EME 199 WQ 2023: Undergraduate Research

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Advanced Research for
Manufacturing Systems

Agenda

- CCD Camera Thermal Management (CTM) Experiment
- Substrate Manufacturing
- Securing Current CCD Camera Fixture
- New CCD Camera Fixture

CTM Experiment: Description

Problem:

- Current CCD camera **overheats** after ~170 thin-wall layers, causing the camera to turn off

Solution:

- Identify which part of the camera is overheating by attaching **thermocouples** to camera and performing depositions
- Design thermal management solution to mitigate overheating

CTM Experiment: Setup

- Use **five** thermocouples to characterize temperature across entire camera
- Use **one** thermocouple for nozzle temperature
- Can improve accuracy by using two thermocouples at each location and using average temperature

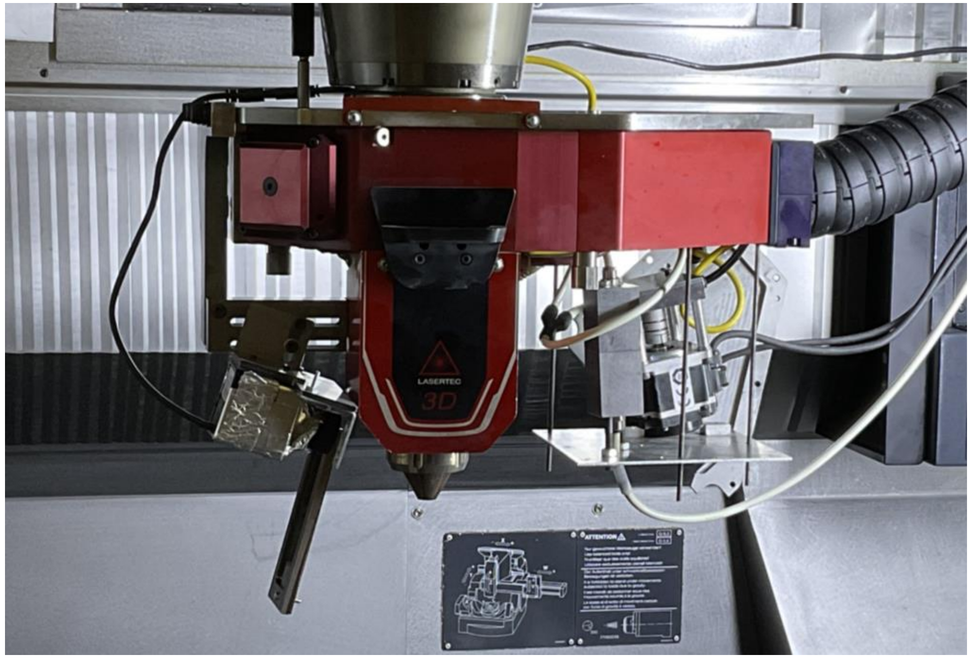


Figure 1: Current camera mounting on laser head

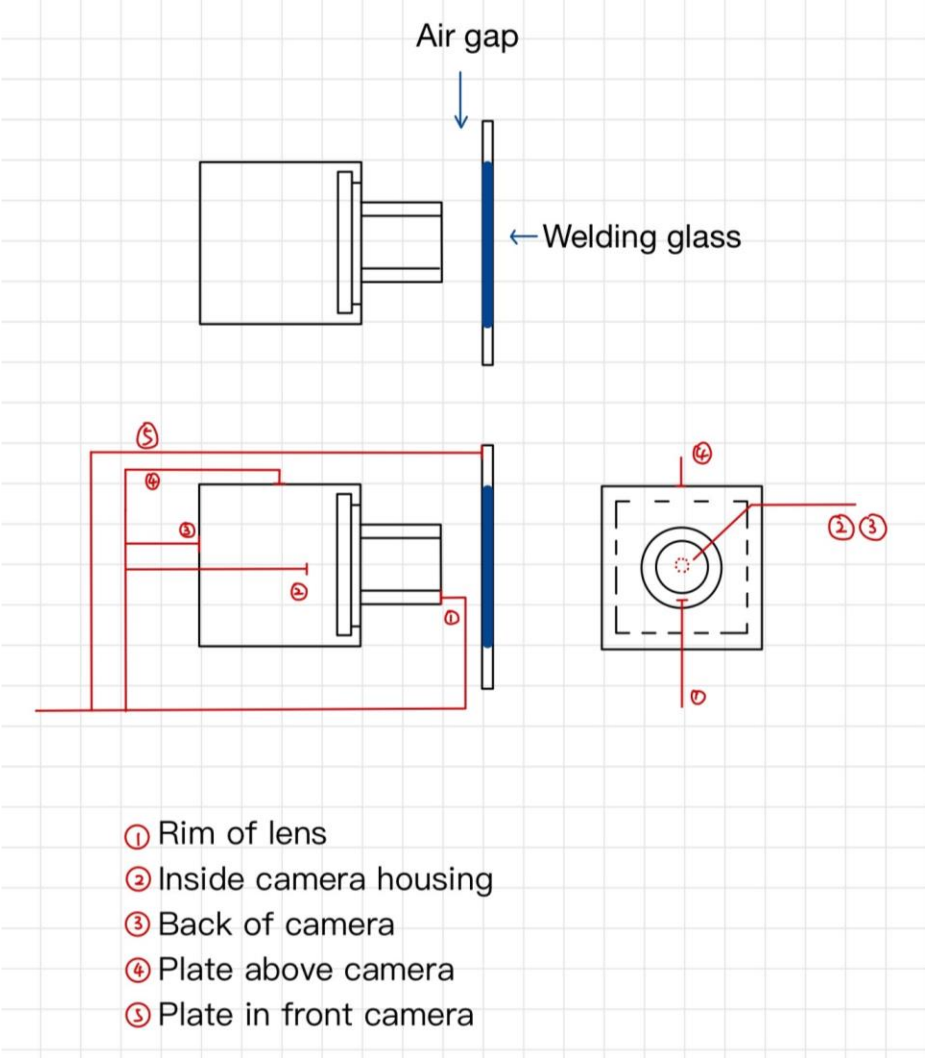


Figure 2: Thermocouple locations on camera

CTM Experiment: Depositions

Three 10-layer and one 50-layer thin-wall depositions

- 5-20 minute intervals in between

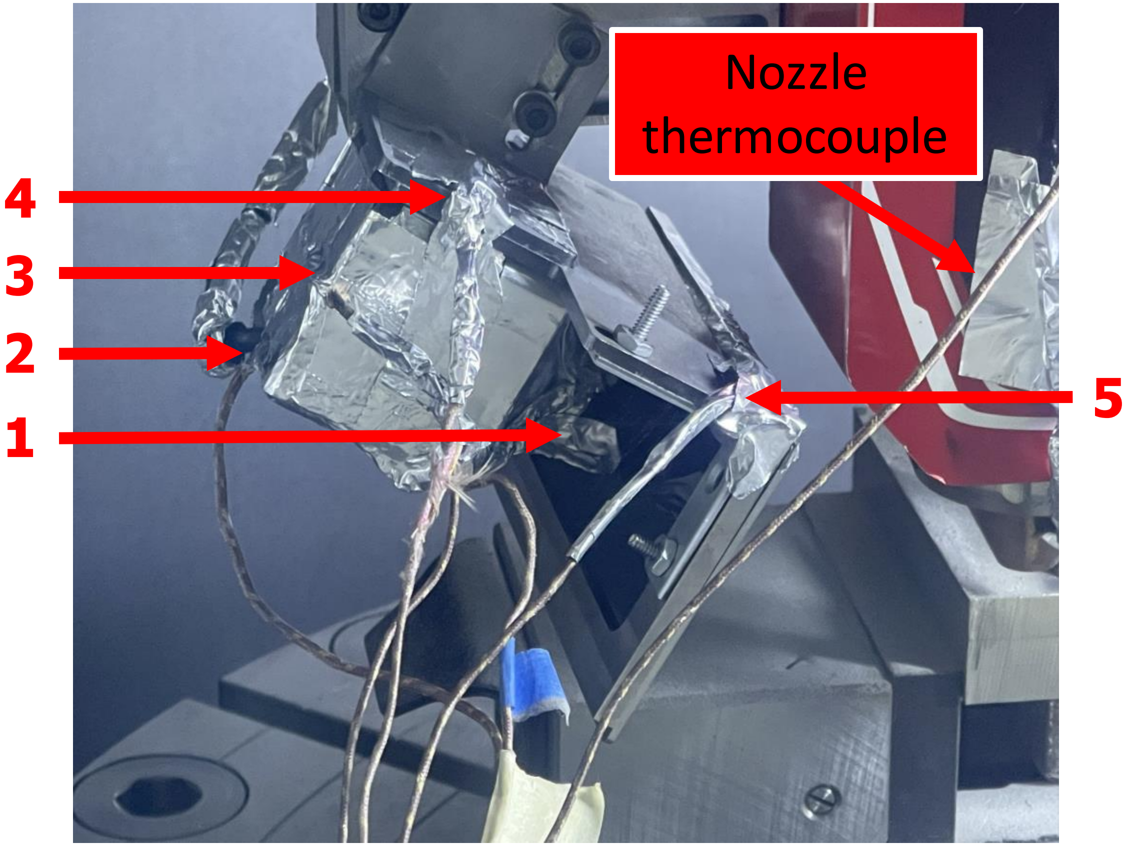


Figure 3: Thermocouples taped on camera

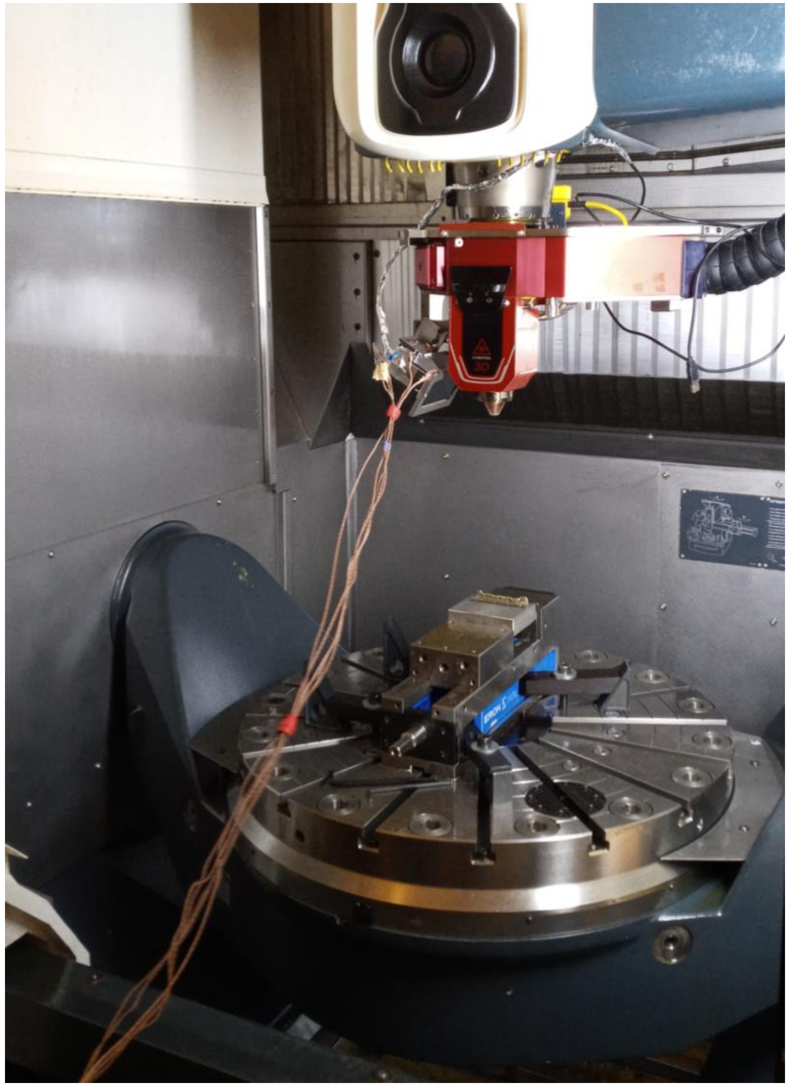
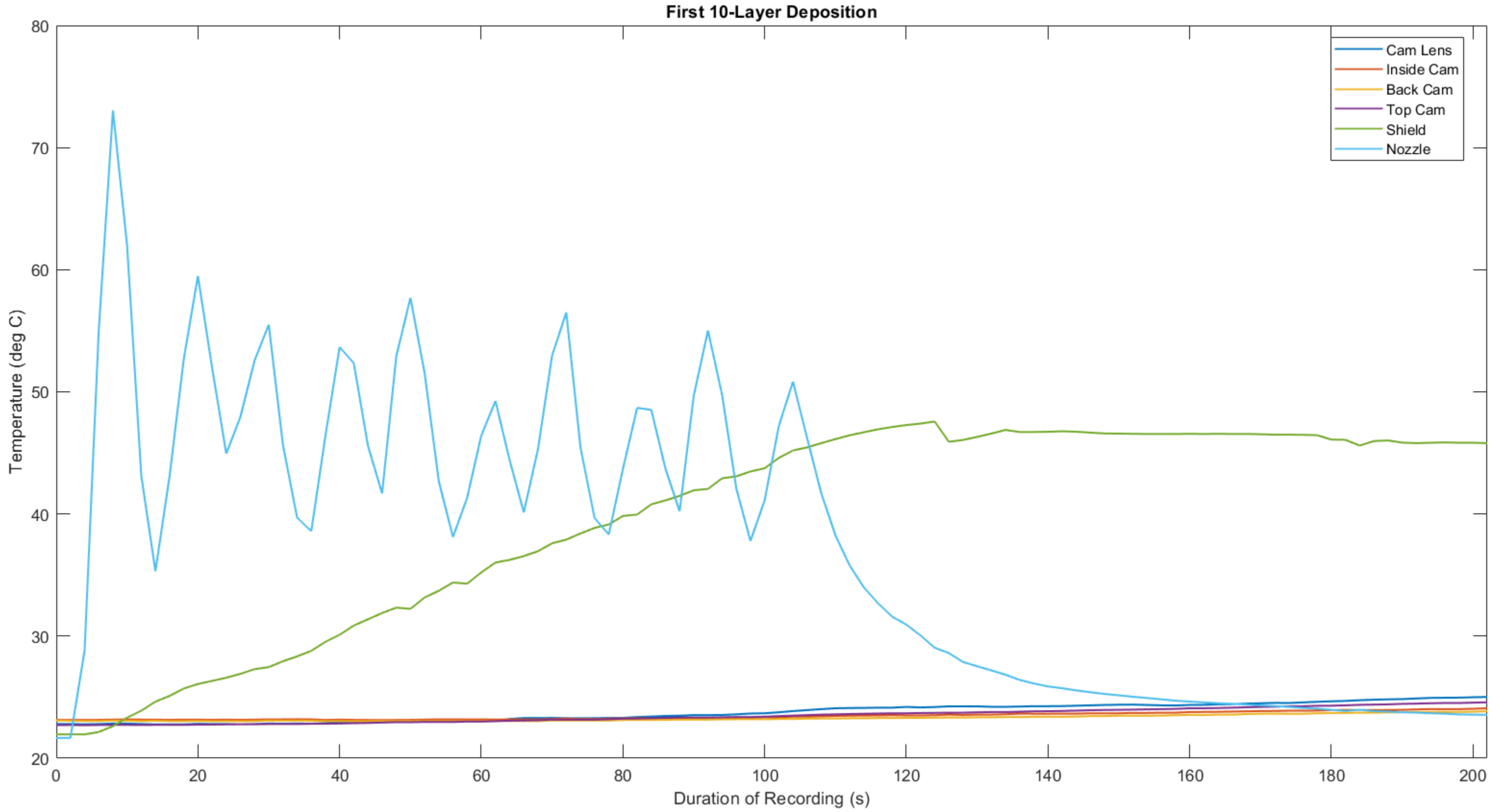


Figure 4: Wide view of thermocouple setup

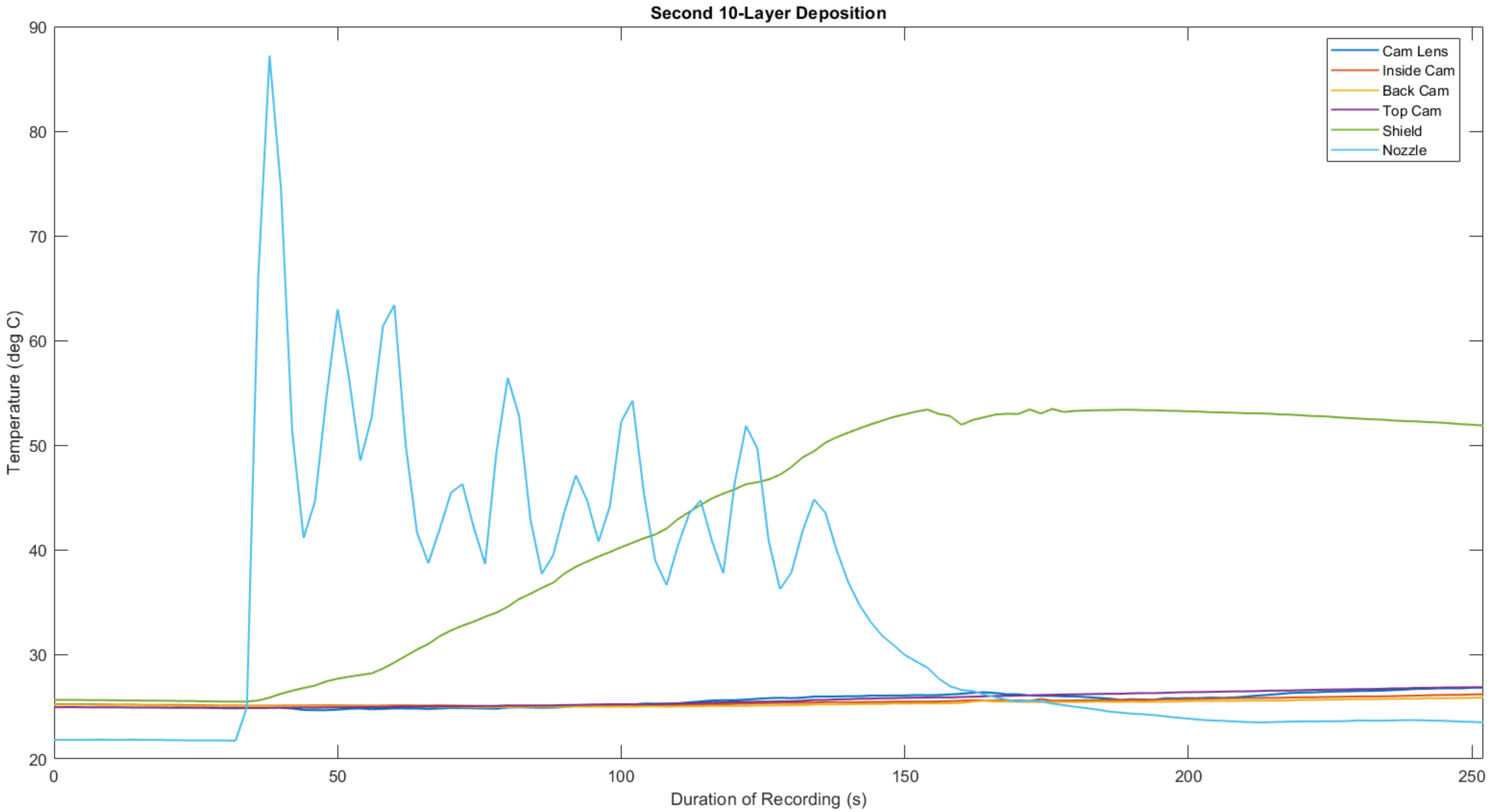
CTM Experiment: Temperature Data

Observations:

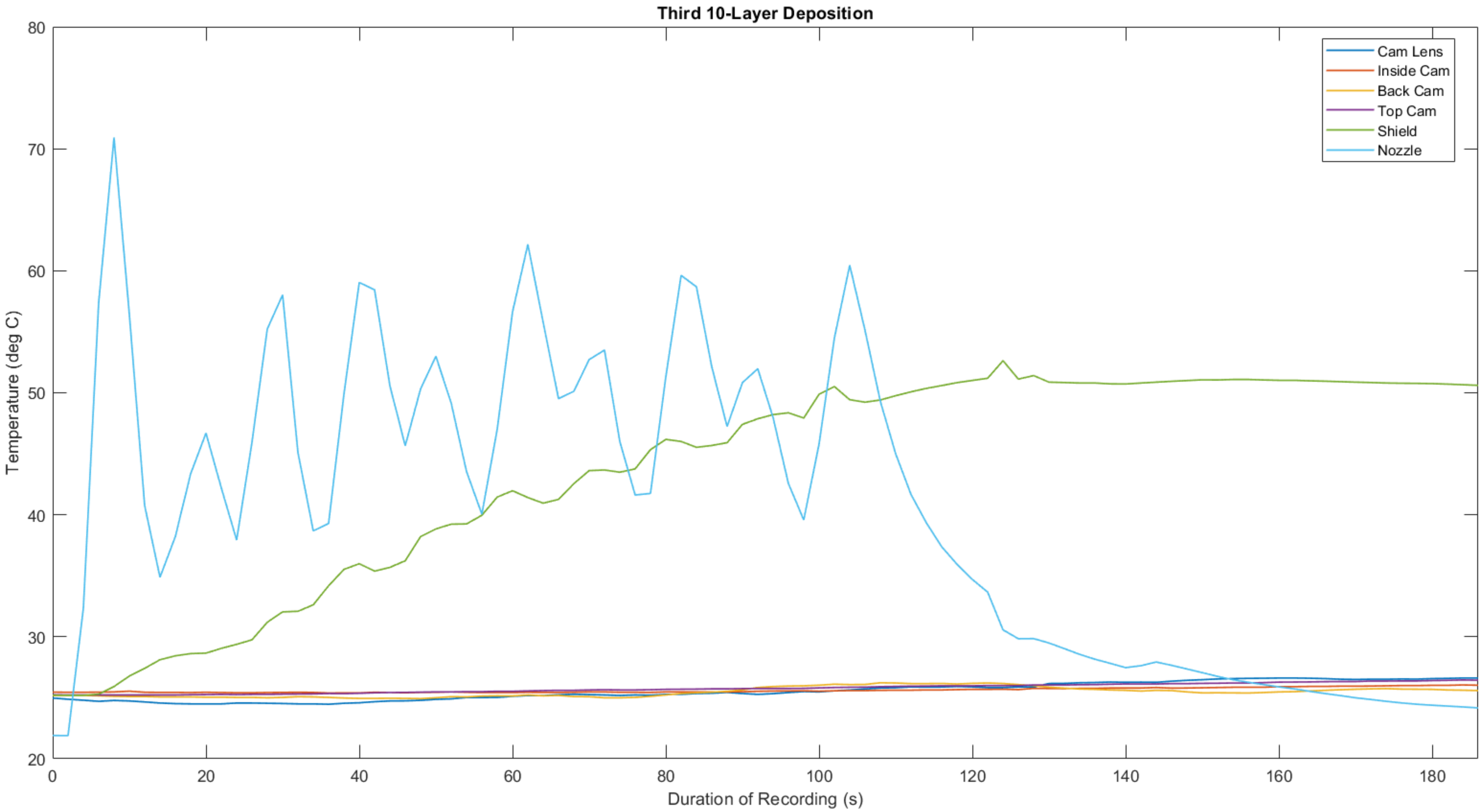
- Camera is protected by shield, but slowly heats up from shield **radiating** absorbed heat
- Shield temperature increases **linearly** then drops slowly after deposition ends
- Due to internal cooling, the nozzle has a controlled, oscillating temperature



CTM Experiment: Temperature Data



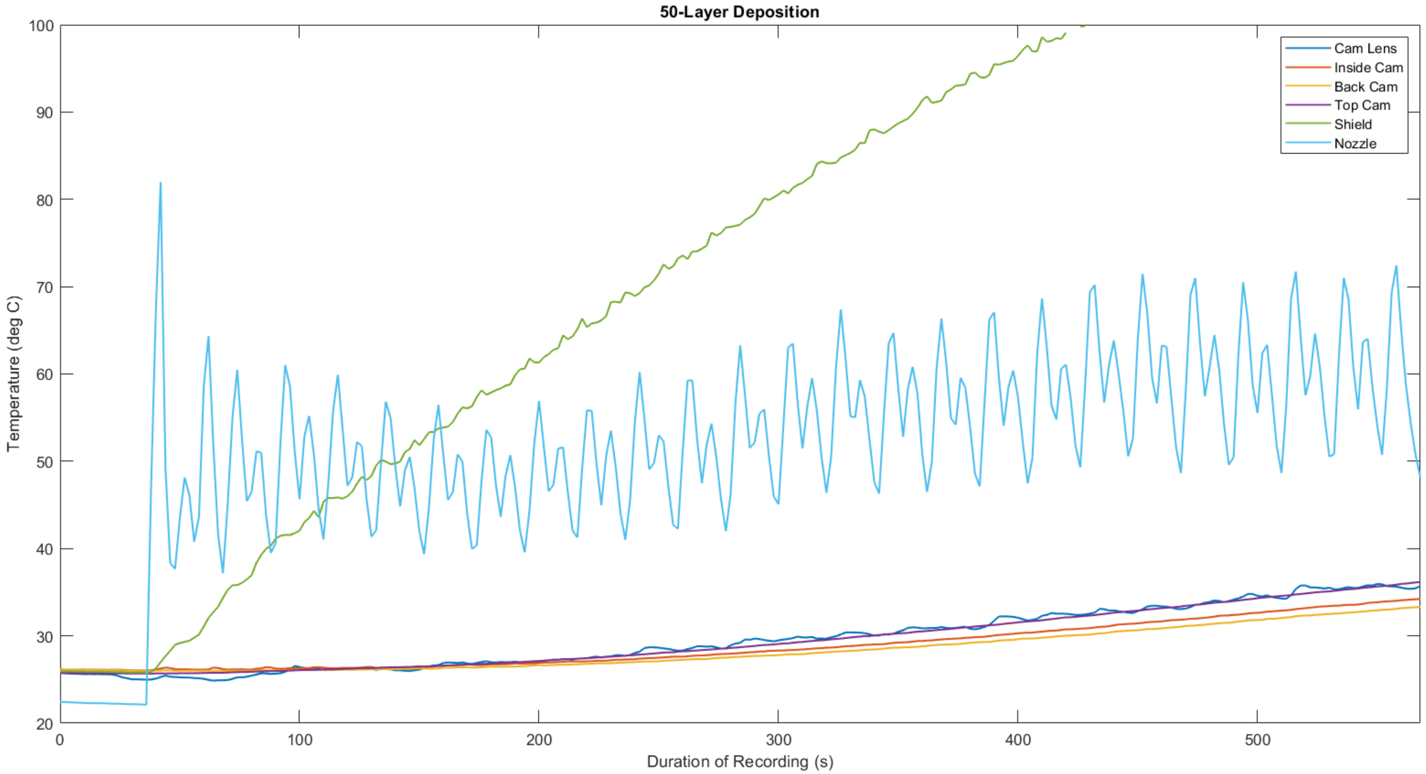
CTM Experiment: Temperature Data



CTM Experiment: Temperature Data

Observations:

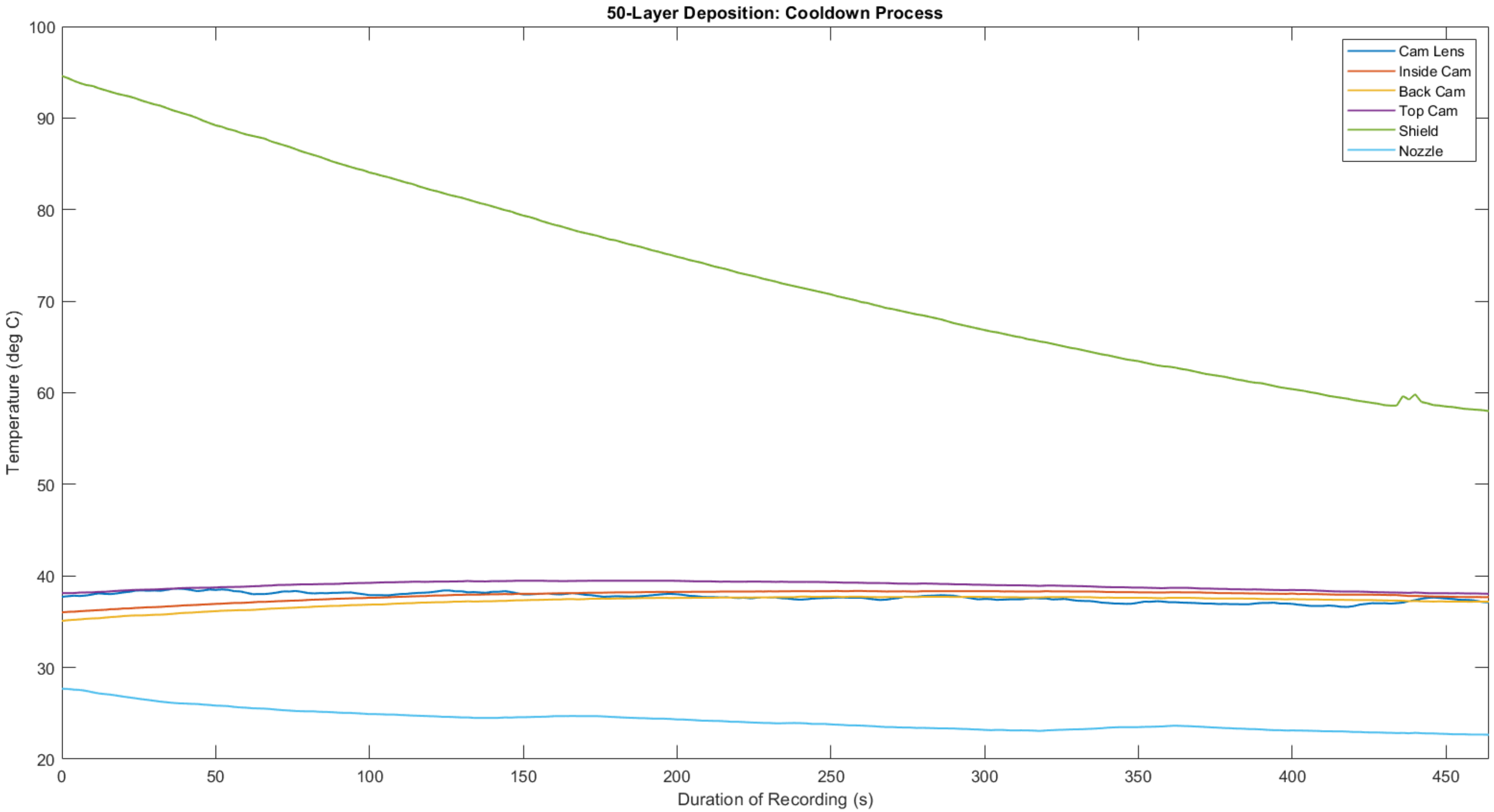
- **Incomplete** data for shield since DAC temperature range not set high enough
- Camera is protected by shield, but slowly heats up from shield **radiating** absorbed heat
- Shield temperature increases **linearly** then drops slowly after deposition ends
- Due to internal cooling, the nozzle has an oscillating temperature that slowly increases



CTM Experiment: Temperature Data

Observations:

- Camera slowly heats up **after** deposition due to shield **radiating** heat absorbed earlier
- Nozzle drops to room temperature quickly after deposition ends, at which point the camera is only being heated by the shield



CTM Experiment: Analysis

Potential reasons for camera overheating:

1. CCD camera circuit board overheats and malfunctions
2. Thermal expansion of shield’s metal frame cover and base

Maximum temperature specs:

- Camera circuit: 70 deg C
- Welding glass: 260 deg C

Picture format	MJPEG or YUY2(YUYV)
Lens Parameter	4mm manual focus lens
Cable	Standard 3M/ Optional 2m,3m,5m
Board Size/Weight	41*41mm optional / about 200g
Sensitivity	5.5V/lux-sec@550nm
Shutter Type	Rolling shutter/ Frame exposure
Connecting Port Type	USB2.0 High speed
OTG protocol	USB2.0 OTG
Free Drive Protocol	USB Video Class(UVC)
Work Temperature	0~70 Degree
Storage Temperature	-20~75 Degree

Figure 5: CCD camera specs

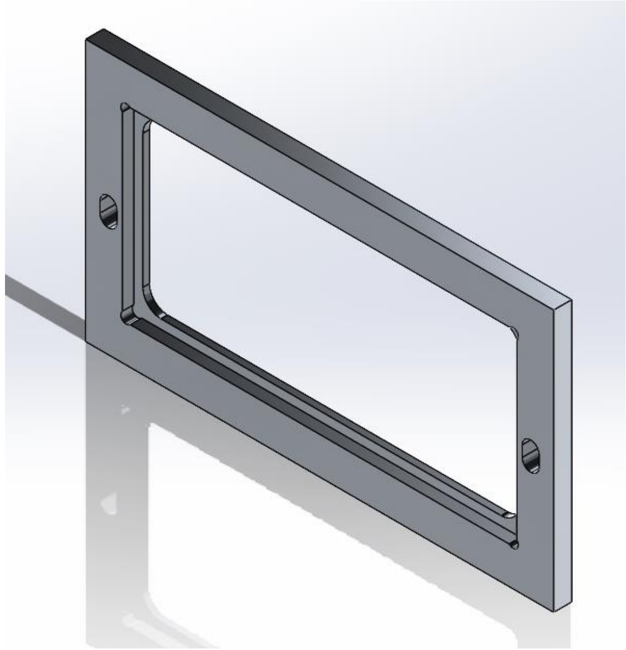


Figure 6: Camera shield CAD

Manufacturer	Forney
Part Number	57011
Item Weight	0.48 ounces
Product Dimensions	0.13 x 4.25 x 2 inches
Item model number	57011
Is Discontinued By Manufacturer	No
Size	4-1/2"
Color	Black
Finish	Uv-protection
Material	Glass

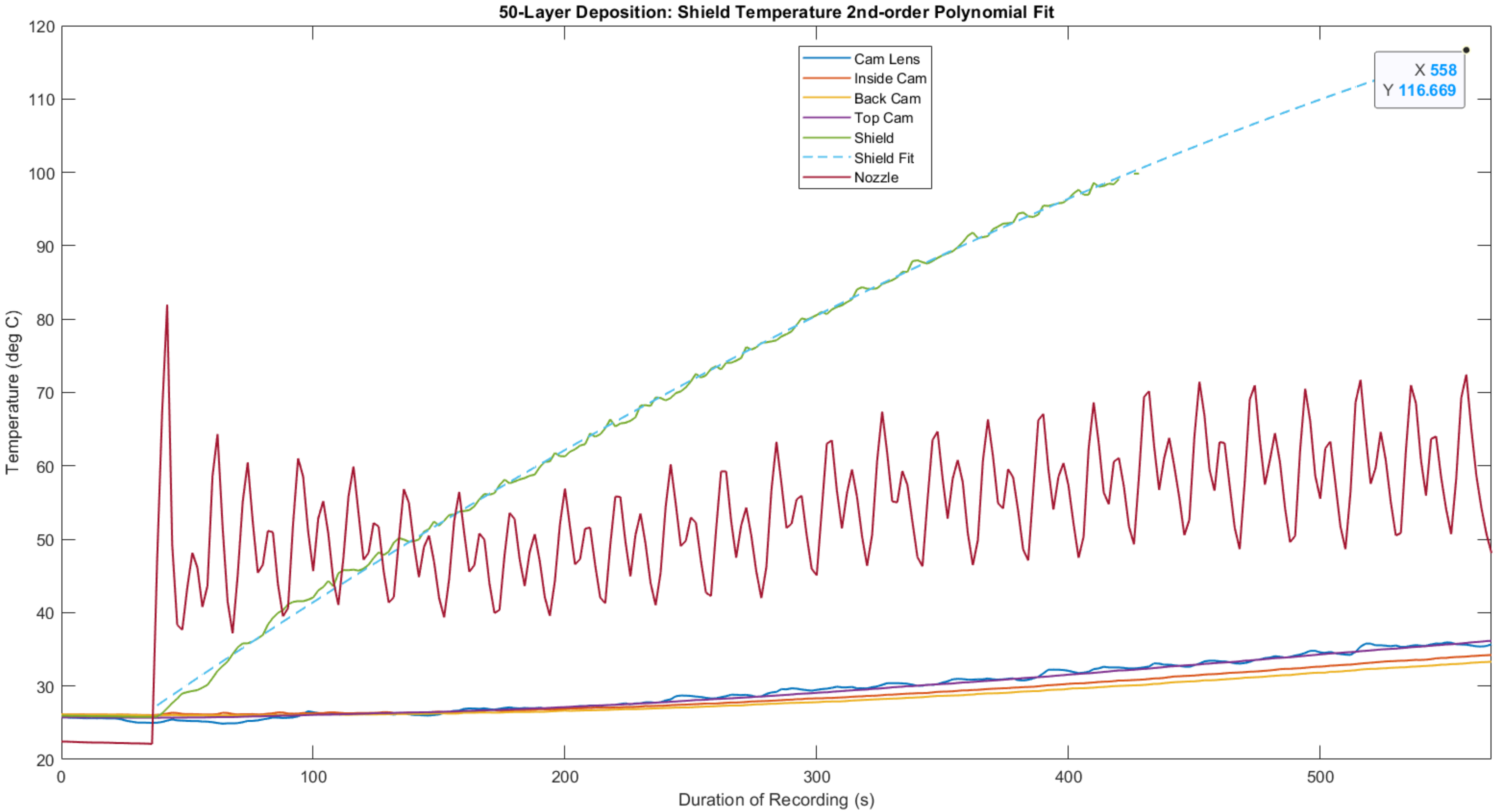
Figure 7: Welding glass specs

CTM Experiment: Data Analysis

Takeaways from experimental data and equipment specs:

- Use **curve fitting** to estimate shield and camera temperature after any number of layers
  - Allows us to estimate when the camera will fail, which we’ll use to determine thermal management solution
  - Among all camera thermocouples, use **camera lens data** for curve fitting since it reads highest temperatures and absorbs most heat

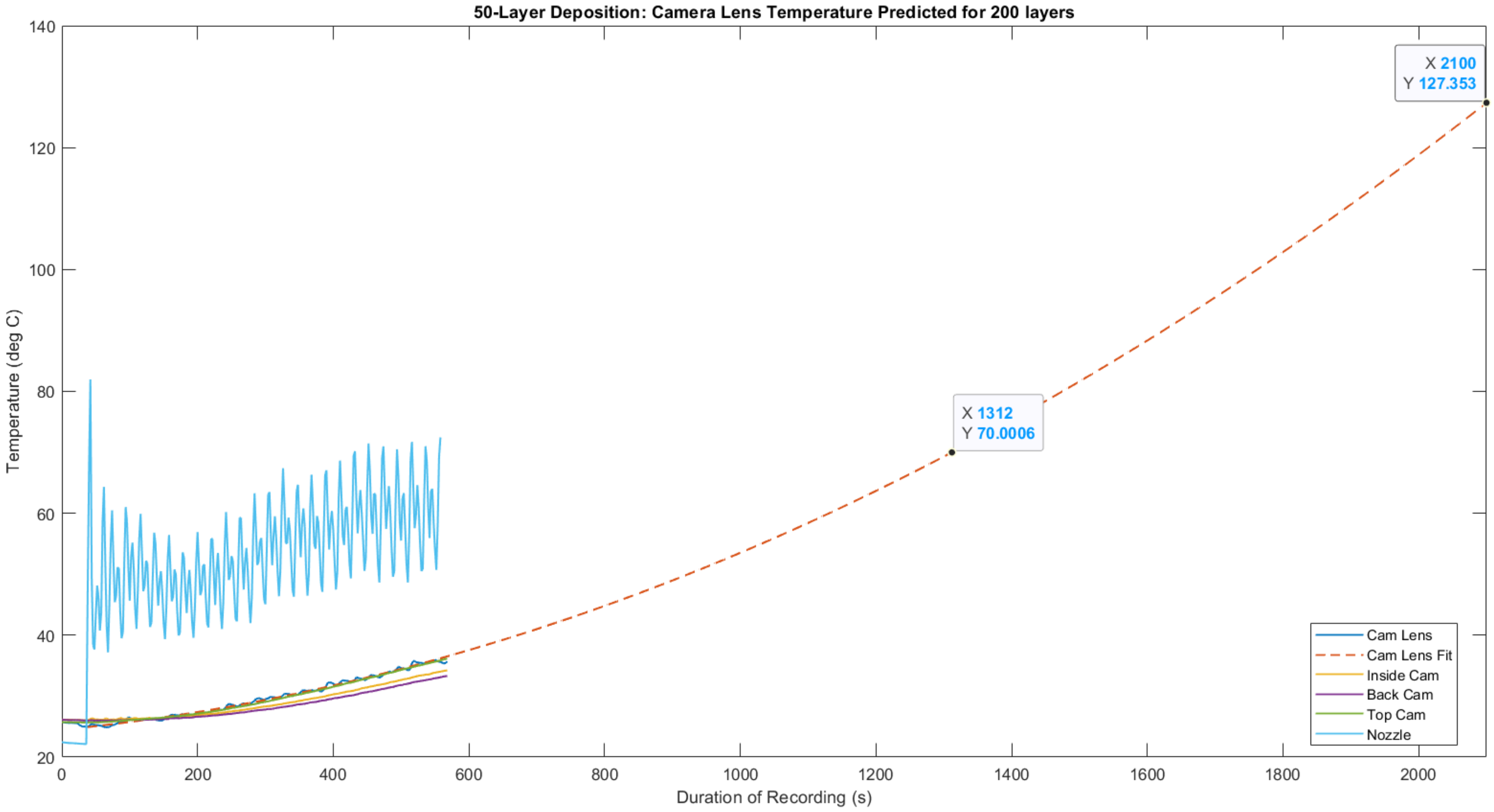
CTM Experiment: Data Analysis



CTM Experiment: Data Analysis

Maximum working temperature for camera: 70 deg C

- Camera lens predicted to reach 70 deg after $\sim 1310\ s - 40\ s\ (start\ delay) = 1270\ s$
  - $(1270\ s) * \frac{10\ layers}{102\ s} = \sim 125\ layers$



CTM Experiment: Thermal Management

Investigate whether **heat sinks** will suffice by quantifying theoretical heat dissipation provided

- Geometry constraints: plates above camera constrain heat sink to 129 x 36 mm area
- Optimize heat dissipation performance by developing MS Excel sheet

Investigate if a **larger air gap** between camera and shield provides sufficient insulation

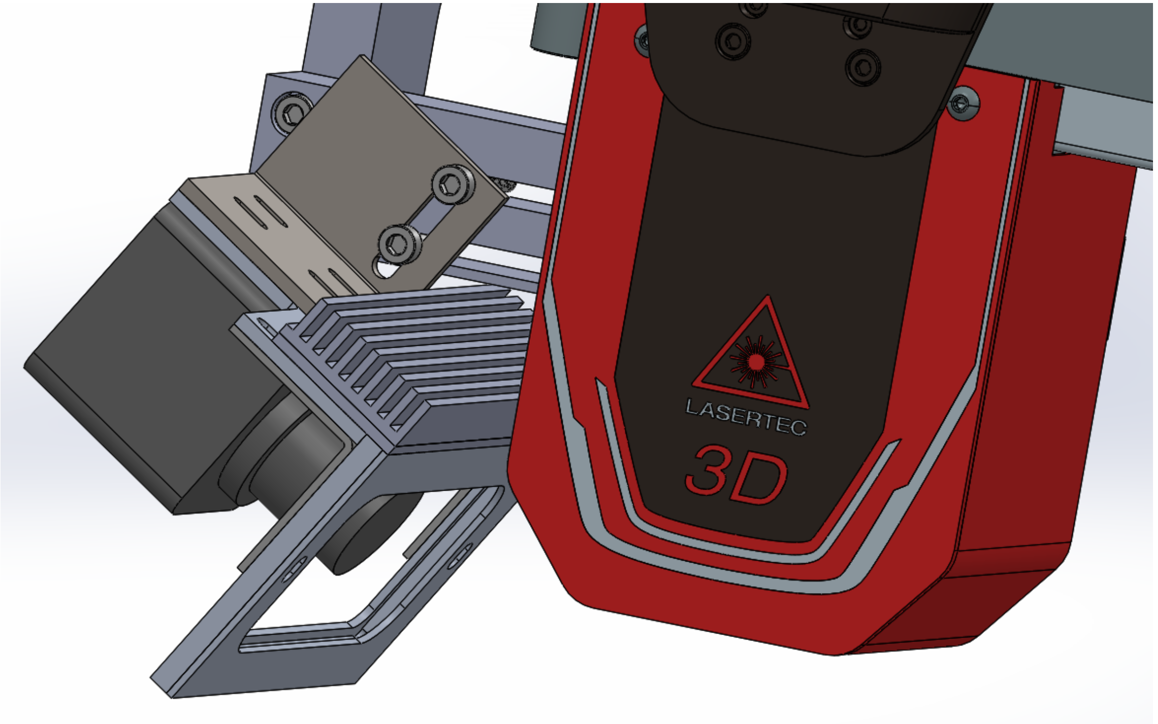


Figure 8: CAD draft of heat sink atop CCD camera shield

Substrate Manufacturing

Use ESDC vertical bandsaw to cut 4”x4”x1” substrates from steel stock

- **12-15 mins** per cut
- **15** substrates produced

Cutting parameters

- Blade speed: 85 ft/min, material feed: 70 lbs

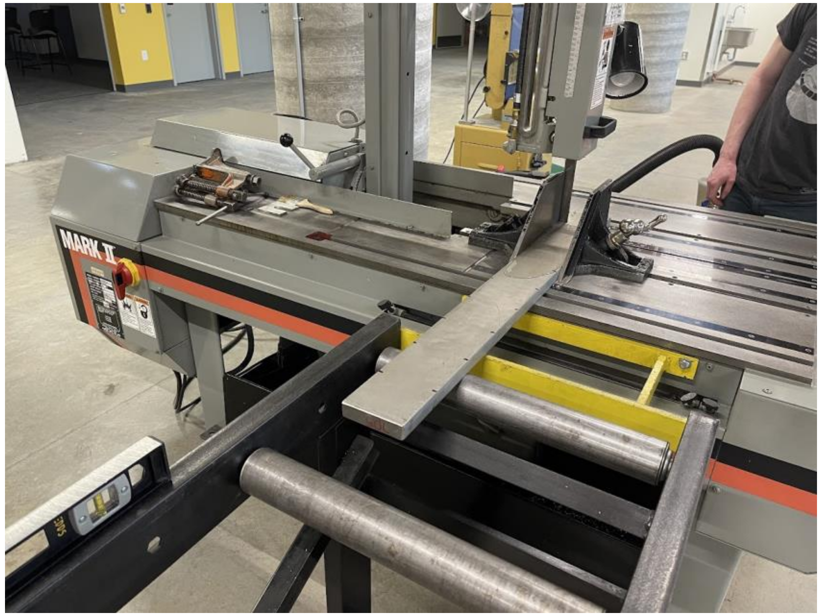


Figure 9: Wide view of stock in bandsaw

Figure 10: Cutting process with coolant

Securing Current CCD Camera Fixture

Problem:

- Screwing the fixture into the laser head causes fixture to **tilt**, making the camera position inaccurate each time it's installed
- Issue is due to laser head not being flush with fixture (see Figure 11)

Possible solutions:

- L-shaped metal piece
    - Fixes fixture in a new plane, preventing rotation
- Thin metal spacer
    - Fills the space in between the laser head and fixture, making them flush

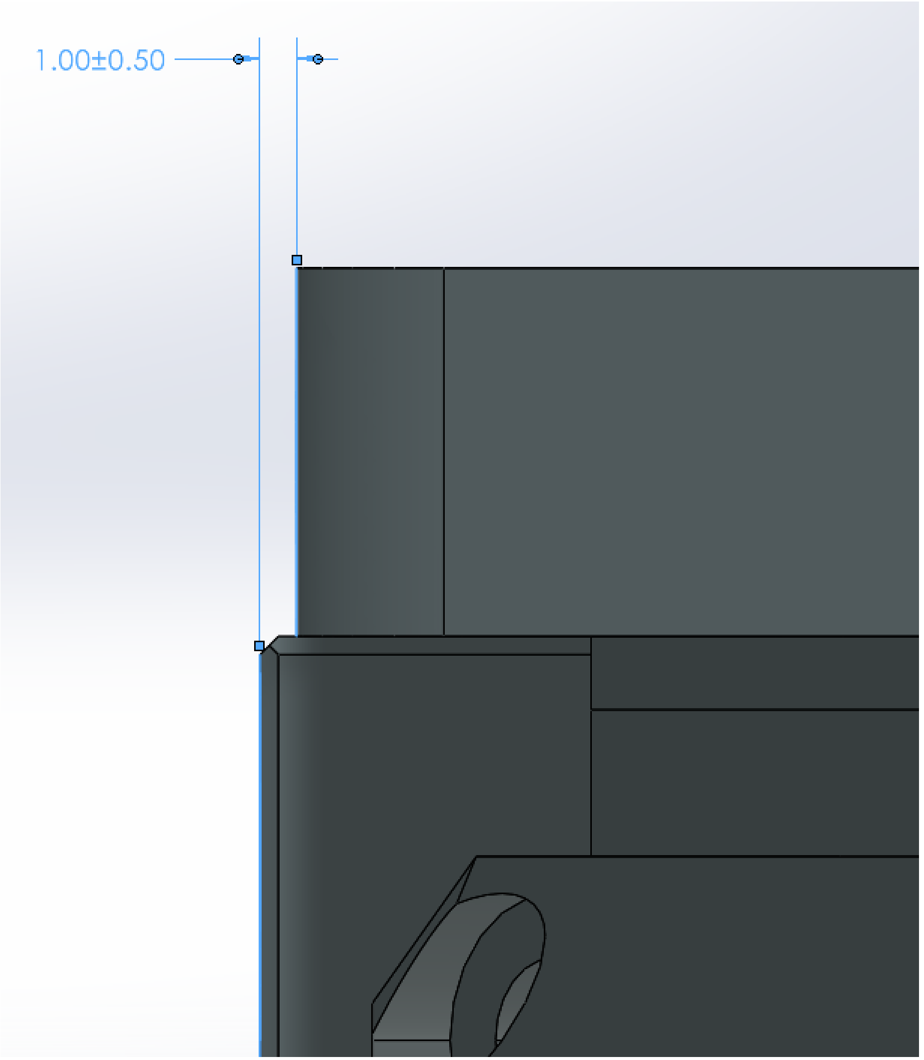


Figure 11: 1mm discrepancy on laser head mating face

Current CCD Camera Fixture: Spacer

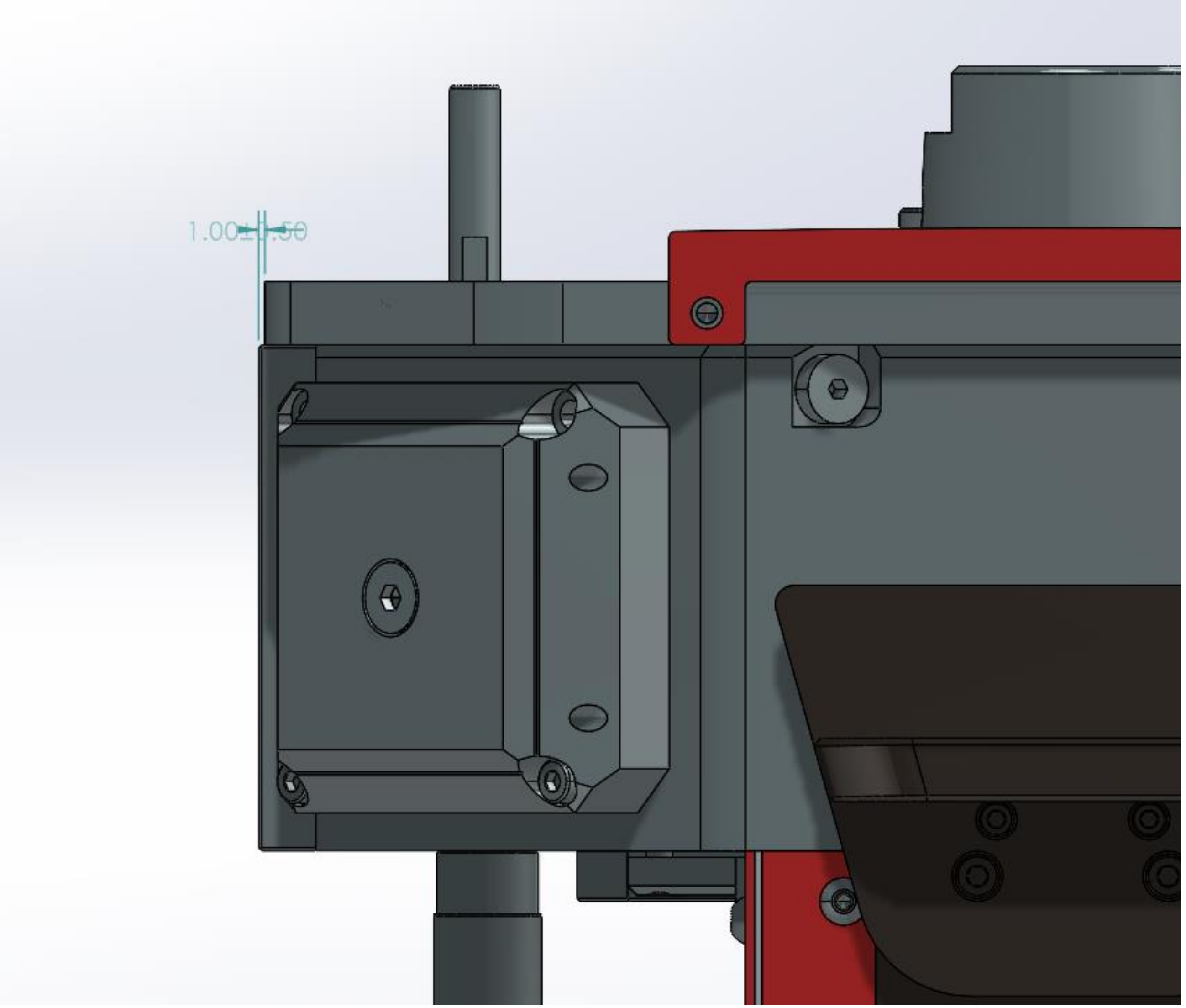


Figure 12: 1mm discrepancy on laser head mating face (zoomed out)

Current CCD Camera Fixture: Spacer

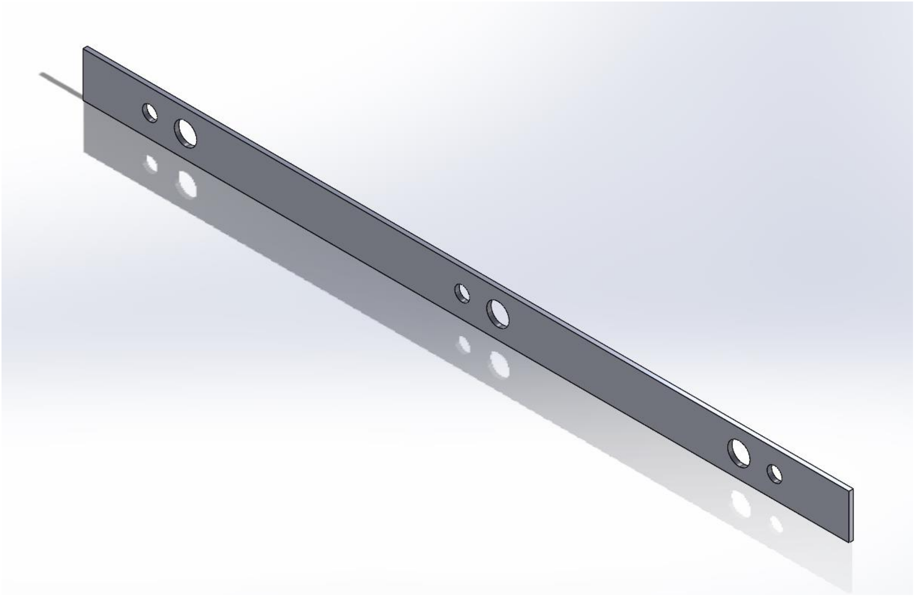


Figure 13: CAD draft of spacer

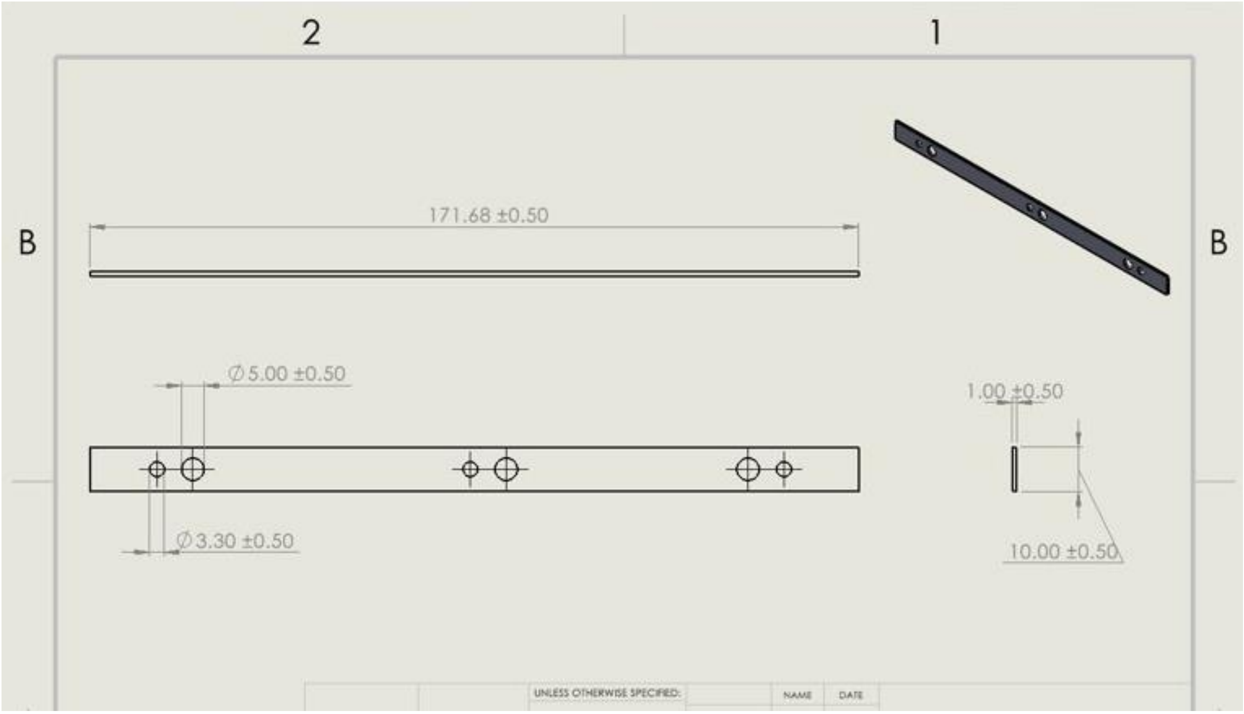


Figure 14: CAD draft of spacer

Current CCD Camera Fixture: Spacer

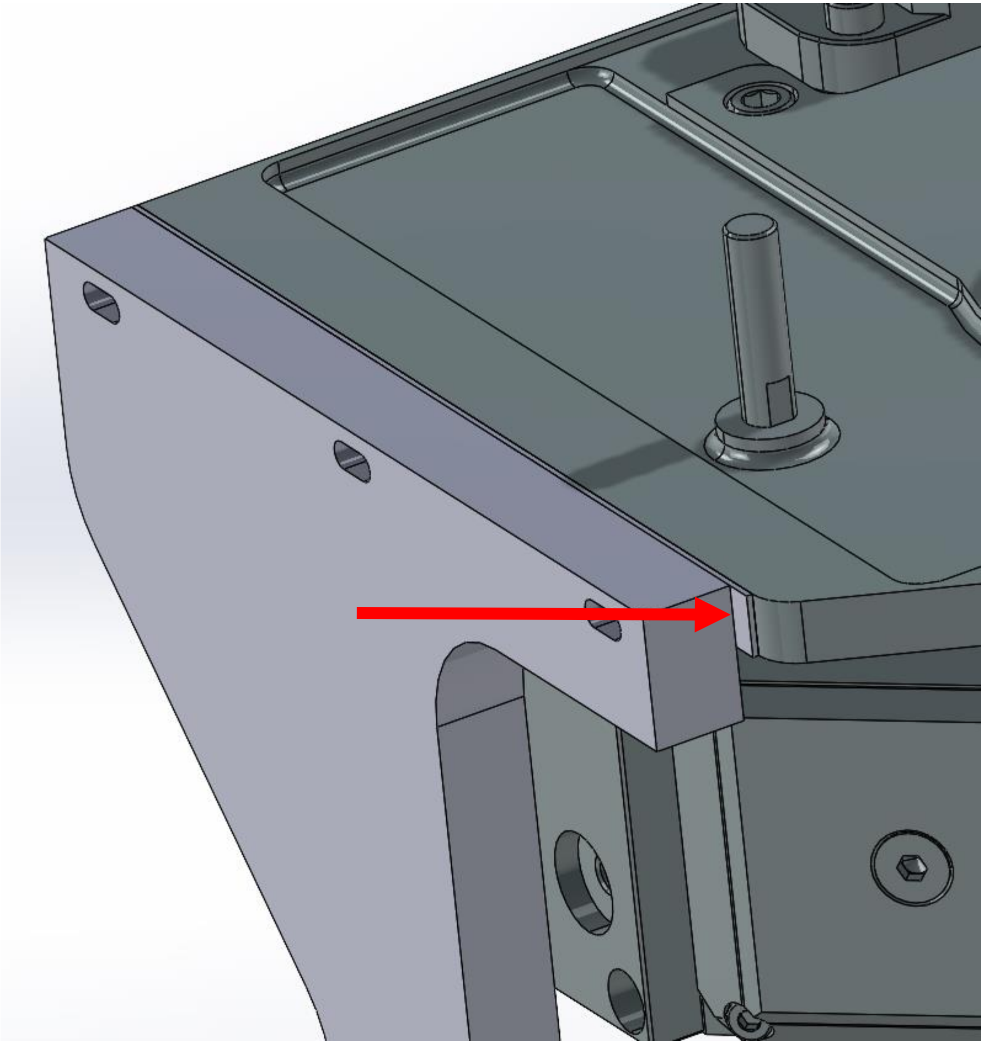


Figure 15: Isometric view of spacer in fixture assembly

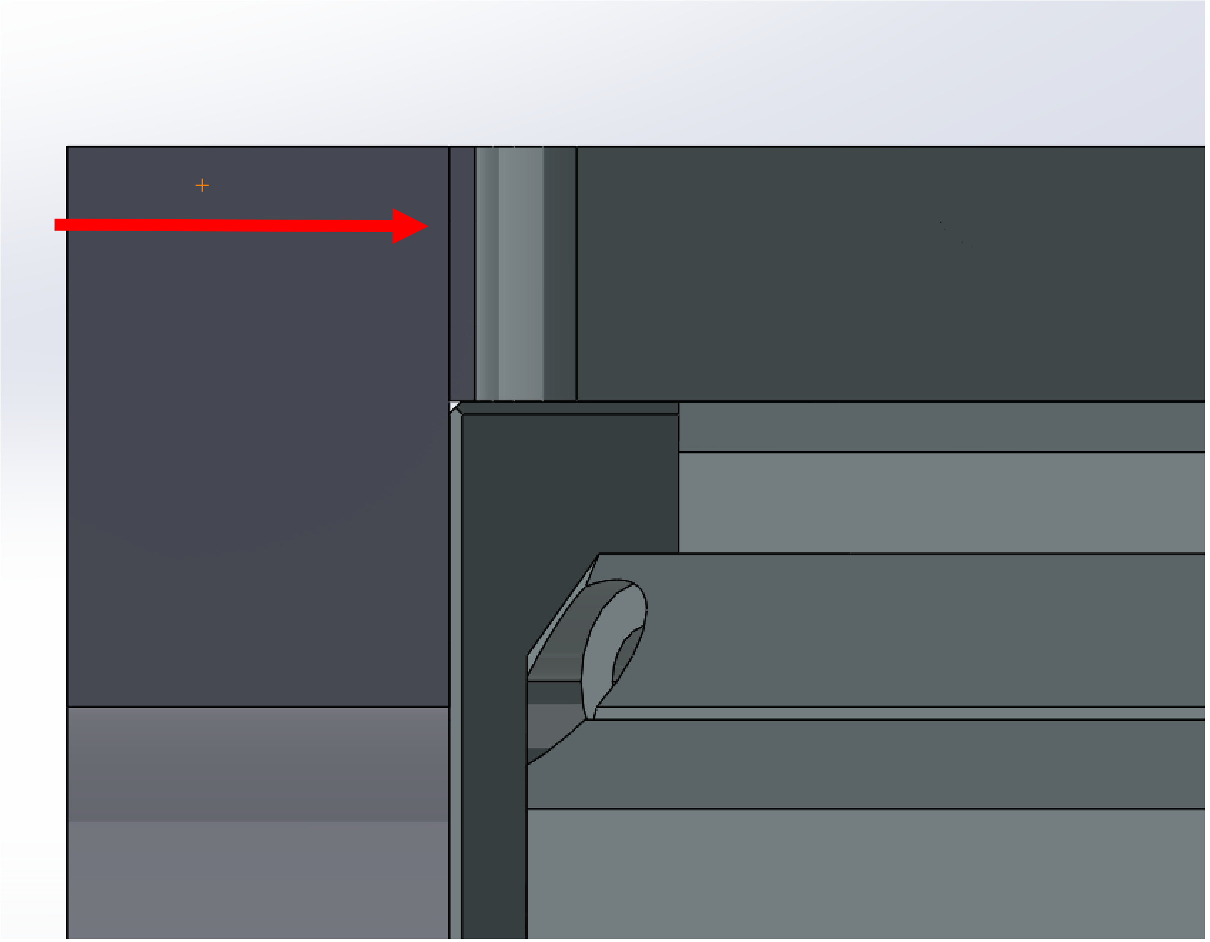


Figure 16: Front view of spacer in fixture assembly

Current CCD Camera Fixture: Angle Bracket

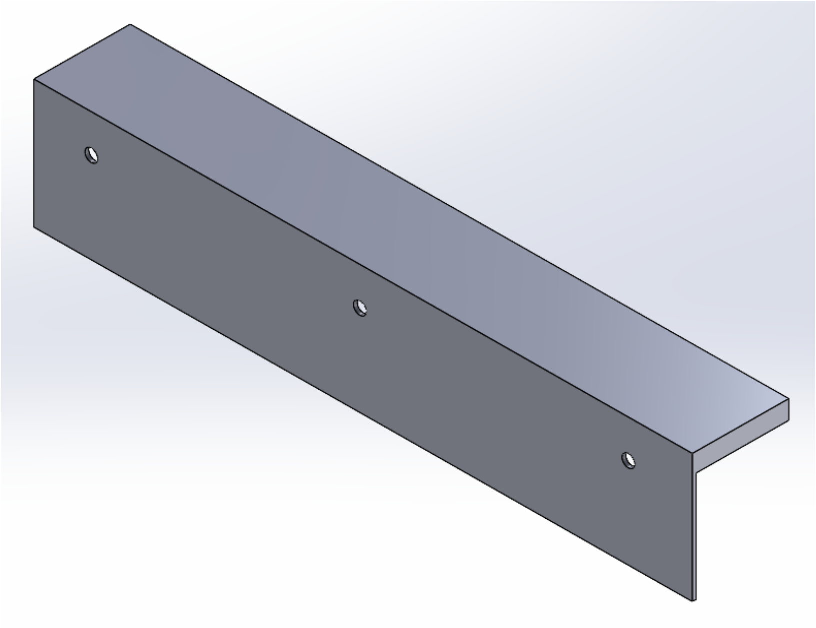


Figure 17: CAD draft for angle bracket

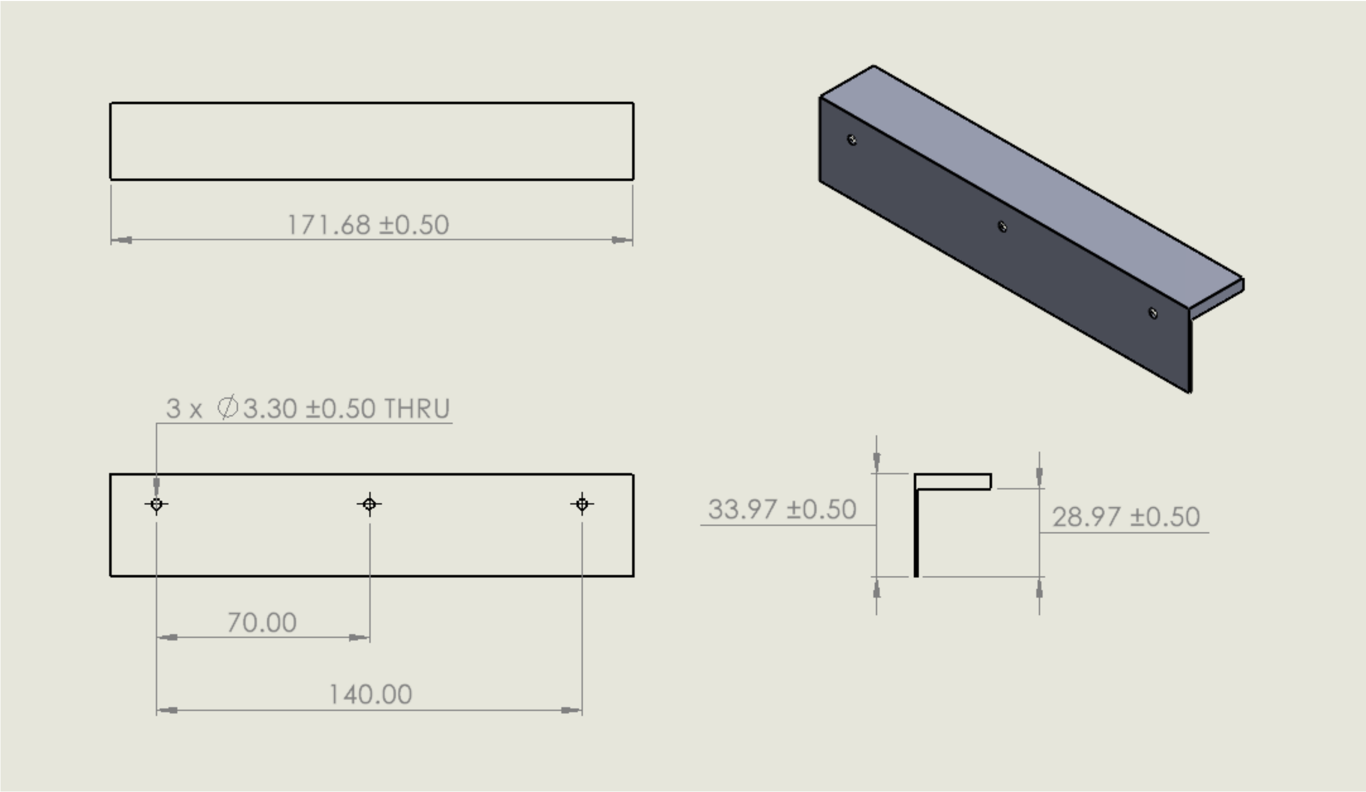


Figure 18: CAD drawing of angle bracket

Current CCD Camera Fixture: Angle Bracket

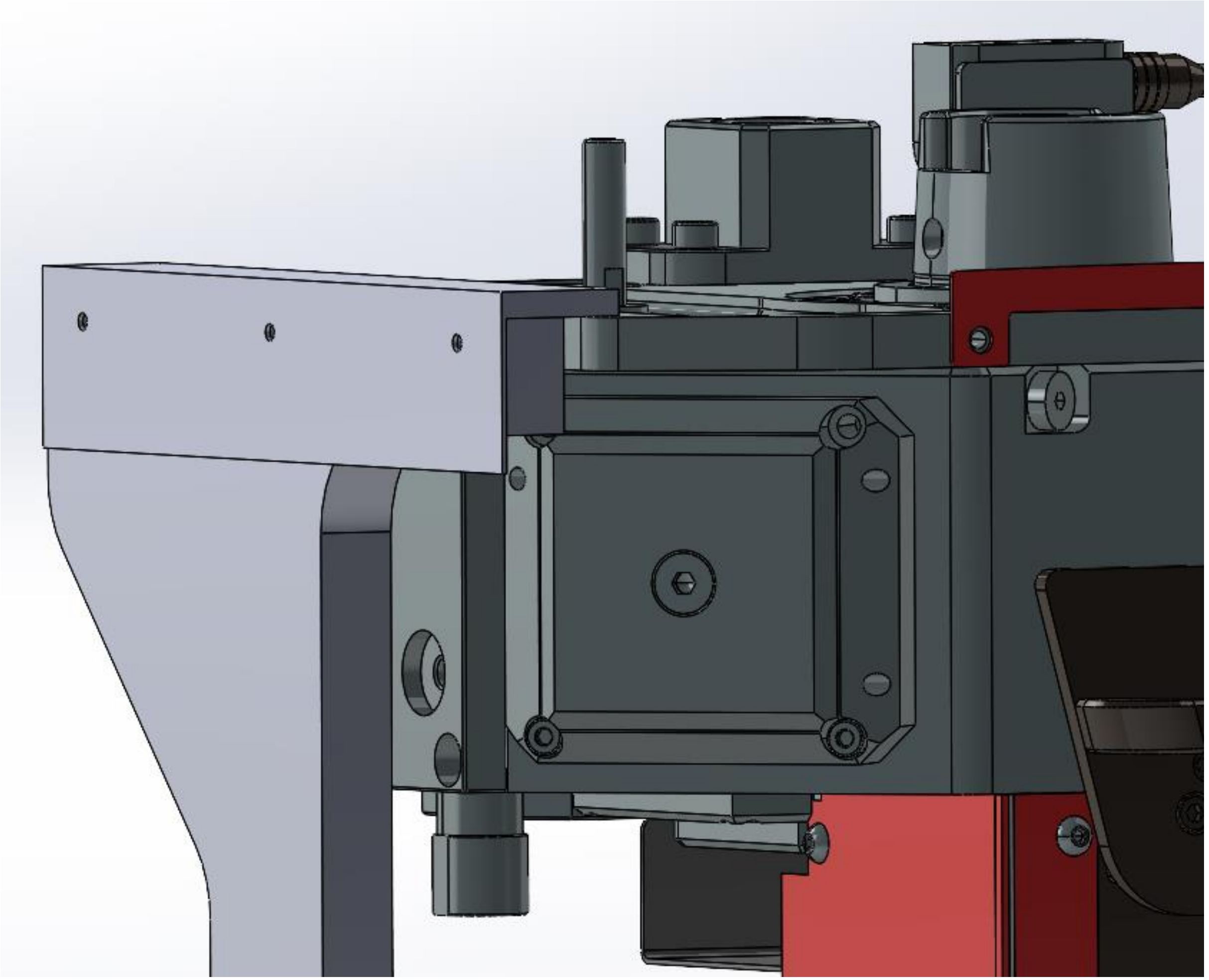


Figure 19: Isometric view of angle bracket in fixture assembly

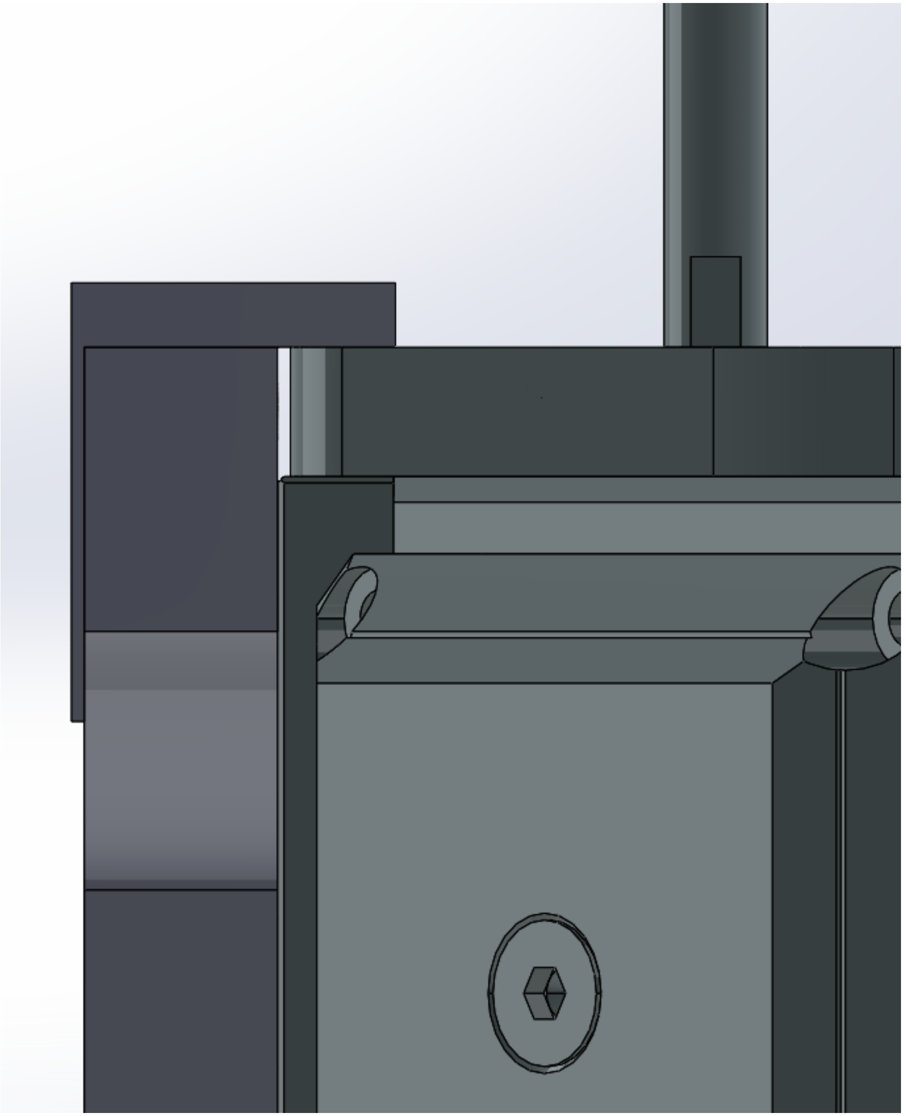


Figure 20: Front view of angle bracket in fixture assembly

New CCD Camera Fixture: Fixture Points

Problem:

- Clad needs to be viewed from another angle to provide more data

Solution:

- New fixture oriented perpendicular to existing camera using **six** fixture points

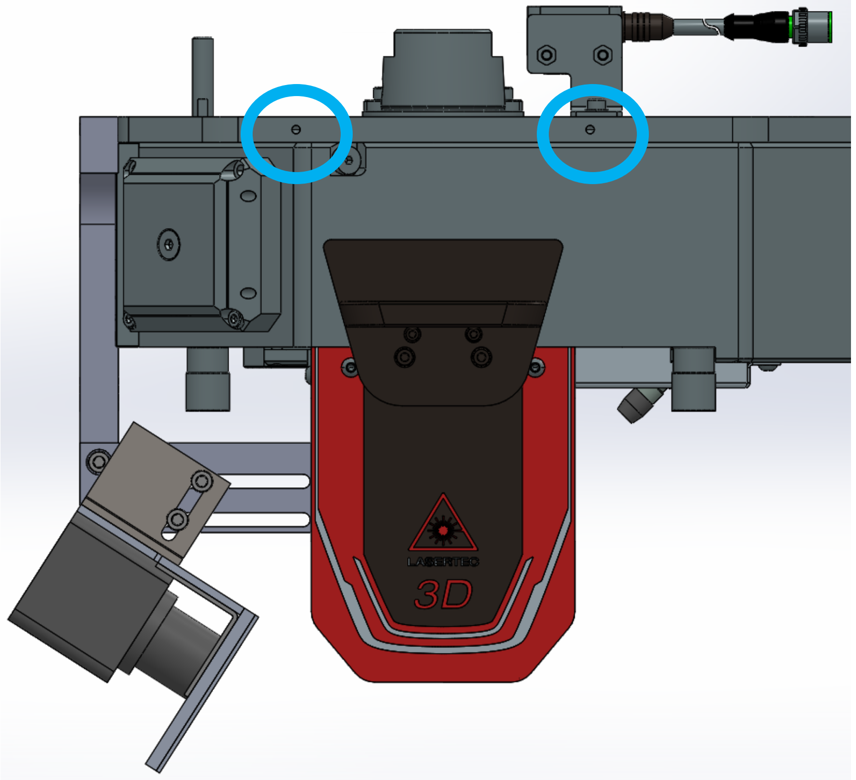


Figure 21: Front fixture points

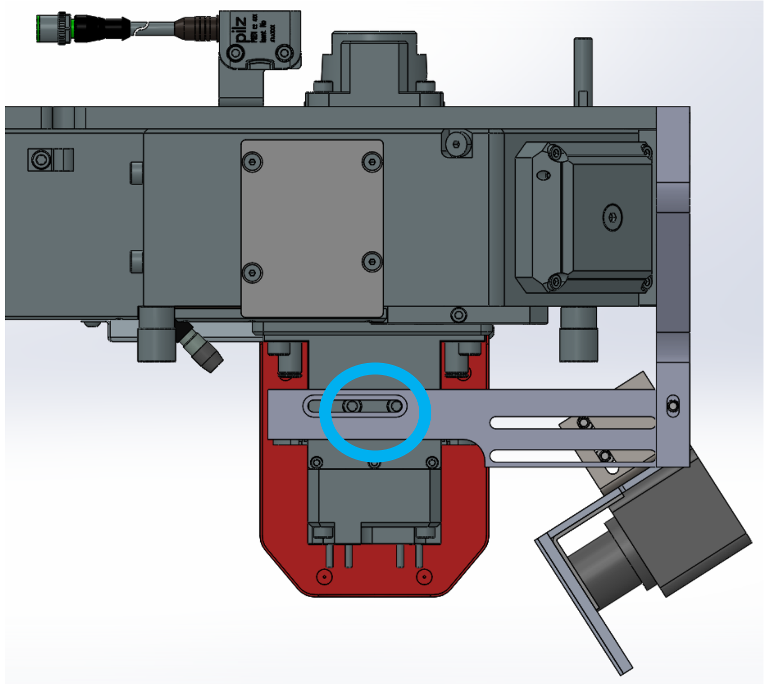


Figure 22: Rear fixture points

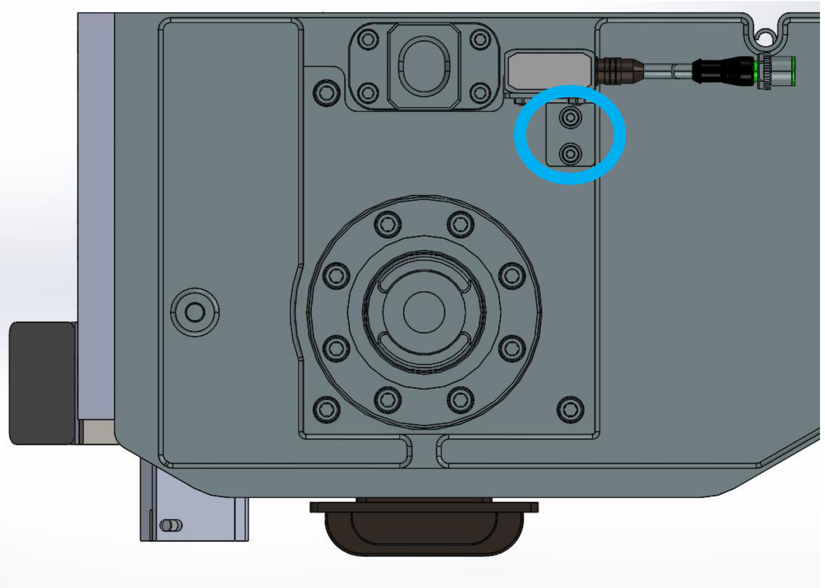


Figure 23: Top fixture points

New CCD Camera Fixture: Draft Assembly

Solution:

- New fixture oriented perpendicular to existing camera

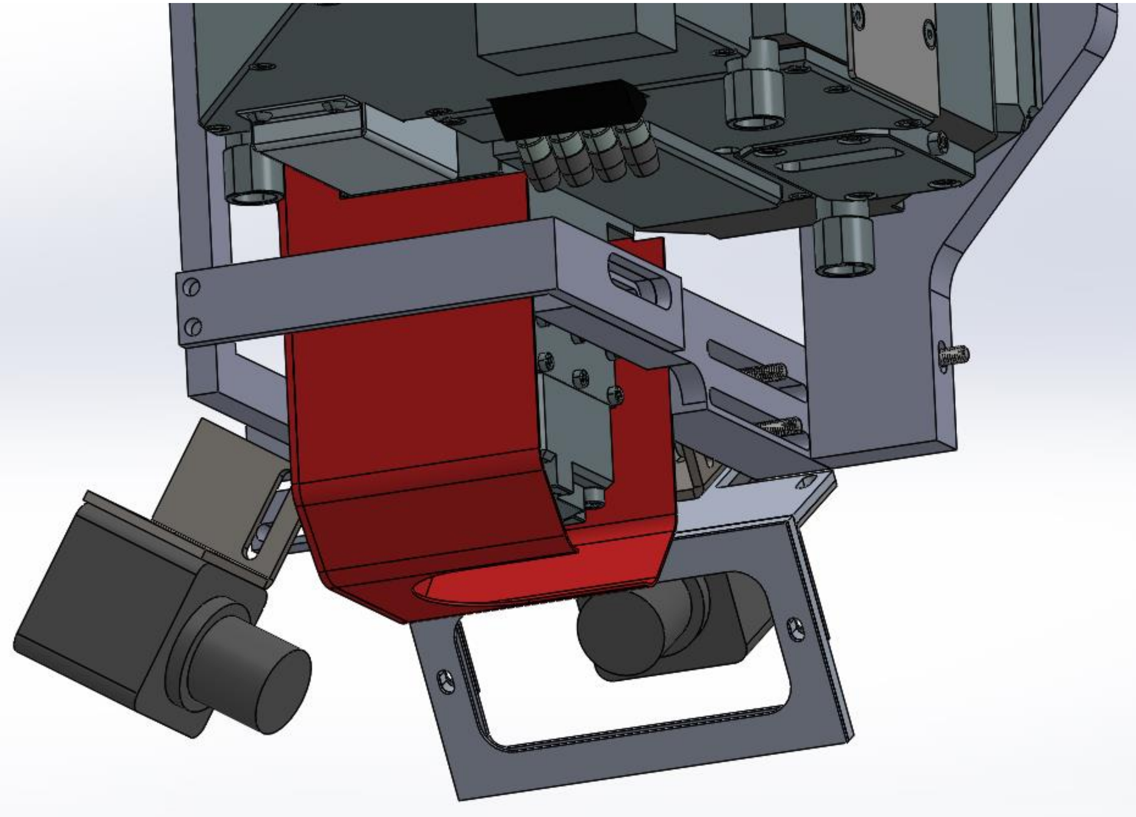


Figure 24: Rear view of CAD draft with new CCD camera

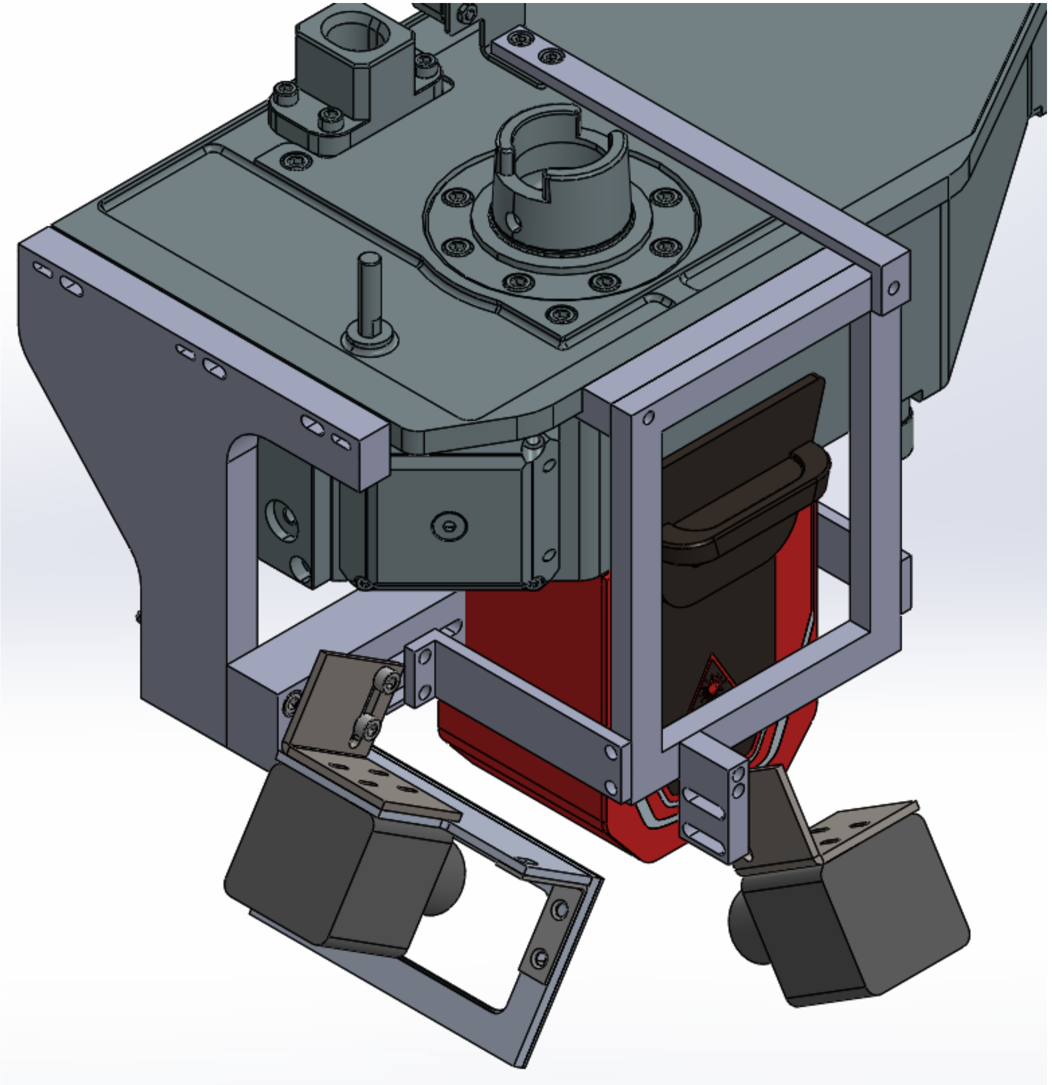


Figure 25: Isometric view of CAD draft with new CCD camera

Future Work

Experiment

- Finish analysis of results
  - Research properties of welding glass and temperature tolerances of camera
- Continue designing thermal management solution
- Manufacture/order and implement solution
- Perform CFD and/or FEA analysis on working solution
- Write report on finished solution

Continue developing current CCD camera fixture addition and new CCD camera fixture

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