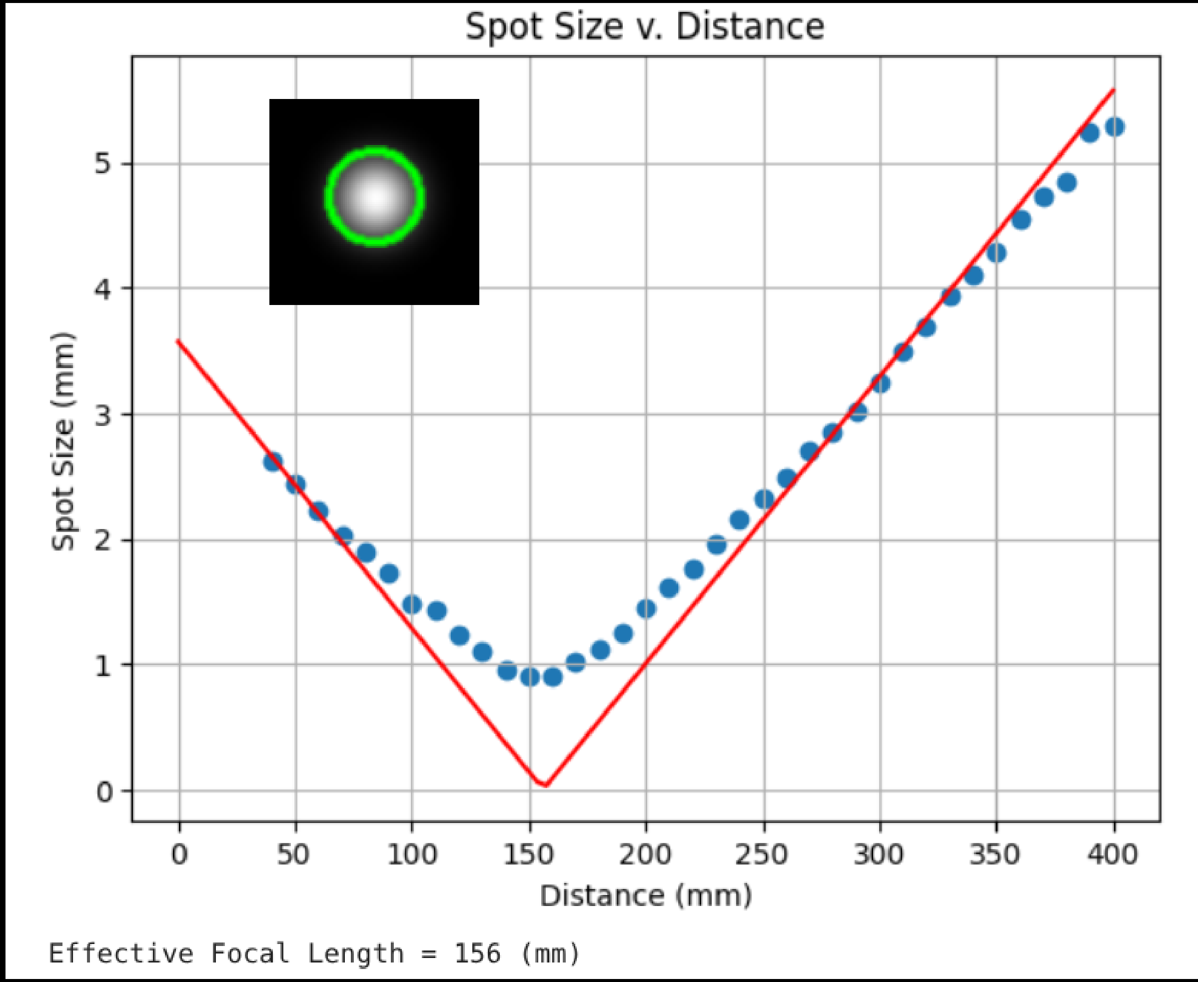
| 1 | Front Sagitta | Back Sagitta | Front Thickness | Back Thickness | Diameter | Distance | D Spot | F Spot | C Spot | Wavelength | Transmission | Reflection | Calibrat |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | -0.3 | 0.1 | 0.006 | 0.005 | 0.0254 | 0.01 | 0.00918032786885246 | 0.00826229508196721 | 0.00734426229508197 | 350 | 2154.1 | 2154.1 | 10 |
| 3 | | | | | | 0.02 | 0.00836065573770492 | 0.00752459016393443 | 0.00668852459016394 | 351 | 2221.7 | 2221.7 | 30 |
| 4 | | | | | | 0.03 | 0.00754098360655738 | 0.00678688524590164 | 0.0060327868852459 | 352 | 2338.9 | 2338.9 | 50 |
| 5 | | | | | | 0.04 | 0.00672131147540984 | 0.00604918032786885 | 0.00537704918032787 | 353 | 2491.8 | 2491.8 | 70 |
| 6 | | | | | | 0.05 | 0.0059016393442623 | 0.00531147540983607 | 0.00472131147540984 | 354 | 2637.1 | 2637.1 | 90 |
| 7 | | | | | | 0.06 | 0.00508196721311475 | 0.00457377049180328 | 0.0040655737704918 | 355 | 2723.7 | 2723.7 | 110 |
| 8 | | | | | | 0.07 | 0.00426229508196721 | 0.00383606557377049 | 0.00340983606557377 | 356 | 2731.6 | 2731.6 | 130 |
| 9 | | | | | | 0.08 | 0.00344262295081967 | 0.00309836065573771 | 0.00275409836065574 | 357 | 2665.5 | 2665.5 | 150 |
| 10 | | | | | | 0.09 | 0.00262295081967213 | 0.00236065573770492 | 0.00209836065573771 | 358 | 2570.9 | 2570.9 | 170 |
| 11 | | | | | | 0.1 | 0.00180327868852459 | 0.00162295081967213 | 0.00144262295081967 | 359 | 2506.2 | 2506.2 | 190 |
| 12 | | | | | | 0.11 | 0.000983606557377049 | 0.000885245901639344 | 0.000786885245901639 | 360 | 2490.8 | 2490.8 | 210 |
| 13 | | | | | | 0.12 | 0.000163934426229508 | 0.000147540983606557 | 0.000131147540983607 | 361 | 2526.9 | 2526.9 | 230 |
| 14 | | | | | | 0.13 | 0.000655737704918033 | 0.00059016393442623 | 0.000524590163934426 | 362 | 2631.8 | 2631.8 | 250 |
| 15 | | | | | | 0.14 | 0.00147540983606557 | 0.00132786885245902 | 0.00118032786885246 | 363 | 2778.3 | 2778.3 | 270 |
| 16 | | | | | | 0.15 | 0.00229508196721311 | 0.0020655737704918 | 0.00183606557377049 | 364 | 2909.3 | 2909.3 | 290 |
| 17 | | | | | | 0.16 | 0.00311475409836066 | 0.00280327868852459 | 0.00249180327868853 | 365 | 2967 | 2967 | 310 |
| 18 | | | | | | 0.17 | 0.0039344262295082 | 0.00354098360655738 | 0.00314754098360656 | 366 | 2940.8 | 2940.8 | 330 |
| 19 | | | | | | 0.18 | 0.00475409836065574 | 0.00427868852459016 | 0.00380327868852459 | 367 | 2872.3 | 2872.3 | 350 |
| 20 | | | | | | 0.19 | 0.00557377049180328 | 0.00501639344262295 | 0.00445901639344262 | 368 | 2812.5 | 2812.5 | 370 |

| 1 | Diameter (m) | Center Thickness (m) | Edge Length (m) | Front Radius of Curvature (m) | Back Radius of Curvature (m) | Lens Shape | Effective Focal Length (m) | Front Focal Length (m) | Back Focal Length (m) | Power (1/m) | F-Stop |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 0.0254 | 0.011 | 0.012097111524474059 | 0.15004166666666666 | -0.05012500000000001 | Negative Meniscus | 0.12199999999999989 | 0.12836759026971492 | 0.11987275448640167 | 8.196721311475418 | 4.8031496062992085 |
| 3 | 0.0254 | 0.011 | 0.012097111524474059 | 0.15004166666666666 | -0.05012500000000001 | Negative Meniscus | 0.12199999999999989 | 0.12836759026971492 | 0.11987275448640167 | 8.196721311475418 | 4.8031496062992085 |
| 4 | 0.0254 | 0.011 | 0.012097111524474059 | 0.15004166666666666 | -0.05012500000000001 | Negative Meniscus | 0.12199999999999989 | 0.12836759026971492 | 0.11987275448640167 | 8.196721311475418 | 4.8031496062992085 |
| 5 | 0.0254 | 0.011 | 0.012097111524474059 | 0.15004166666666666 | -0.05012500000000001 | Negative Meniscus | 0.12199999999999989 | 0.12836759026971492 | 0.11987275448640167 | 8.196721311475418 | 4.8031496062992085 |
| 6 | 0.0254 | 0.011 | 0.012097111524474059 | 0.15004166666666666 | -0.05012500000000001 | Negative Meniscus | 0.12199999999999989 | 0.12836759026971492 | 0.11987275448640167 | 8.196721311475418 | 4.8031496062992085 |
| 7 | 0.0254 | 0.011 | 0.012097111524474059 | 0.15004166666666666 | -0.05012500000000001 | Negative Meniscus | 0.12199999999999989 | 0.12836759026971492 | 0.11987275448640167 | 8.196721311475418 | 4.8031496062992085 |
| 8 | 0.0254 | 0.011 | 0.012097111524474059 | 0.15004166666666666 | -0.05012500000000001 | Negative Meniscus | 0.12199999999999989 | 0.12836759026971492 | 0.11987275448640167 | 8.196721311475418 | 4.8031496062992085 |
| 9 | 0.0254 | 0.011 | 0.012097111524474059 | 0.15004166666666666 | -0.05012500000000001 | Negative Meniscus | 0.12199999999999989 | 0.12836759026971492 | 0.11987275448640167 | 8.196721311475418 | 4.8031496062992085 |
| 10 | 0.0254 | 0.011 | 0.012097111524474059 | 0.15004166666666666 | -0.05012500000000001 | Negative Meniscus | 0.12199999999999989 | 0.12836759026971492 | 0.11987275448640167 | 8.196721311475418 | 4.8031496062992085 |
| 11 | 0.0254 | 0.011 | 0.012097111524474059 | 0.15004166666666666 | -0.05012500000000001 | Negative Meniscus | 0.12199999999999989 | 0.12836759026971492 | 0.11987275448640167 | 8.196721311475418 | 4.8031496062992085 |
| 12 | 0.0254 | 0.011 | 0.012097111524474059 | 0.15004166666666666 | -0.05012500000000001 | Negative Meniscus | 0.12199999999999989 | 0.12836759026971492 | 0.11987275448640167 | 8.196721311475418 | 4.8031496062992085 |
| 13 | 0.0254 | 0.011 | 0.012097111524474059 | 0.15004166666666666 | -0.05012500000000001 | Negative Meniscus | 0.12199999999999989 | 0.12836759026971492 | 0.11987275448640167 | 8.196721311475418 | 4.8031496062992085 |
| 14 | 0.0254 | 0.011 | 0.012097111524474059 | 0.15004166666666666 | -0.05012500000000001 | Negative Meniscus | 0.12199999999999989 | 0.12836759026971492 | 0.11987275448640167 | 8.196721311475418 | 4.8031496062992085 |
| 15 | 0.0254 | 0.011 | 0.012097111524474059 | 0.15004166666666666 | -0.05012500000000001 | Negative Meniscus | 0.12199999999999989 | 0.12836759026971492 | 0.11987275448640167 | 8.196721311475418 | 4.8031496062992085 |
| 16 | 0.0254 | 0.011 | 0.012097111524474059 | 0.15004166666666666 | -0.05012500000000001 | Negative Meniscus | 0.12199999999999989 | 0.12836759026971492 | 0.11987275448640167 | 8.196721311475418 | 4.8031496062992085 |
| 17 | 0.0254 | 0.011 | 0.012097111524474059 | 0.15004166666666666 | -0.05012500000000001 | Negative Meniscus | 0.12199999999999989 | 0.12836759026971492 | 0.11987275448640167 | 8.196721311475418 | 4.8031496062992085 |
| 18 | 0.0254 | 0.011 | 0.012097111524474059 | 0.15004166666666666 | -0.05012500000000001 | Negative Meniscus | 0.12199999999999989 | 0.12836759026971492 | 0.11987275448640167 | 8.196721311475418 | 4.8031496062992085 |
| 19 | 0.0254 | 0.011 | 0.012097111524474059 | 0.15004166666666666 | -0.05012500000000001 | Negative Meniscus | 0.12199999999999989 | 0.12836759026971492 | 0.11987275448640167 | 8.196721311475418 | 4.8031496062992085 |
| 20 | 0.0254 | 0.011 | 0.012097111524474059 | 0.15004166666666666 | -0.05012500000000001 | Negative Meniscus | 0.12199999999999989 | 0.12836759026971492 | 0.11987275448640167 | 8.196721311475418 | 4.8031496062992085 |

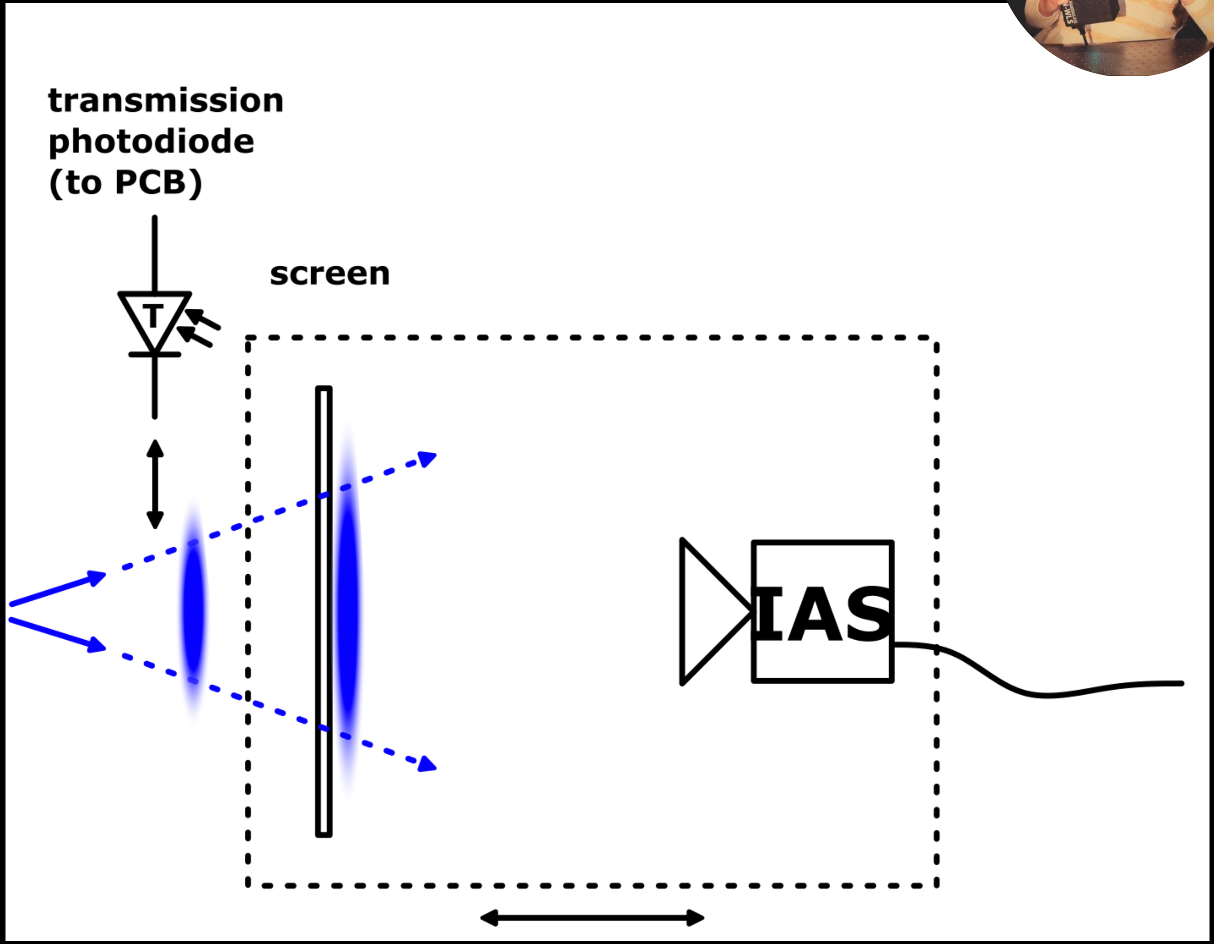


Code Editor
Visual Editor
Normal text
main.tex
%------------ Geometry ---------------
\begin{tikzpicture}
\node [mybox] (box){%
\begin{minipage}[t]{.95\linewidth}
\centering
\renewcommand{\arraystretch}{2}
\textbf{Front Radius of Curvature (mm)} & \Fradvalue \\
\textbf{Back Radius of Curvature (mm)} & \Bradvalue
\end{tabular}
\raisebox{-.5\height}{\includegraphics{Geometry.p
\end{minipage}
};
\hfill
\begin{minipage}[t]{.95\linewidth}
\begin{center}
\includegraphics[width=.49\linewidth]{spectra.pdf} \in
{spectra.pdf}
\end{center}
\end{minipage}
};
%------------ Spectra ---------------
\node[fancytitle, right=10pt] at (box.north west) {Spectra
\end{tikzpicture}
%------------ Optical ---------------
LaTeX
CSV
# Sample Datasheet Generation
# LaTeX Source
def source(figname):
template = r"""
\documentclass{article}
\usepackage{graphicx}
\begin{document}
Hello, \LaTeX!
\begin{figure}[h!]
\includegraphics[width=0.5\linewidth]{inputf
\end{figure}
\end{document}
"""
python
TM
# Generate LaTeX source using the function
latex_source = source("example.pdf")
# Write LaTeX Source to .tex file
with open("document.tex", "w") as f:
f.write(latex_source)
# Compile PDF
subprocess.run(
["pdflatex", "-interaction=nonstopmode", "docume
stdout=subprocess.PIPE,
stderr=subprocess.PIPE
)
# Display PDF
IFrame("document.pdf", width=400, height=610)
⌀25.4 × 122.0 mm EFL
Geometry
Lens Shape Positive Meniscus
Diameter (mm) 25.4
Center Thickness (mm) 6.7
Edge Thickness (mm) 6.0
Front Radius of Curvature (mm) 150.6
Back Radius of Curvature (mm) −451.3
R=451.3 mm
6.0 mm
Spectra
Optical
Effective Focal Length (mm) 122.0 122.0 122.0
Front Focal Length (mm) 122.9 122.9 122.9
Back Focal Length (mm) 119.4 119.4 119.4
Power (m⁻¹) 8.20 8.20 8.20
Index of Refraction 1.93 1.93 1.93
Abbe Number 1 396 736 048 075 399.8
Substrate N-BK7
Detected Coatings AR Coated
Scan for .CSV File
Created by
Kiva McCracken, Ollie Mueller, Zachary Kassner, and Daniel Gomez.

# IAS DESIGN

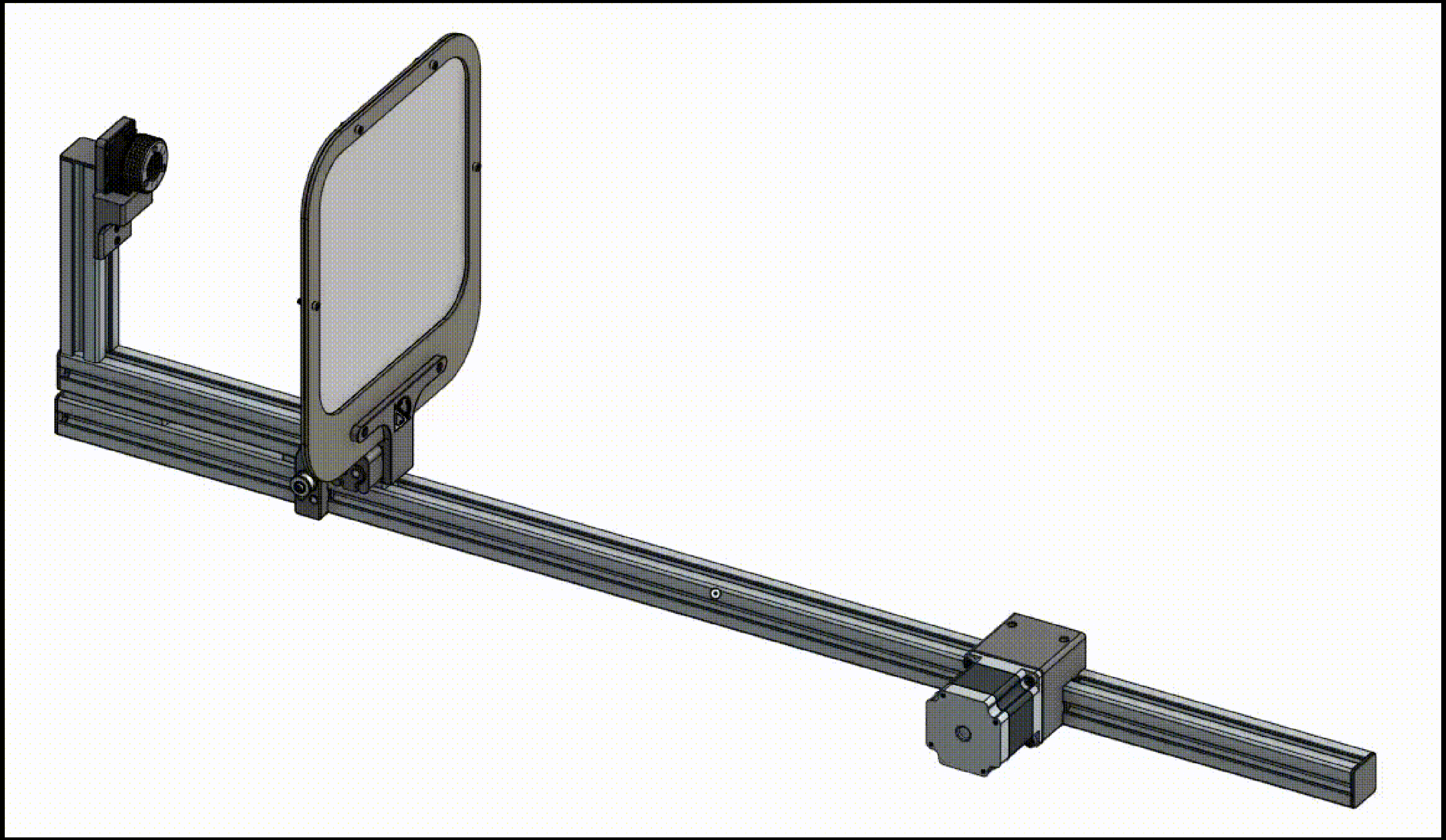


Spot Size v. Distance
Spot Size (mm)
0
1
2
3
4
5
0
50
100
150
200
250
300
350
400
Distance (mm)
Effective Focal Length = 156 (mm)

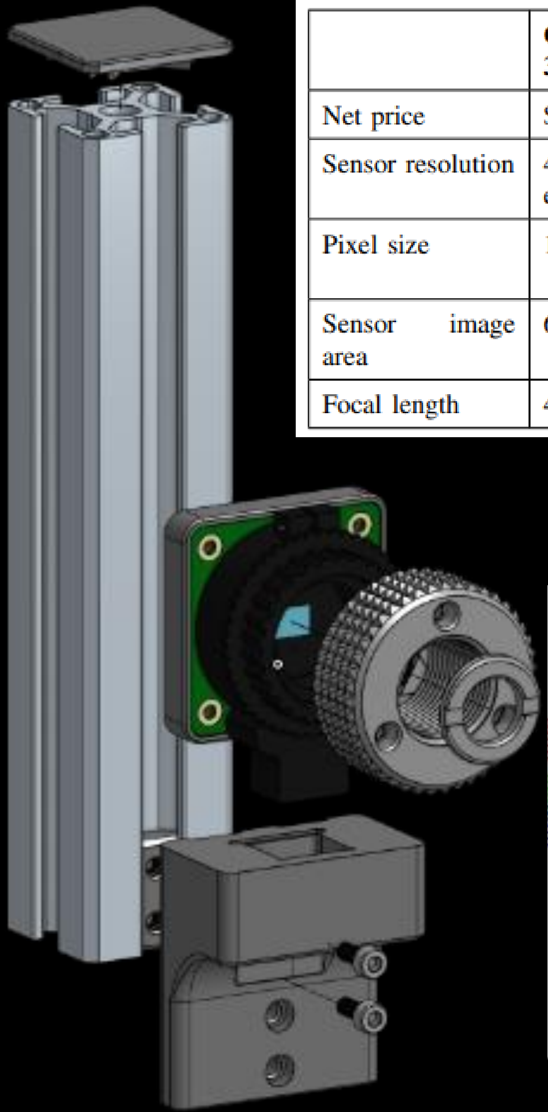



transmission
photodiode
(to PCB)
T
screen
IAS

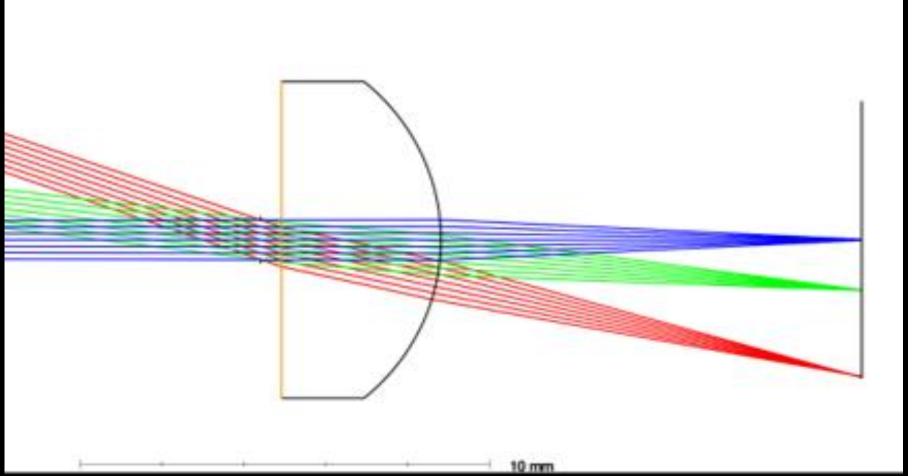

# IAS LINEAR GANTRY



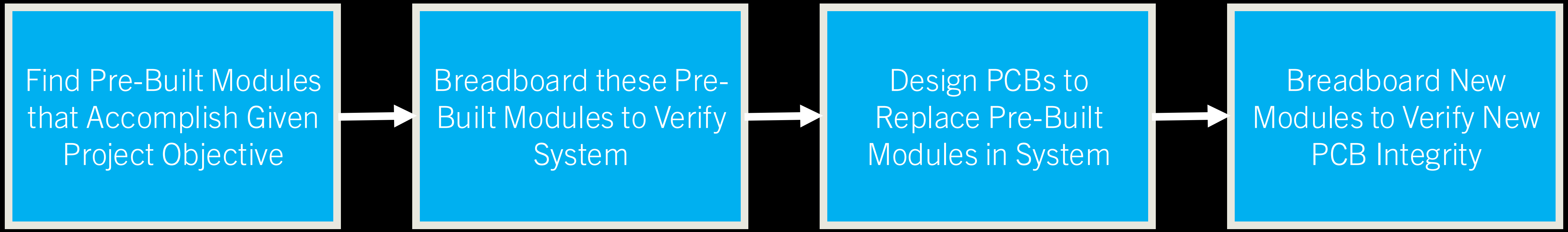
# IAS COMPARISON & SELECTION



| | Camera Module 3 | Camera Module 3 Wide | HQ Camera | AI Camera |
|---|---|---|---|---|
| Net price | $25 | $35 | $50 | $70 |
| Sensor resolution | 4608 × 2592 pixels | 4608 × 2592 pixels | 4056 × 3040 pixels | 4056 × 3040 pixels |
| Pixel size | 1.4 µm × 1.4 µm | 1.4 µm × 1.4 µm | 1.55 µm × 1.55 µm | 1.55 µm × 1.55 µm |
| Sensor image area | 6.45 × 3.63mm | 6.45 × 3.63mm | 6.287mm × 4.712 mm | 6.287mm × 4.712 mm |
| Focal length | 4.74 mm | 2.75 mmm | Depends on lens | 4.74 mm |

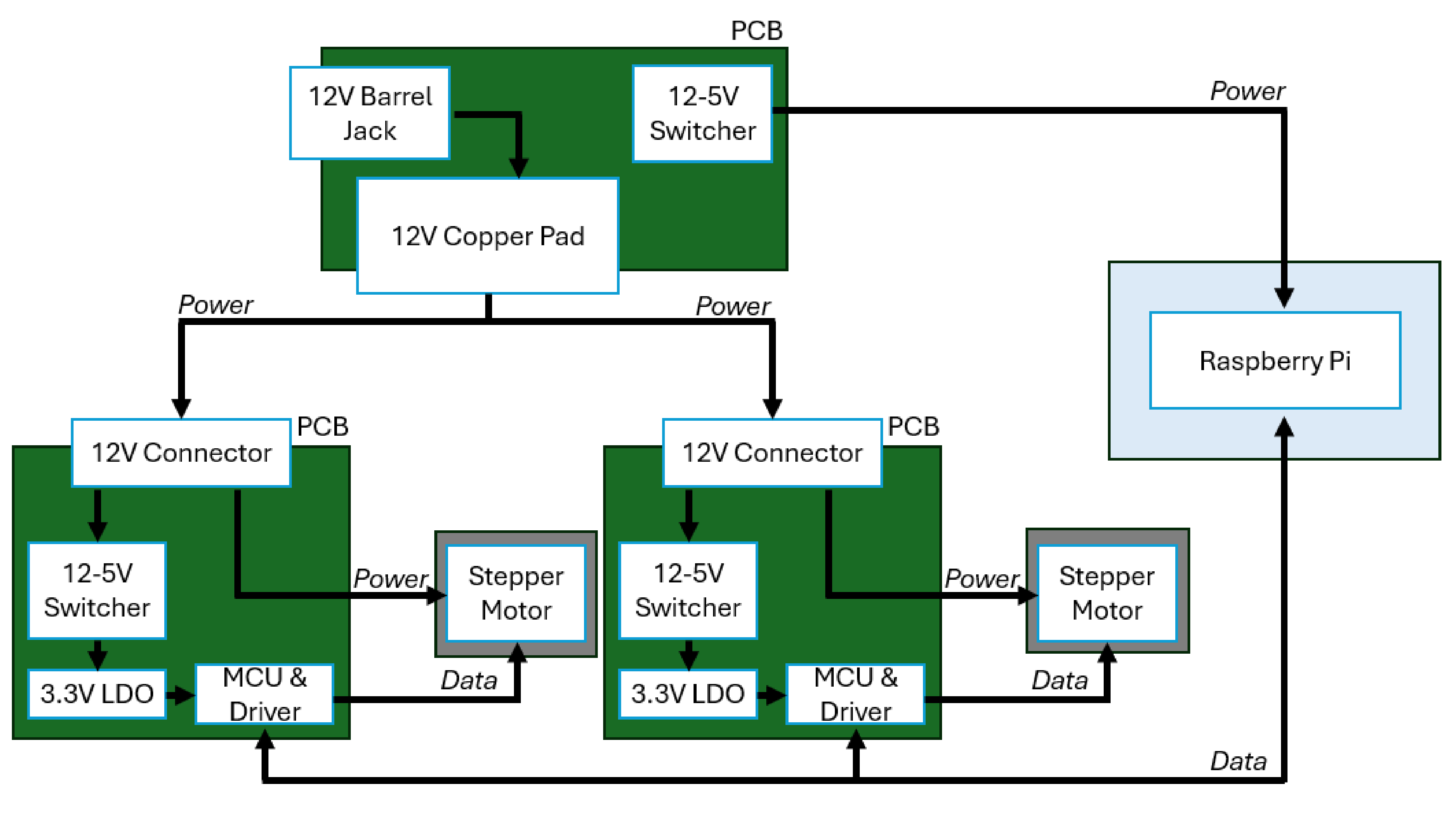



# PCB DESIGN VERIFICATION STRATEGY

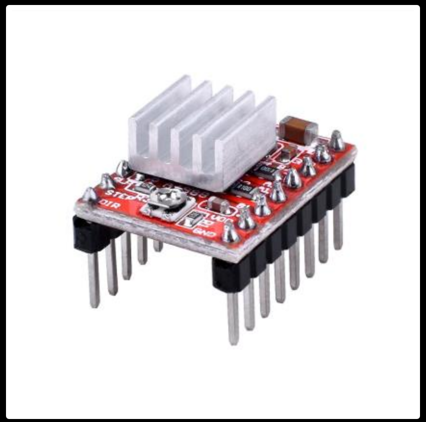


# PCB DESIGN MAIN OBJECTIVE

# BLOCK DIAGRAM FOR ACHIEVING OBJECTIVE



# FINDING PRE-BUILT MODULES TO VERIFY SYSTEM

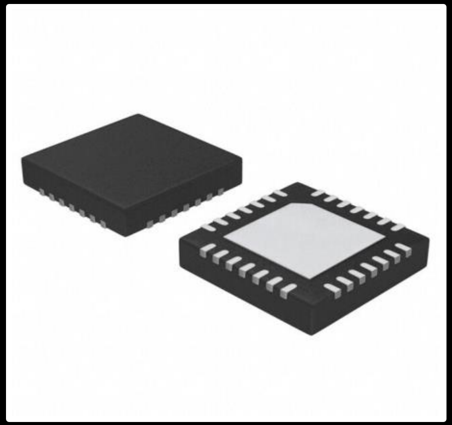
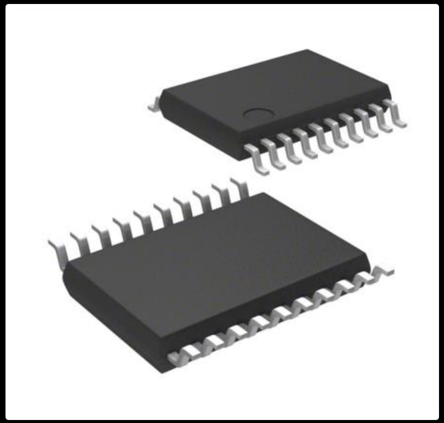
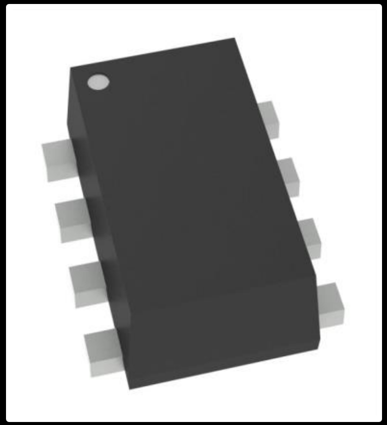


Cheap Stepper Driver
From Amazon

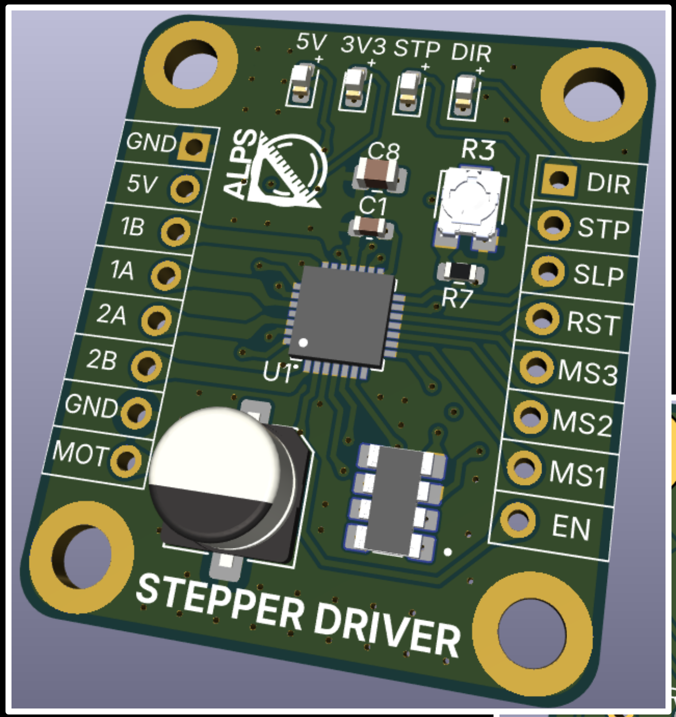
Cheap Microcontroller
from Amazon

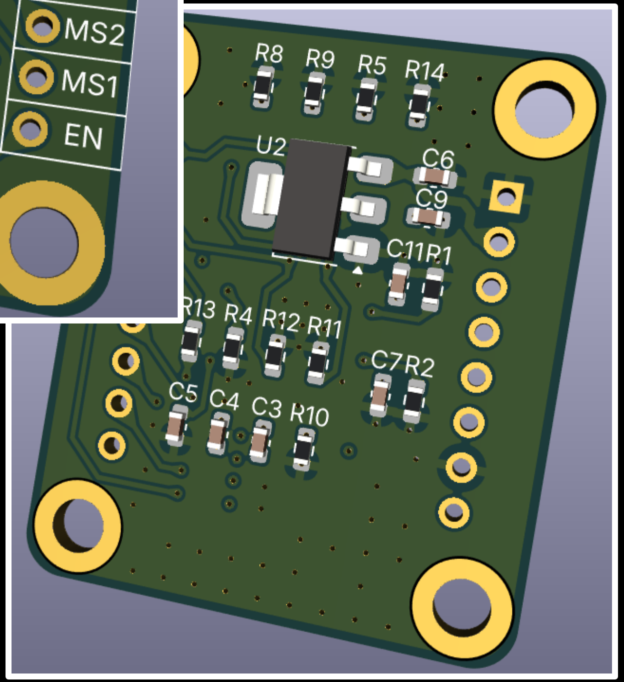

Cheap DC-DC Convertor
from Amazon

# HARDWARE SELECTION
# FINDING ICS TO MAKE BETTER HARDWARE

| Stepper Driver | MCU | Switching Regulator |
| --- | --- | --- |
|  |  |  |
| a4988 Stepper Driver IC<br>By Allegro MicroSystems | STM8S003F3P6TR<br>By STMicroelectronics | TPS62932DRLR<br>By Texas Instruments |

# WHY USE THAT STEPPER DRIVER?

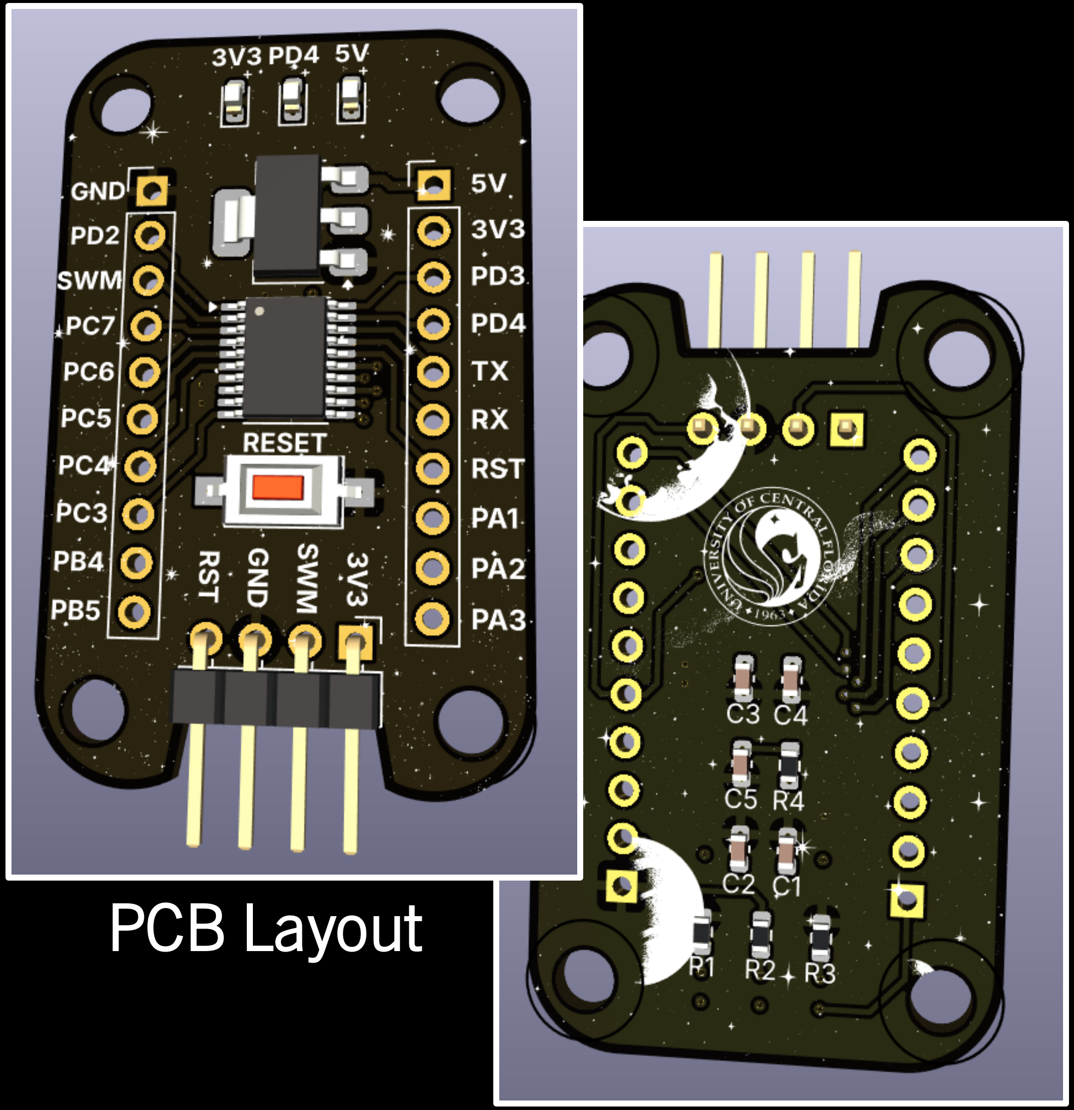



PCB Layout

- Simple STEP/DIR interface (no SPI, UART, or firmware configuration required)
- Very low cost compared to newer drivers (DRV8825, TMC2209, etc.)
- Massive ecosystem and proven reliability from years of 3D-printer/CNC use
- Easy hardware integration
- Microstepping set with pins, not registers
- Built-in current limiting and chopper control (no external current regulation needed)
- Existing Adafruit module makes PCB layout easier

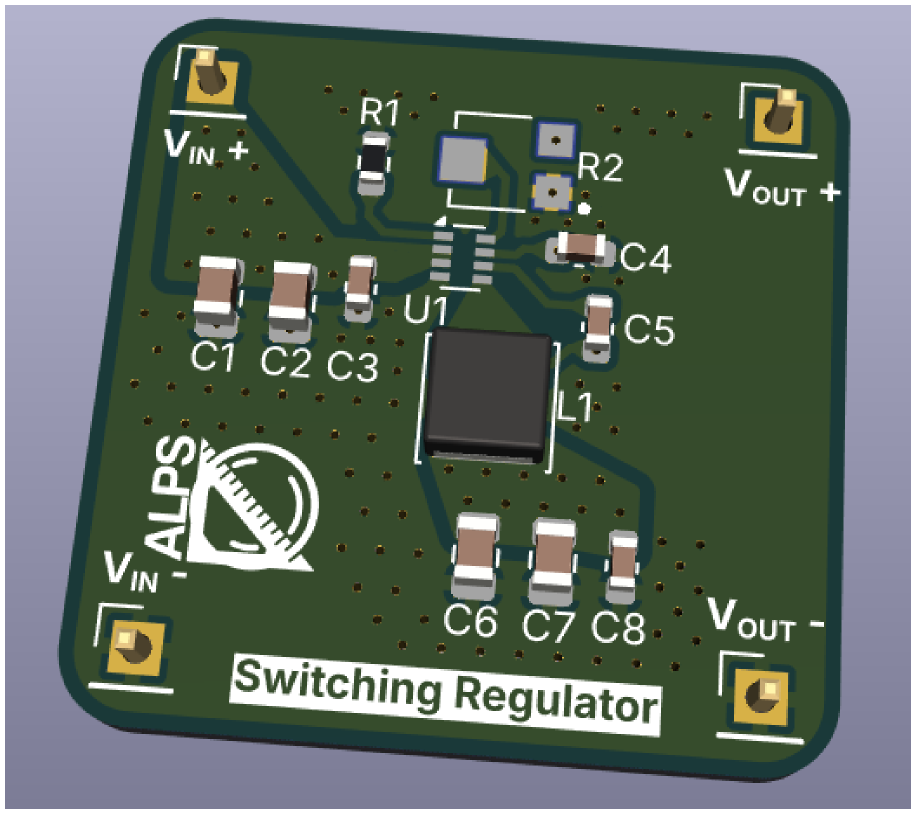
# WHY USE THAT MCU?



PCB Layout

- Incredibly low price of only $0.40 per MCU
- Strong price-to-peripheral ratio. It gives us GPIO, timers, ADC, UART, SPI, $I^2C$, watchdogs, etc. without paying for high-end features we don't need.
- Lower firmware complexity than larger MCUs like Arduino and ESP32. With fewer abstraction layers, it becomes easier to write low-level code

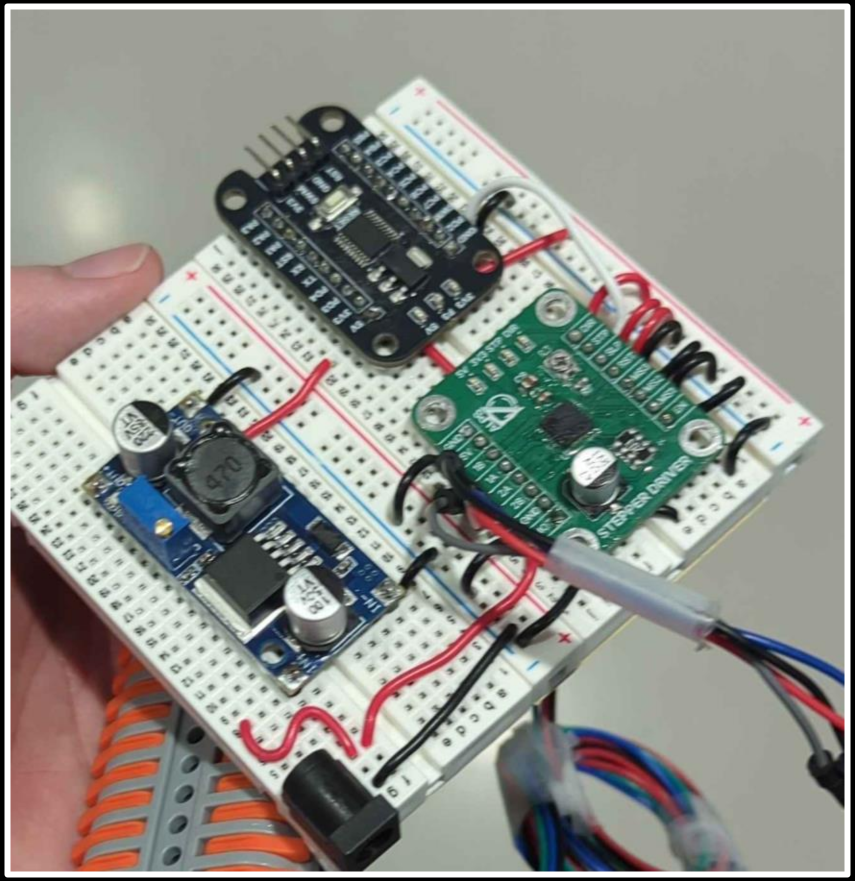
# WHY USE THAT SWITCHING REGULATOR?




PCB Layout

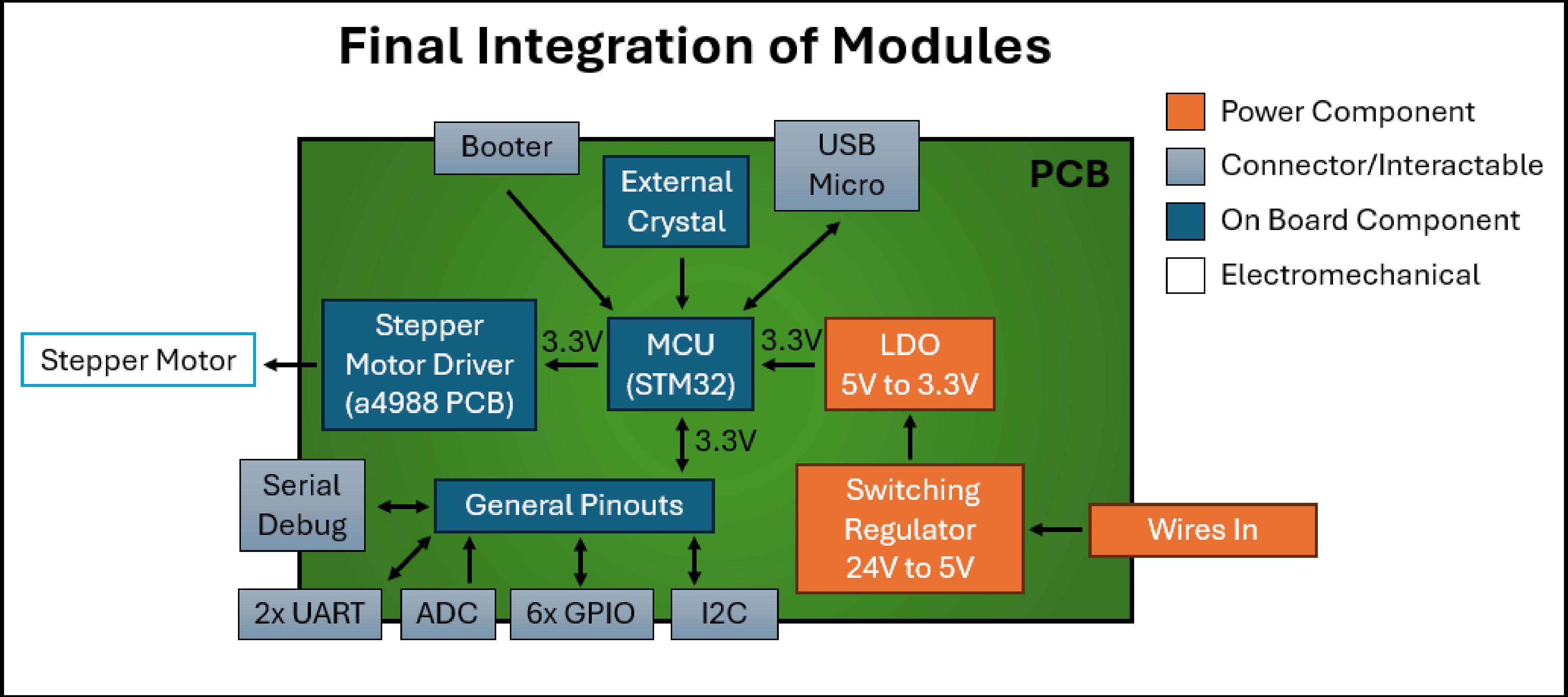
- Ultra-low quiescent current (~12 µA)
- Wide input range (3.8 V–30 V) allows use to use 12-24V to power our project
- Spread-spectrum EMI reduction built-in which lowers noise emissions compared to legacy regulators
- High duty-cycle capability (~98%)
- Peak current-mode control with fast transient response, necessary when steppers cause current spikes

# VERIFICATION




- Switching regulator PCB has been manufactured but still needs to be assembled
- All other PCBs have been verified to work in demo
- All that’s left is integration and programming

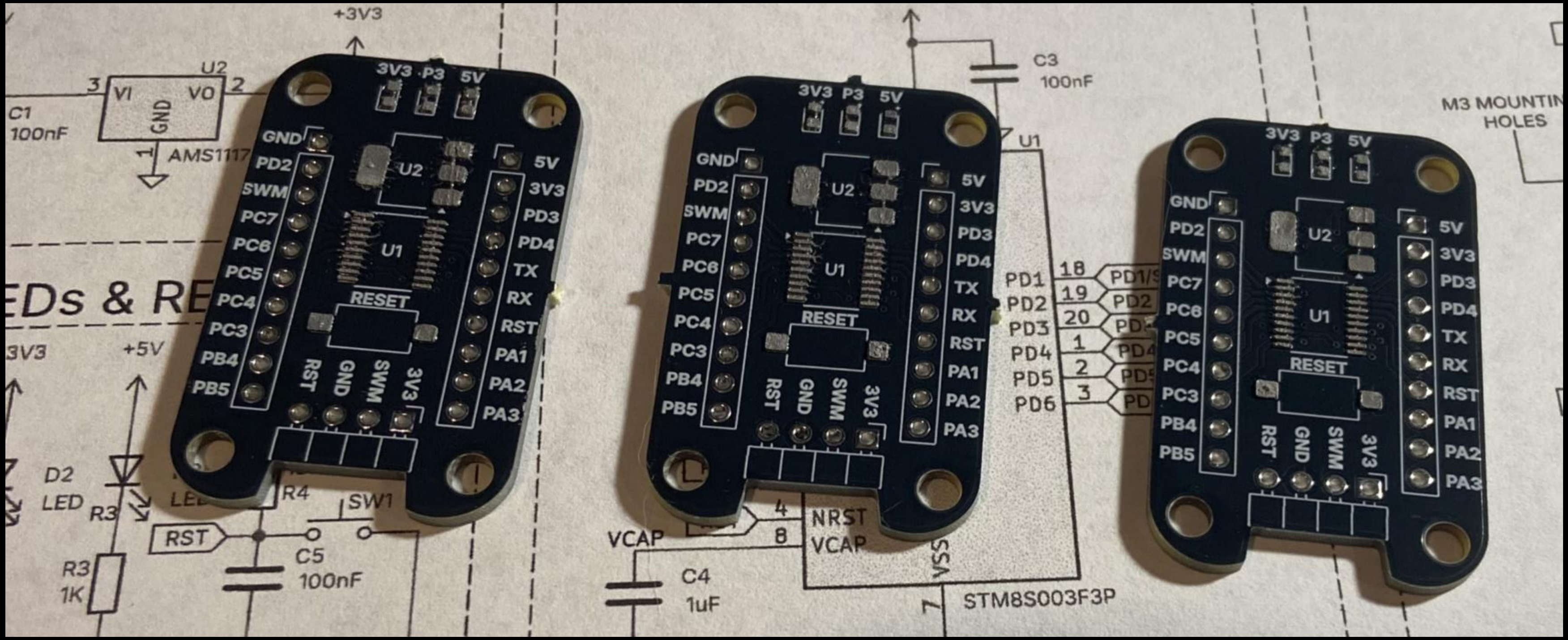
# WHAT'S NEXT?



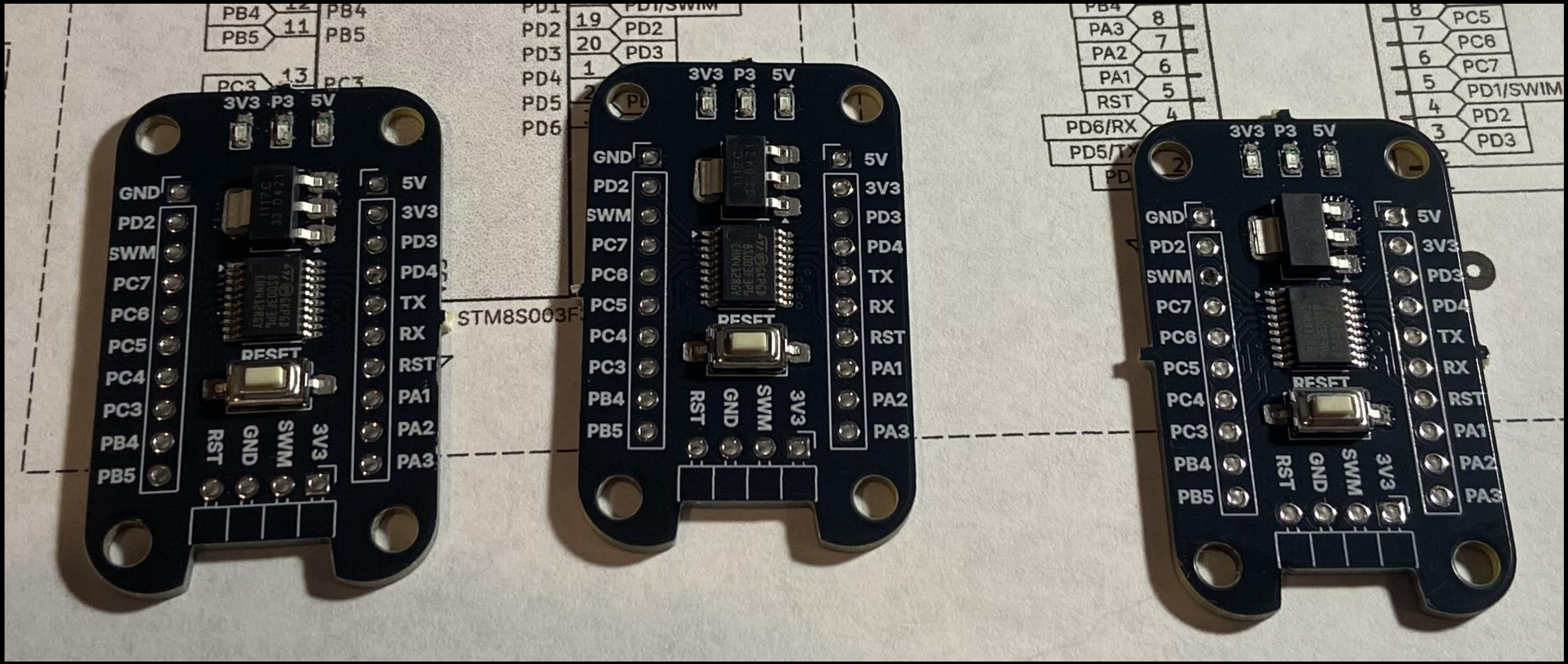
Final Integration of Modules
Power Component
Connector/Interactable
On Board Component
Electromechanical
PCB
Booter
External Crystal
USB Micro
Stepper Motor
Stepper Motor Driver (a4988 PCB)
3.3V
MCU (STM32)
3.3V
LDO 5V to 3.3V
3.3V
Serial Debug
General Pinouts
Switching Regulator 24V to 5V
Wires In
2x UART
ADC
6x GPIO
I2C

# HOW ARE THEY MADE?

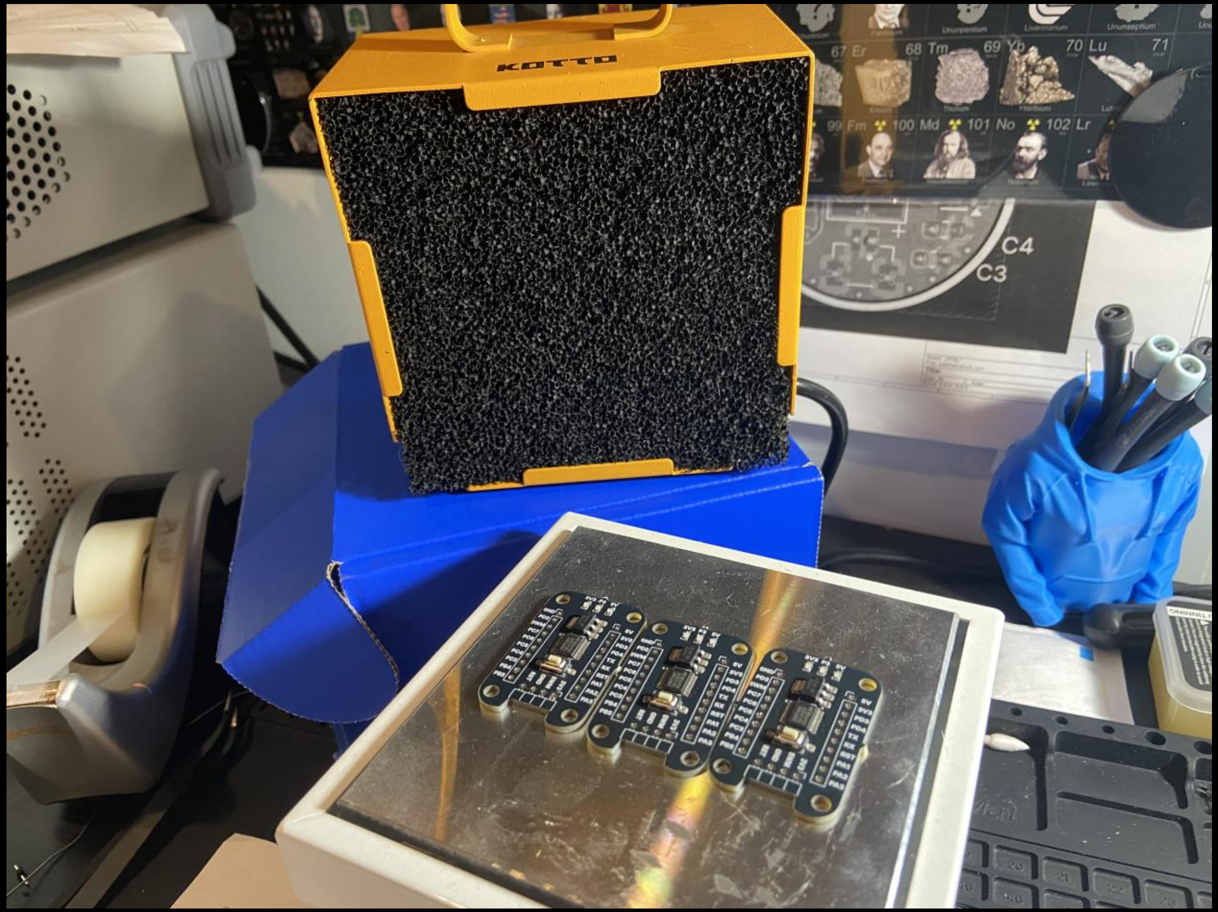
# LAYING THE FRONT STENCIL



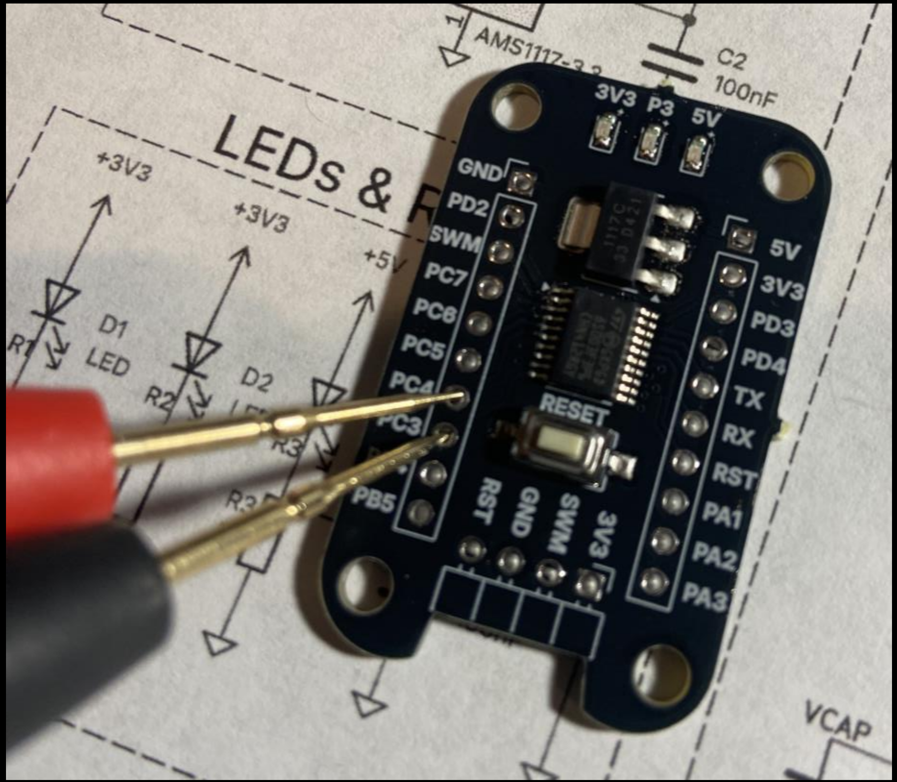
# PLACING COMPONENTS

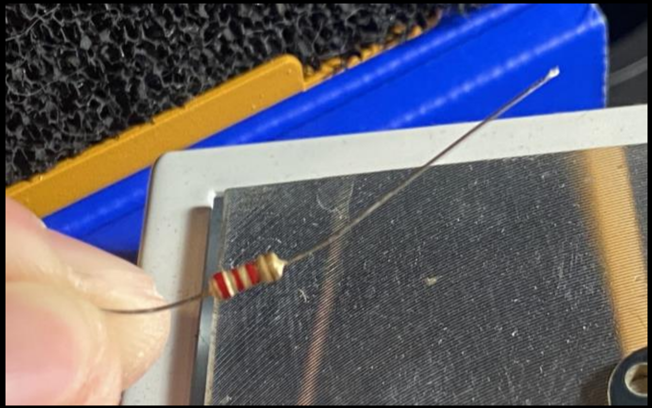


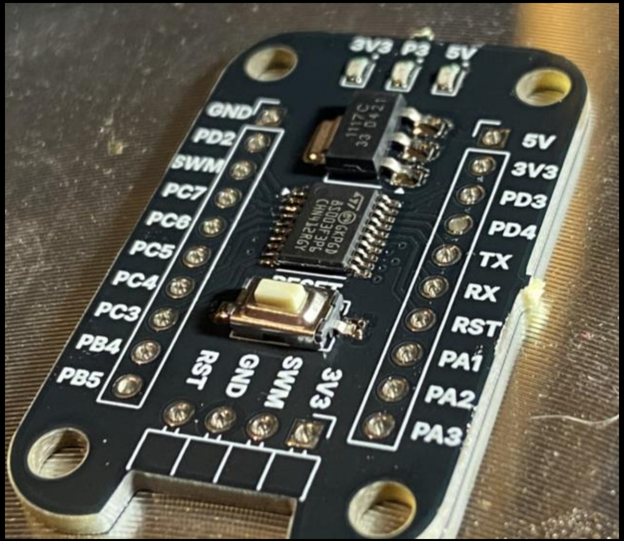
# HOT PLATE TIME!

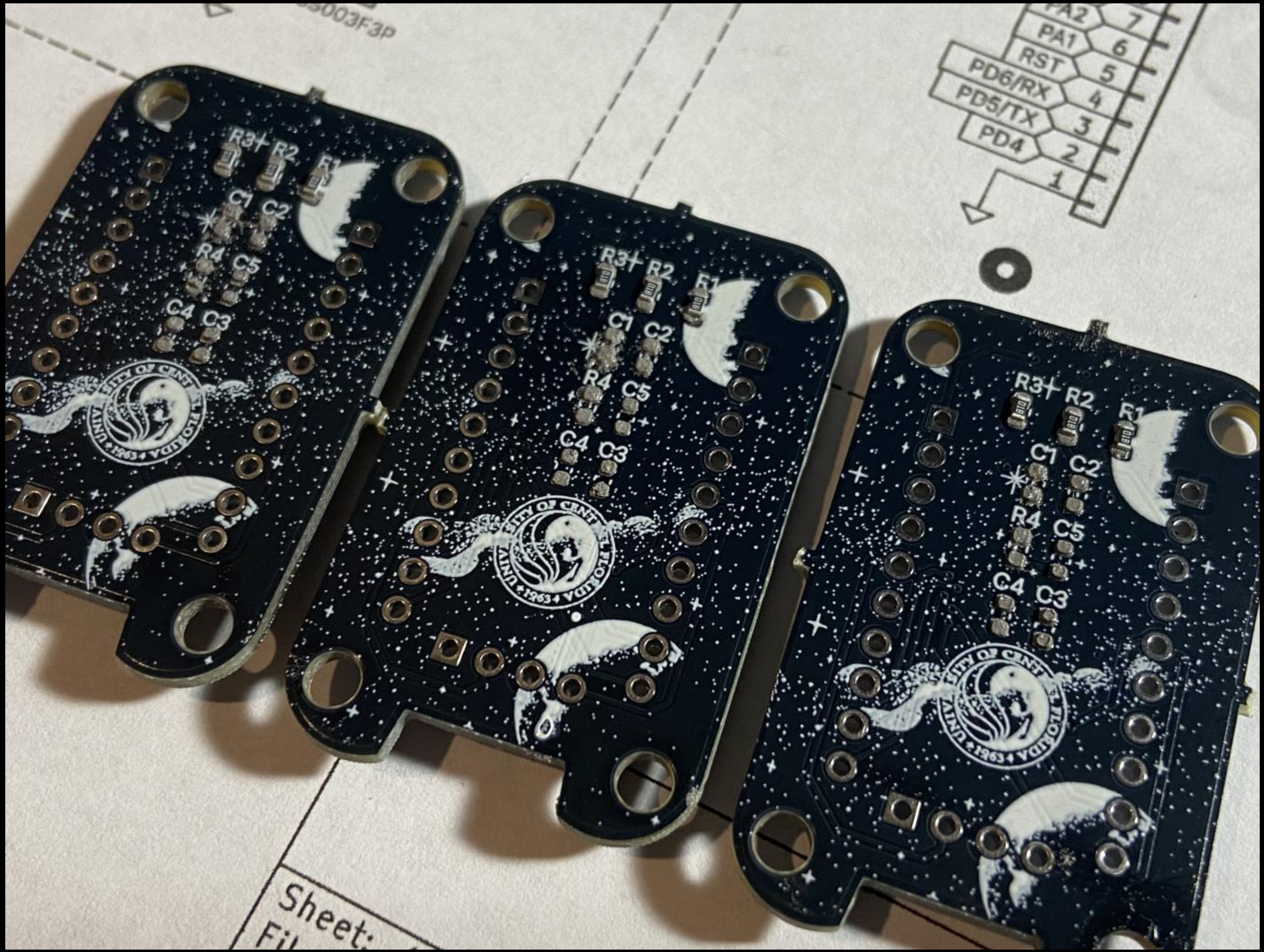
# QUALITY ASSURANCE TESTING



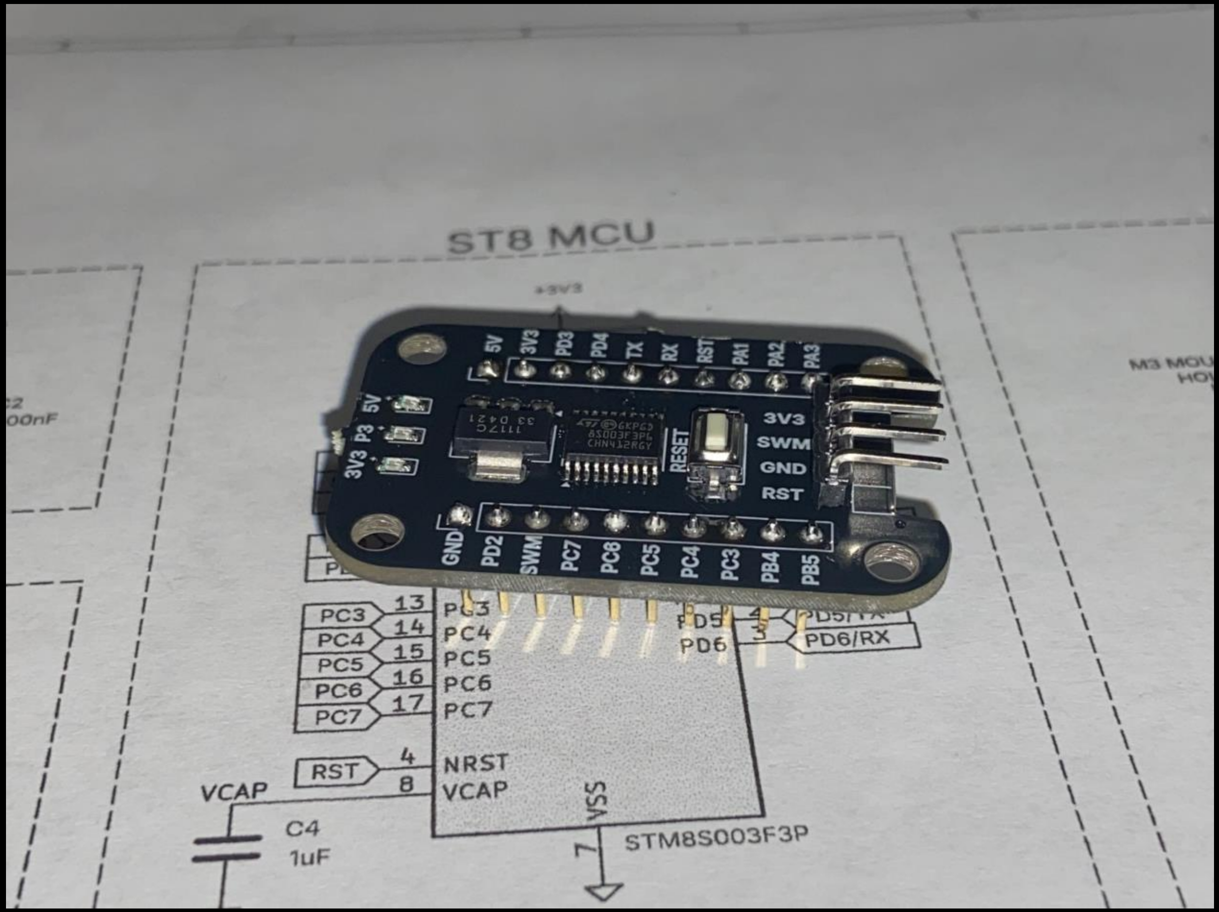


# LAYING THE BACK STENCIL

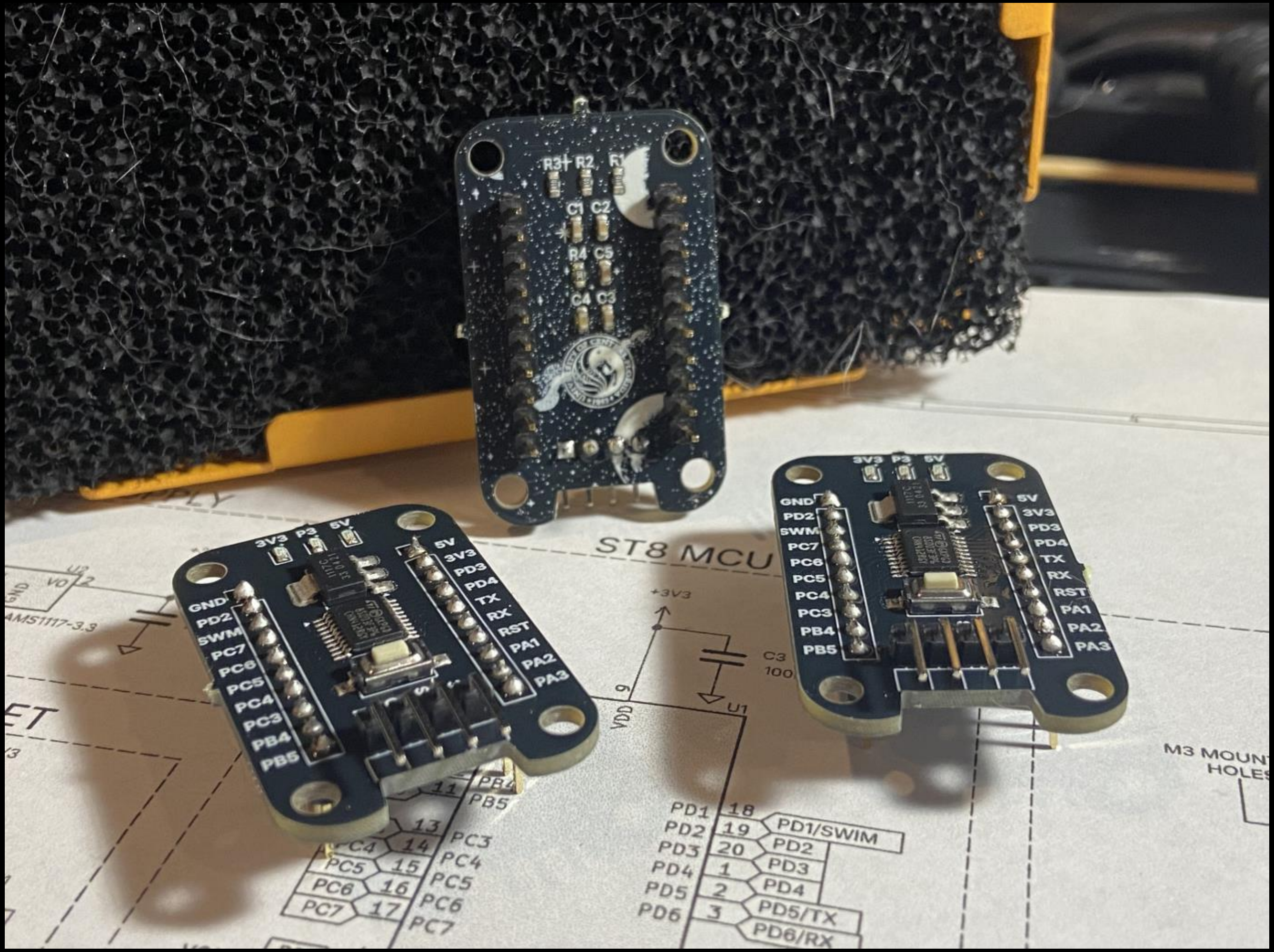


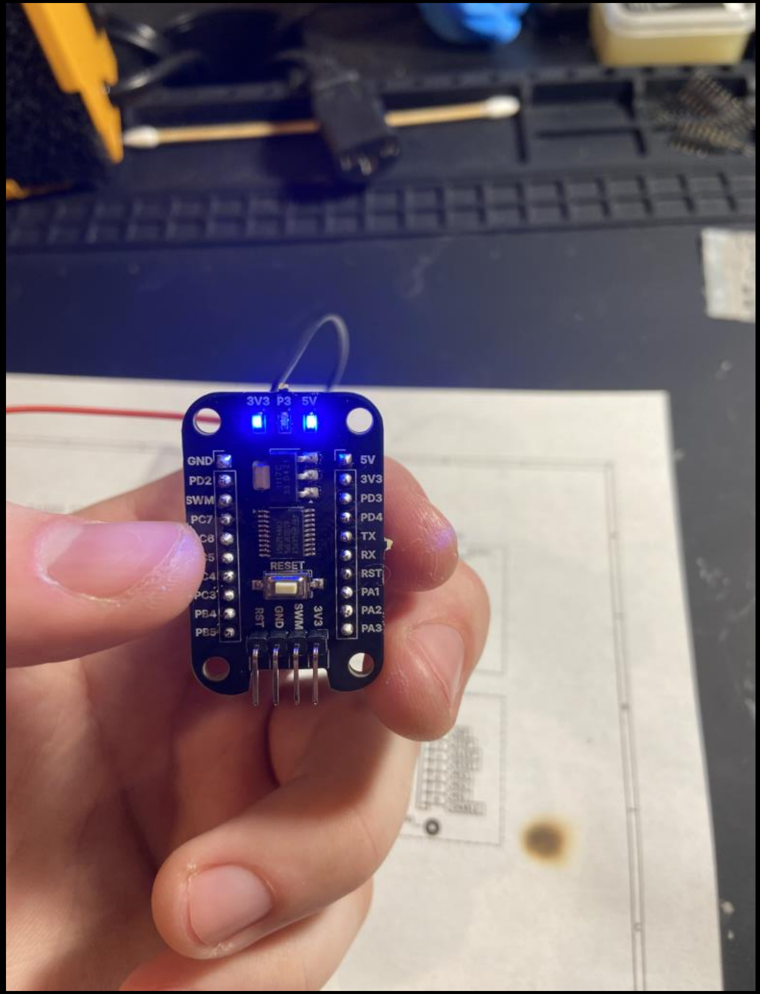

# COMPONENT PLACEMENT AND SOLDERING... WITH A TWIST

# PIN HEADER SOLDERING




# THE FINISHED PRODUCT

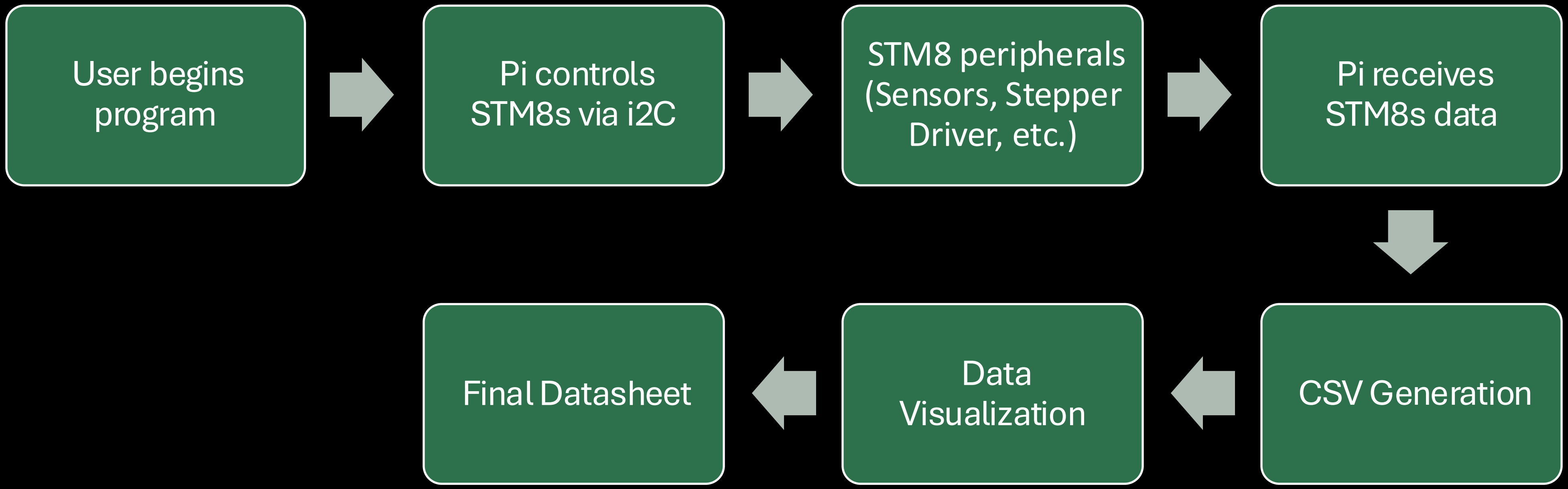



# SOFTWARE REQUIRED

- ALM Software
  - STM8 Programming
  - Raspberry Pi Automation
  - CSV Data Visualization

# SOFTWARE BLOCK DIAGRAM



# SINGLE PASS MEASUREMENT FLOW

## SINGLE-PASS MEASUREMENT FLOW

### ① Setup

Lens geometry
via numpad wizard

### ② Spot Imaging (Phase 1)

Gantry homes once · 0→400 mm
At each stop: servo → C → cam · D → cam · F → cam

### ③ Transmission

Gantry holds
Mono sweeps λ
Reads AIN5

### ④ Rotate

Lens holder
rotates 30°
via STM8 0x40

### ⑤ Reflection

Mono sweeps
Reads AIN6
Gantry → 0

### ⑥ Export

FWHM extract
CSV → pdflatex
main.pdf

# GANTRY SPECIFICATIONS

TABLE III: Gantry Positioning Summar (mean of repeated runs)

| Steps/mm | Target (mm) | Mean (mm) | $\sigma$ (mm) | Error (mm) | Error (%) |
|---|---|---|---|---|---|
| 3*55 | 50 | 50.0 | 0.00 | 0.00 | 0.00 |
| | 215 | 214.5 | 0.58 | −0.50 | −0.23 |
| | 400 | 396.3 | 1.26 | −3.75 | −0.94 |
| 3*52 | 50 | 51.0 | 0.00 | +1.00 | +2.00 |
| | 215 | 202.0 | 0.00 | −13.0 | −6.05 |
| | 400 | 375.0 | 0.00 | −25.0 | −6.25 |
| 3*58 | 50 | 52.0 | 0.00 | +2.00 | +4.00 |
| | 215 | 227.0 | 0.00 | +12.0 | +5.58 |
| | 400 | 420.0 | 0.00 | +20.0 | +5.00 |

# LENS HOLDER SPECIFICATIONS

TABLE III: Gantry Positioning Summar (mean of repeated runs)

| Steps/mm | Target (mm) | Mean (mm) | $\sigma$ (mm) | Error (mm) | Error (%) |
|---|---|---|---|---|---|
| 3*55 | 50 | 50.0 | 0.00 | 0.00 | 0.00 |
| | 215 | 214.5 | 0.58 | −0.50 | −0.23 |
| | 400 | 396.3 | 1.26 | −3.75 | −0.94 |
| 3*52 | 50 | 51.0 | 0.00 | +1.00 | +2.00 |
| | 215 | 202.0 | 0.00 | −13.0 | −6.05 |
| | 400 | 375.0 | 0.00 | −25.0 | −6.25 |
| 3*58 | 50 | 52.0 | 0.00 | +2.00 | +4.00 |
| | 215 | 227.0 | 0.00 | +12.0 | +5.58 |
| | 400 | 420.0 | 0.00 | +20.0 | +5.00 |

# SPECTRAL SPECIFICATIONS

| Monochromator Position vs Peak Wavelength | | | | |
|---|---|---|---|---|
| Servo Angle (degrees) | Target Peak Wavelength (nm) | Mean Peak Wavelength (nm) | Error (nm) | Error (%) |
| 49.5 | 486 | 484 | -2 | -0.41 |
| 37 | 589 | 588 | -1 | -0.17 |
| 29.5 | 656 | 653 | -3 | -0.46 |

# LENS TESTED

TABLE III: Gantry Positioning Summar (mean of repeated runs)

| Steps/mm | Target (mm) | Mean (mm) | $\sigma$ (mm) | Error (mm) | Error (%) |
|---|---|---|---|---|---|
| 3*55 | 50 | 50.0 | 0.00 | 0.00 | 0.00 |
| | 215 | 214.5 | 0.58 | −0.50 | −0.23 |
| | 400 | 396.3 | 1.26 | −3.75 | −0.94 |
| 3*52 | 50 | 51.0 | 0.00 | +1.00 | +2.00 |
| | 215 | 202.0 | 0.00 | −13.0 | −6.05 |
| | 400 | 375.0 | 0.00 | −25.0 | −6.25 |
| 3*58 | 50 | 52.0 | 0.00 | +2.00 | +4.00 |
| | 215 | 227.0 | 0.00 | +12.0 | +5.58 |
| | 400 | 420.0 | 0.00 | +20.0 | +5.00 |

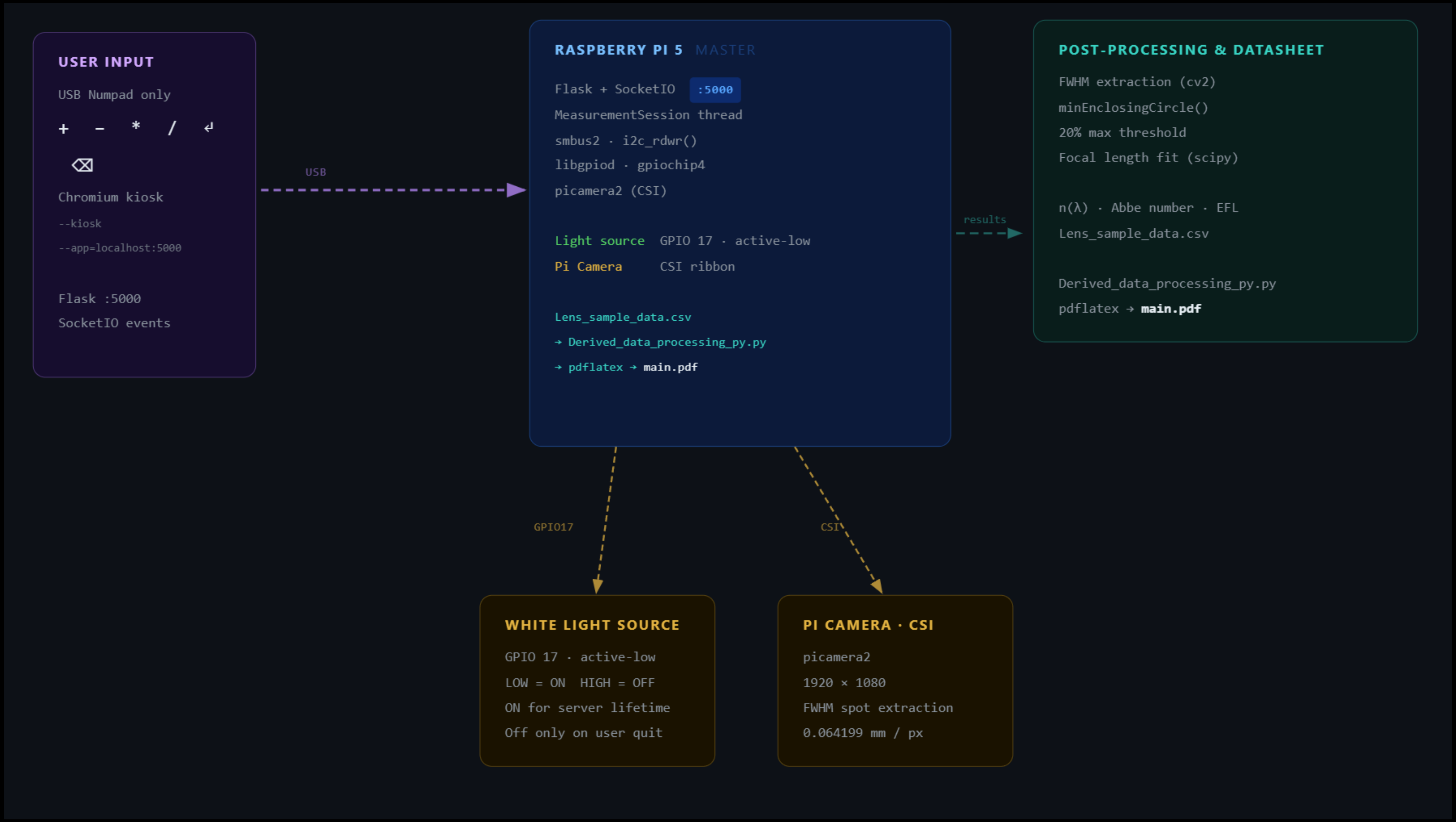
# IDE OPTIONS FOR THE STM8

| IDE / Toolchain | Compiler Support | Debugging Support | Ease of Setup | Cost | Pros | Cons |
|---|---|---|---|---|---|---|
| ST Visual Develop (STVD) | Cosmic C, Raisonance, SDCC | Full ST-LINK hardware debugging | Moderate | Free (IDE) | Native STM8 support, strong debugger integration, stable, professional workflow | Requires external compiler install |
| IAR Embedded Workbench | IAR C Compiler | Excellent debugging | Easy | Expensive (license required) | Very optimized compiler, professional toolchain | High cost, limited free version |
| PlatformIO (VS Code) | SDCC | Limited STM8 debug support | Moderate | Free | Modern UI, cross-platform | STM8 support is not mature |
| Eclipse CDT + SDCC | SDCC | Manual configuration | Difficult | Free | Highly customizable | Complex setup, not STM8-specific |
| Raisonance Ride | Raisonance C | Yes | Moderate | Limited free version | Good integration | License restrictions |

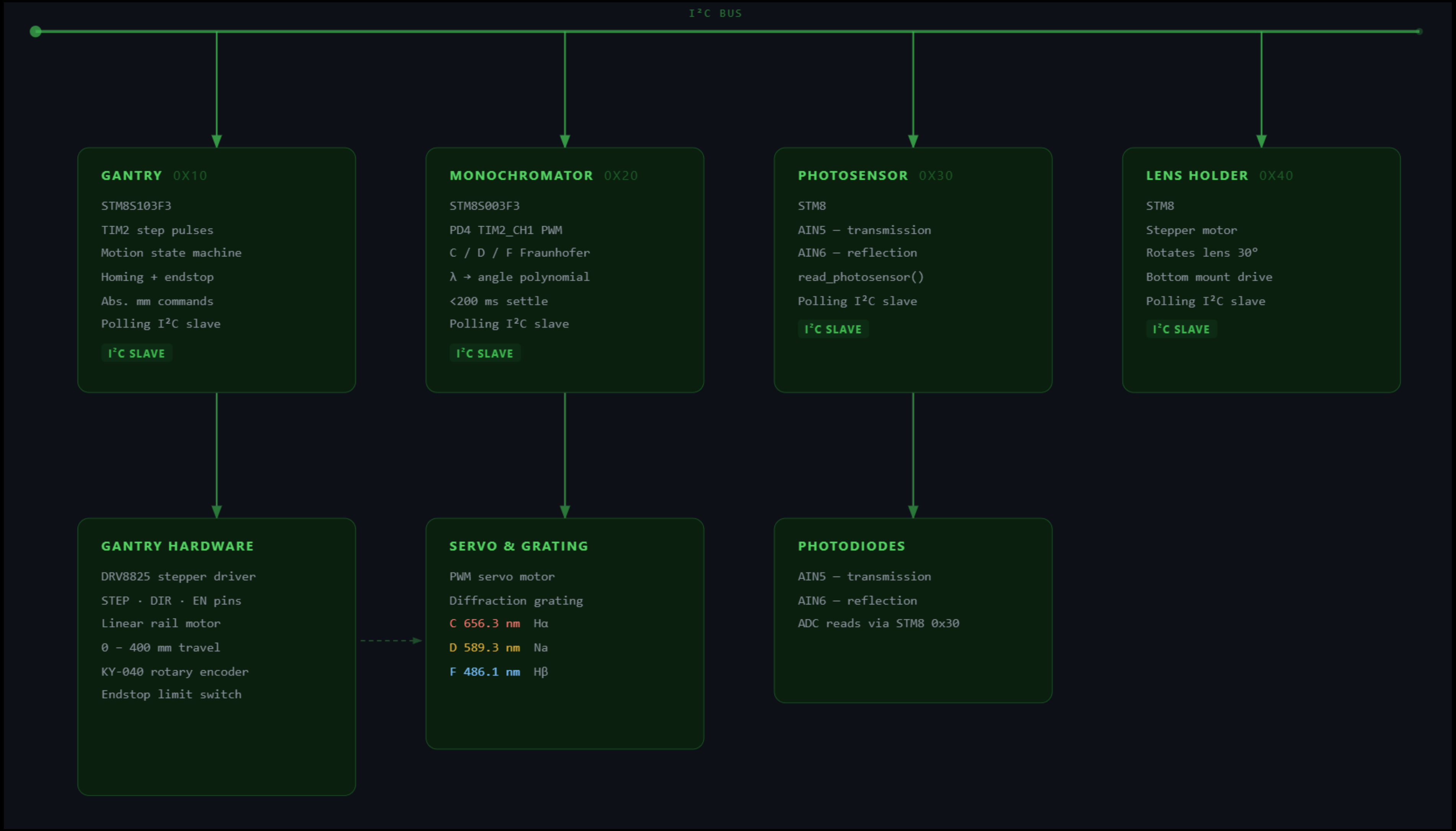
# SINGLE BOARD COMPUTER SELECTION


- Raspberry Pi 5 has built in Wi-Fi, more memory, and a faster CPU.
- Raspberry Pi 5 CPU is favored for general-purpose computing, while the Jetson Nano CPU is favored for embedded AI projects.

# RASPBERRY PI PERIPHERALS



# STM8 PERIPHERALS

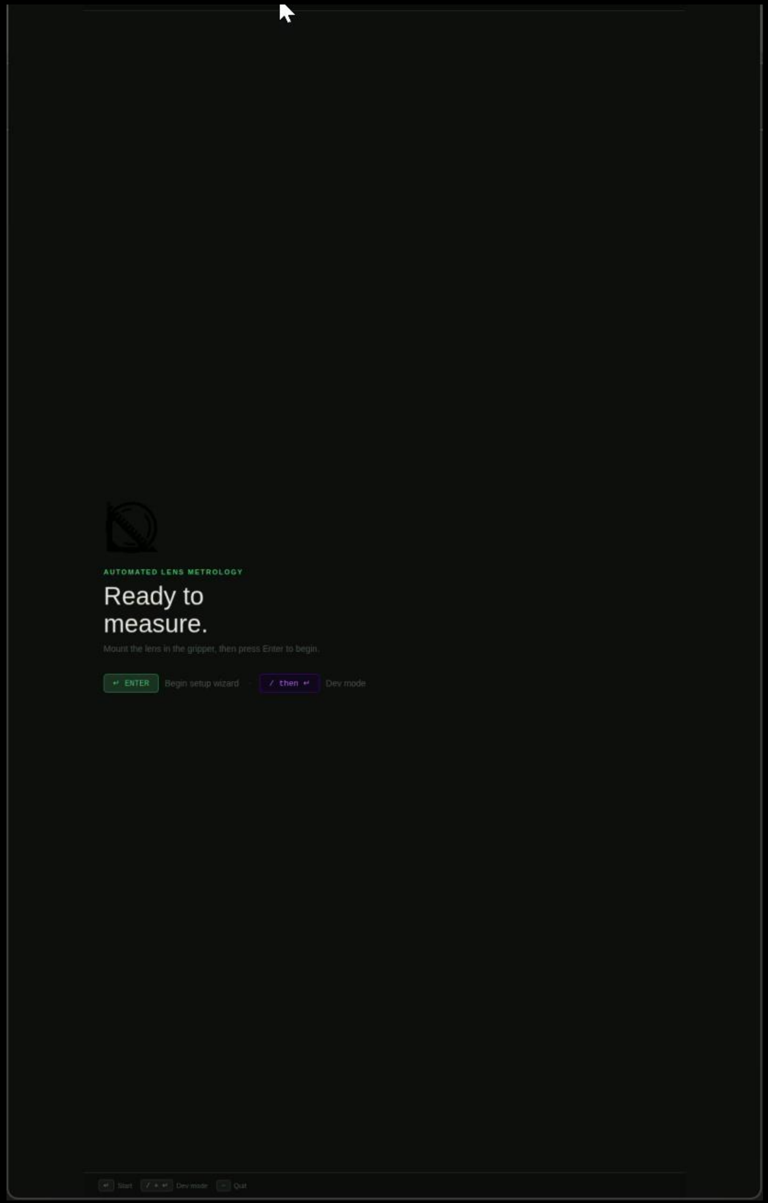



# I2C DATA PACKET FORMAT

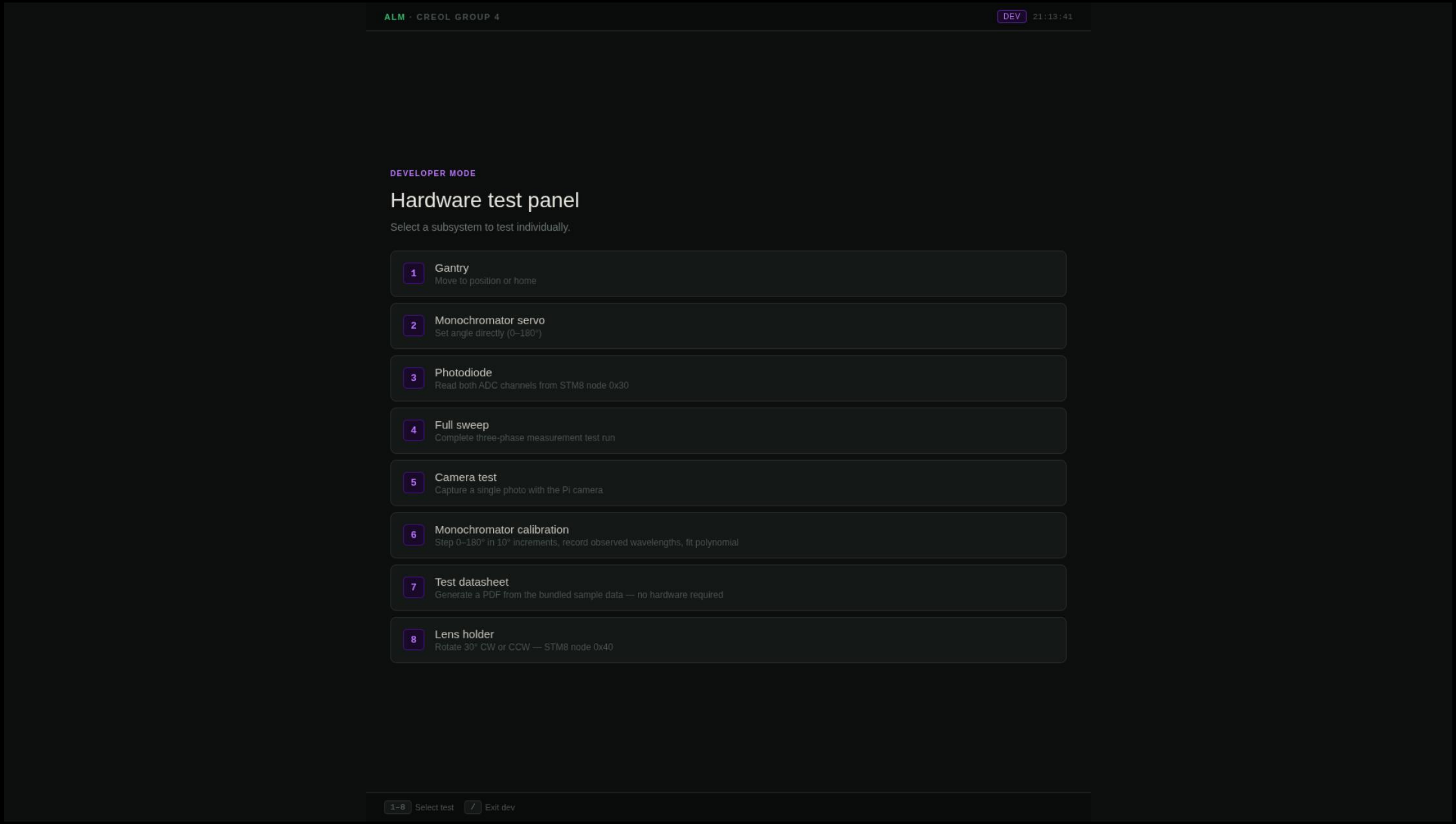

- I2C chosen over UART because UART ultimately failed during tests.

- Inside each data packet sent contains information on the task the stm8 needs to perform, or data being sent back to the pi.
- All stm8s share the same i2c bus, each stm8 has it's own unique address.

# USER INTERFACE




# DEV MODE

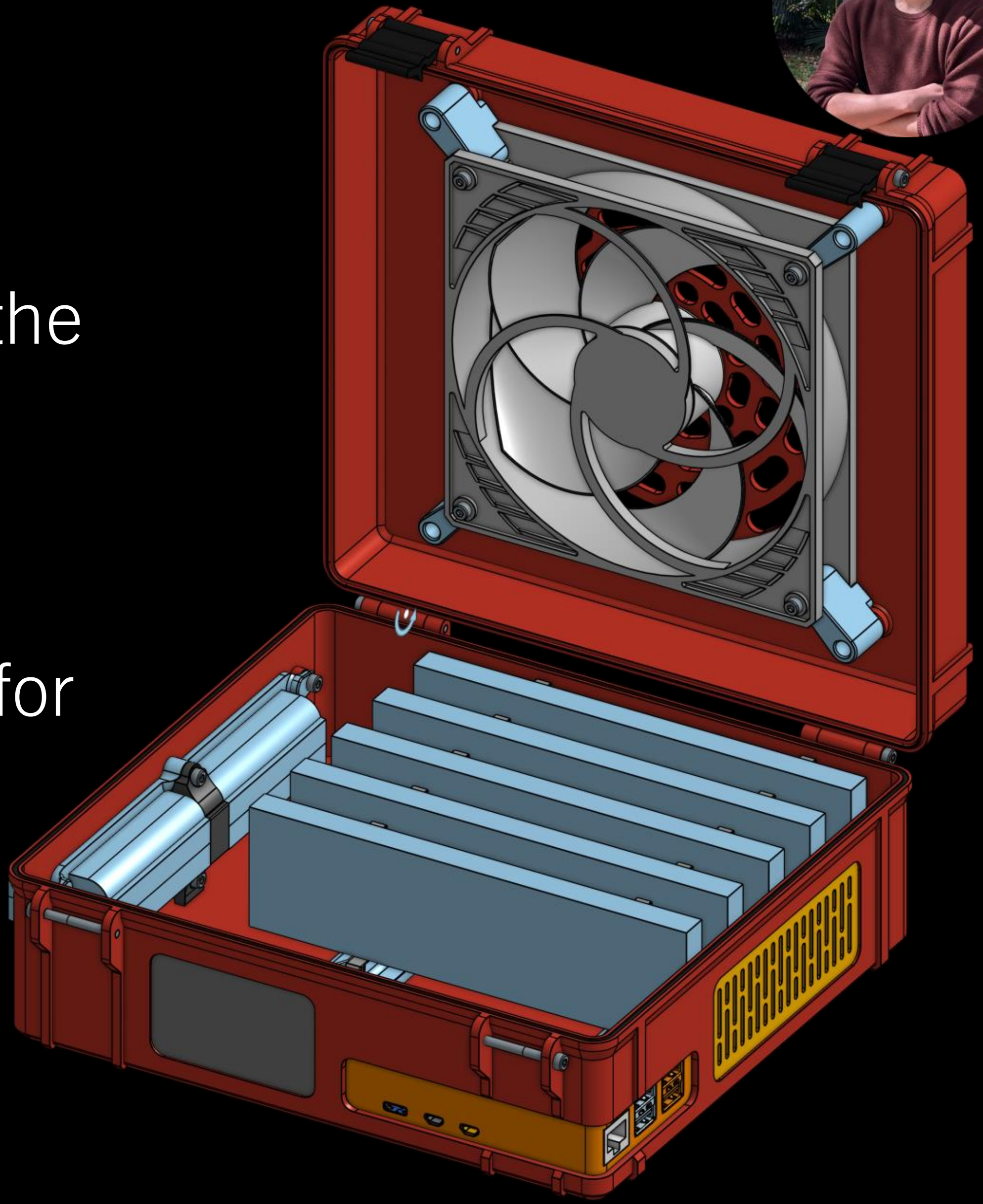

ALM · CREOL GROUP 4
DEV 21:13:41
DEVELOPER MODE
Hardware test panel
Select a subsystem to test individually.
1 Gantry
Move to position or home
2 Monochromator servo
Set angle directly (0–180°)
3 Photodiode
Read both ADC channels from STM8 node 0x30
4 Full sweep
Complete three-phase measurement test run
5 Camera test
Capture a single photo with the Pi camera
6 Monochromator calibration
Step 0–180° in 10° increments, record observed wavelengths, fit polynomial
7 Test datasheet
Generate a PDF from the bundled sample data — no hardware required
8 Lens holder
Rotate 30° CW or CCW — STM8 node 0x40
1–8 Select test
/ Exit dev

# CSV GENERATION

- Sensor data coming from stm8 will be inputted and categorized into csv via a python script
- The C spot, D spot, and F spot will also be calculated and inputted into the csv.
- This csv will then be inputted into LaTeX to start the datasheet process.

# ELECTRONIC CASE

- The case will act as an enclosure for all the PCBs.
- Wire clamps make sure wires are not suddenly yanked from PCBs.
- Cooling fan helps regulate temperature for all the electronics.



# FUTURE PLANS

- Have an app that the Pi sends the datasheet to
- Improve accounts of grating and photodiode efficiency on data

# ADMINISTRATIVE CONTENT

| Major | PSE | | EE | CPE |
| --- | --- | --- | --- | --- |
| Member | Kiva | Ollie | Zachary | Daniel |
| Tasks | WLS, IAS, Optical Data Processing & Mechanical Systems | Diffraction Grating & Monochromator | System Supporting Electronics & PCB | Embedded Development & Data Collection |
| Alternates | Ollie | Daniel | Kiva | Zach |

TABLE XIX: Task Distribution

| | Hardware | Optics | Electronics | Total |
| --- | --- | --- | --- | --- |
| Budget Total | $350 | $350 | $2,500 | $3,200 |
| Budget Spent | $106.97 | $288.38 | $1,934.12 | $2,329.47 |

# OUR NEXT STEPS

| Milestone | Start Date | Completion Date |
|---|---|---|
| Order Initial PCB | 1/1/26 | 2/1/26 |
| Fabrication of Tray and Lens Mount Assembly | 1/1/26 | 2/1/26 |
| STM32 Firmware Development and Raspberry Pi Software Development | 1/1/26 | 4/1/26 |
| PCB Assembly | 3/1/26 | 4/1/26 |
| Optical Light Source and Photodiode Assembly | 1/1/26 | 3/1/26 |
| Imaging System Integration | 2/23/26 | 3/9/26 |
| System Integration and Debugging | 3/1/26 | 4/1/26 |
| Final Prototype Build | 3/1/26 | 4/1/26 |
| Final Testing | 3/1/26 | 4/1/26 |
| Final Presentation | 4/20/26 | 4/23/26 |

TABLE XVIII: Project Fabrication (SD-II)