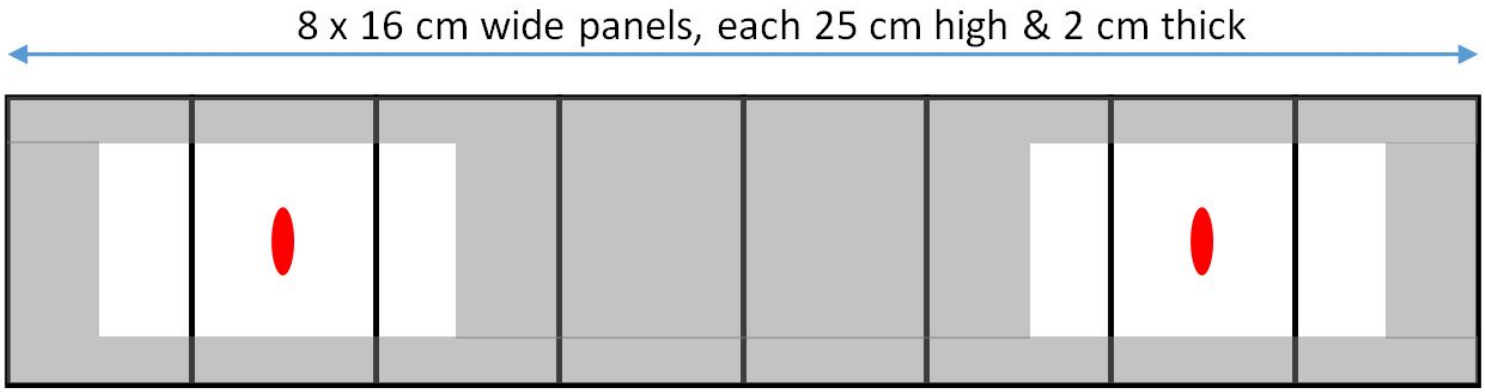
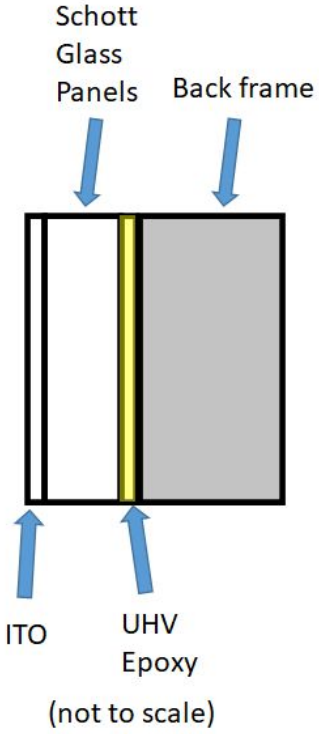
ACME Alternative Field Plate Assembly “Plan”

Basic Idea





Laser beams

Available for stiffening (white indicates required clear aperture)

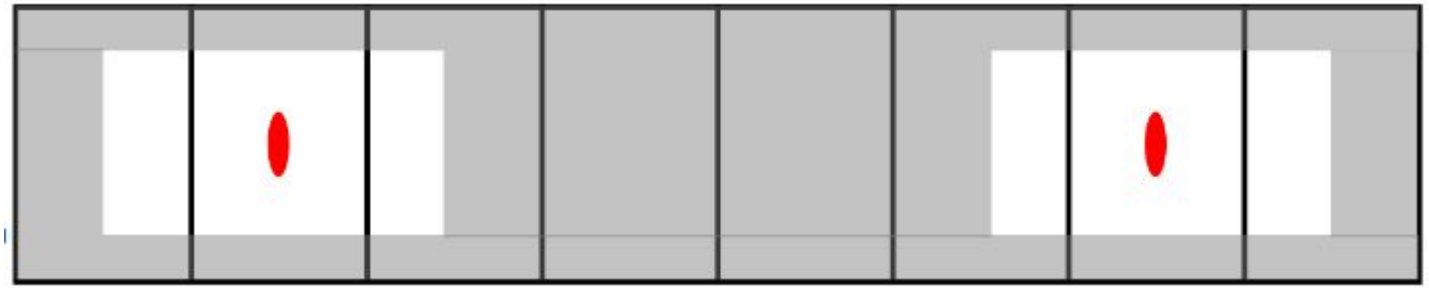
Total thickness? (including stiffeners) as large as 7.5 cm (5 cm preferred)

Questions & Concerns

- UHV-compatible epoxy?
- Structural integrity/strength
- Epoxy to fill gaps from chamfers at boundaries between panels
- Thermal expansion mismatches between panels, panels & frame, epoxy & panels/frame

Questions & Concerns

- Availability of materials?
- How to assemble for max flatness on electrode surface?
- Questions we have:
  - How large an opening for fluorescence collection optics?
  - How thick can frame be?



- UHV-compatible epoxy?
  - Masterbond LIGO-approved epoxy, maybe others too
  - https://www.google.com/url?q=https://dcc.ligo.org/LIGO-E1000386/public&sa=D&ust=1590438337694000&usg=AFQjCNHkVLPb2wrPTXrLD9YKkfTrEpyc5w

LIGO Document E1000386-v1

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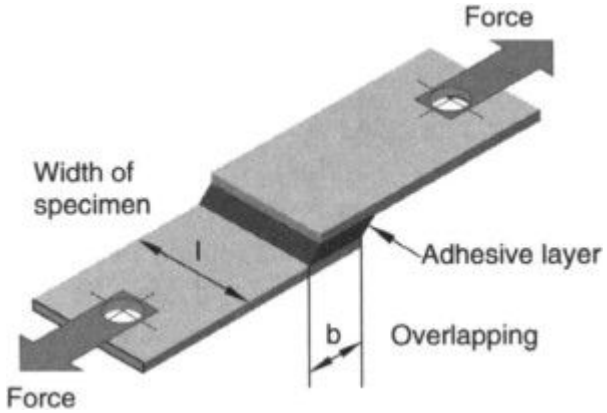
Material Qualification RGA Test Results: MasterBond EP30-2 epoxy

Species	AMU	Outgassing Rate (Torr-L/s/cm^2)
Sum HC		5.0E-13

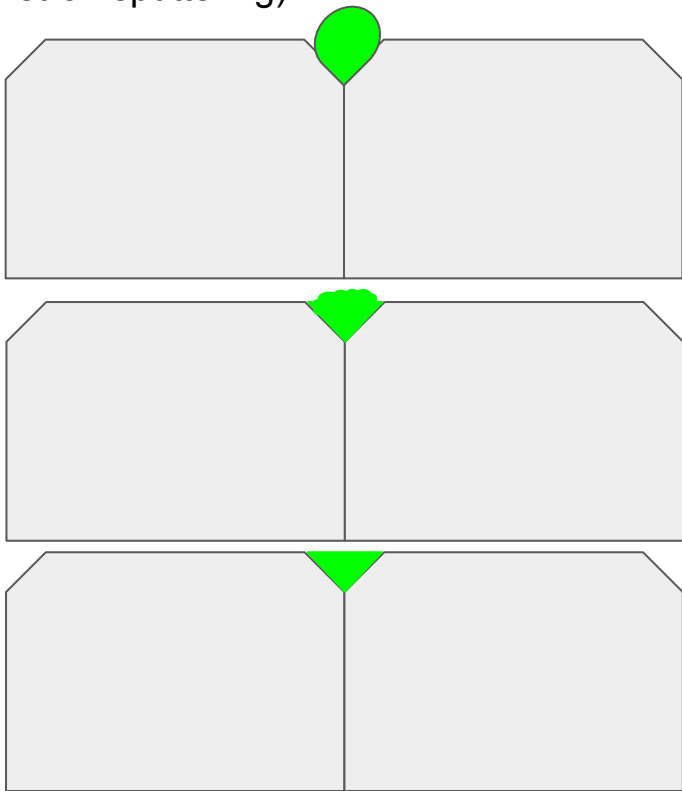
- Structural integrity/strength
  - Rely on thick backing frame and strong epoxy bond over large area
  - From epoxy strength calculation, for a 16cm x 25cm x 2cm panel, minimal glue area is ~0.01%
  - More confirmation needed from testing to be done at Yale

Tensile lap shear strength, aluminum to aluminum, 75°F	3,000-3,200 psi
Tensile strength, 75°F	10,000-11,000 psi
Compressive strength, 75°F	14,000-15,000 psi



- Epoxy to fill gaps from chamfers at boundaries between panels
  - How flat is possible?
  - How to get continuous ITO coating?
    - Low-temp ITO coating techniques for plastics
    - One paper found for epoxy (Low temperature RF magnetron sputtering)
      - More details in the next slide

Plan: Overfill the chamfer and use razor blade to cut extra materials. The blade will need to be softer than our glass (i.e. lower in Mohs hardness scale) to decrease possibility of scratching. Additional polishing may be needed

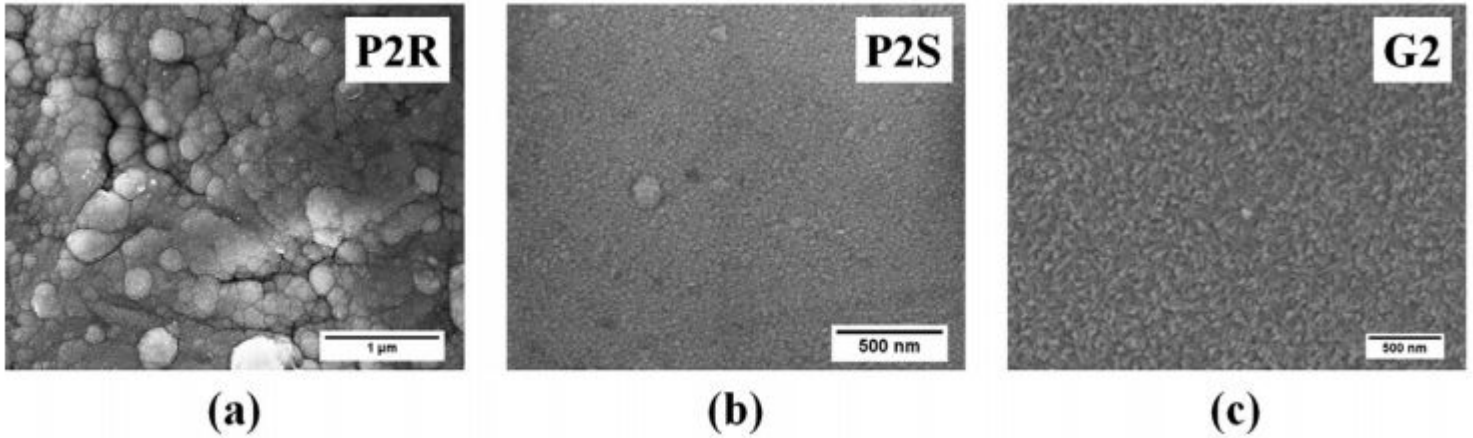


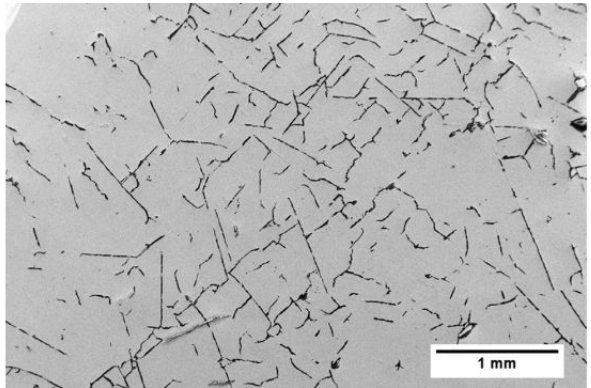
Low temperature sputtered ITO on glass and epoxy resin substrates (https://www.sciencedirect.com/science/article/pii/S2468023019302470)

Summary:

- Success ITO deposition. Smoother surface gave lower surface resistance.
- Deposition temperature should be lower than Tg of epoxy (~100 C)
- Despite good conductivity, ITO film deposited on smooth surface contains microcracks.
    - Possibly due to factors including “thermal expansion, stability under the deposition conditions and Tg”

SEM micrographs of rough/smooth substrate





- Thermal expansion mismatches between panels, panels & frame, epoxy & panels/frame
  - At least two panels of SF57HTULTRA “good” glass (for laser transmission)
  - Could make other panels of ordinary SF57. Exact thermal match to “good” glass (just lower purity)
  - Frame: maybe possible with SF57 (checking on size availability)
  - OR: soda-lime float glass:

SF57HTULTRA, SF57:

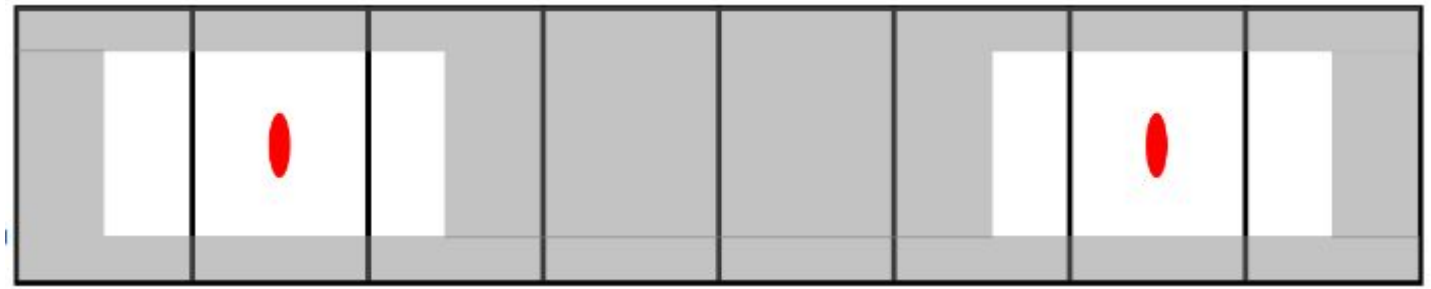
Soda lime float glass at 0/300C:

$\alpha_{-30/+70°C}$ [10^{-6}/K]	8.3
$\alpha_{+20/+300°C}$ [10^{-6}/K]	9.2

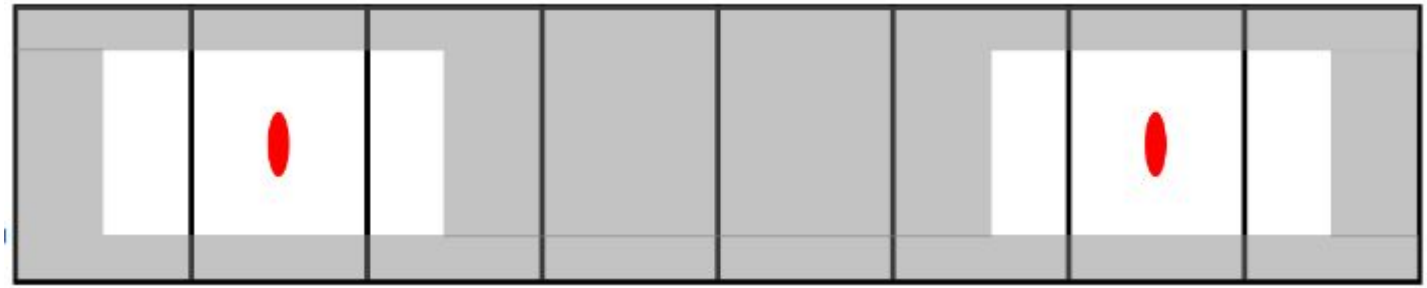
Epoxy at 23 C

ITO at ~60 C (on PET):

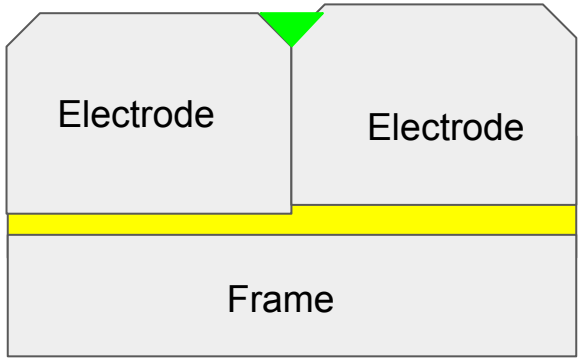
$40\text{-}45 \times 10^{-6}$ in/in/°C

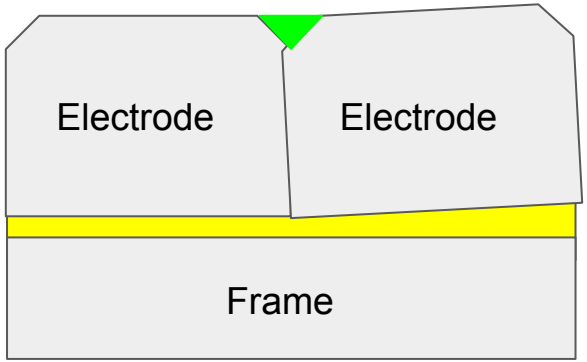


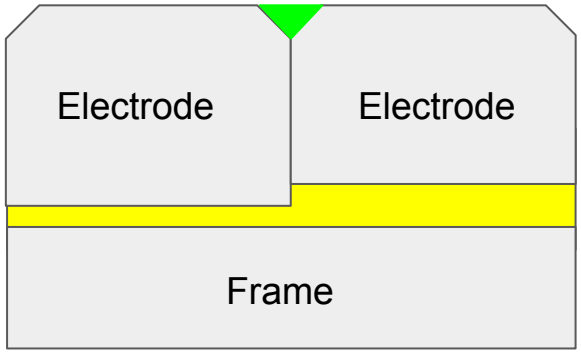
- Availability of materials?
  - SF57HTULTRA available in panel size
  - SF57 available in panel size, maybe also in frame size
  - Soda-lime glass available in frame size



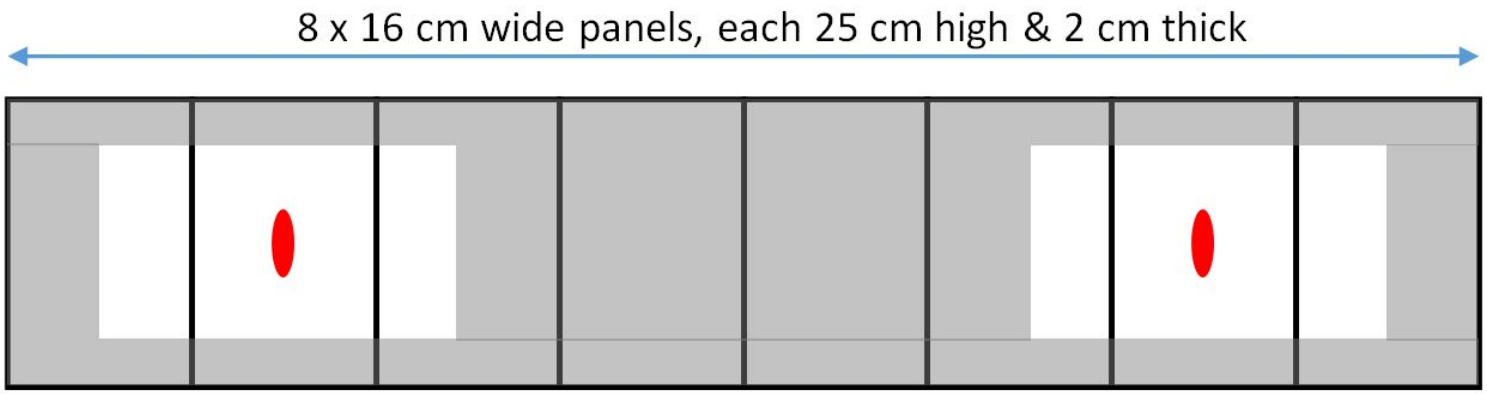
- How to assemble for max flatness on electrode surface?
  - Method on Next slides

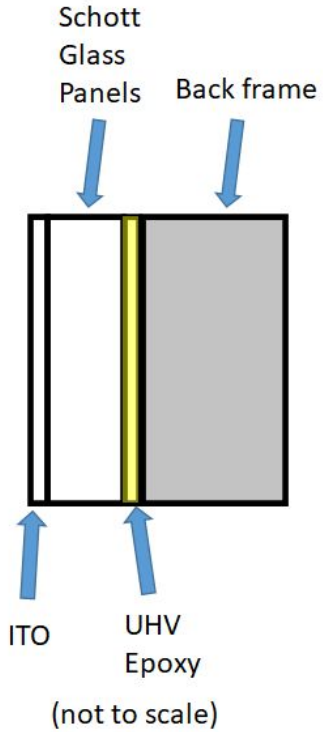






- Questions we have:
  - How large an opening for fluorescence collection optics?
  - How thick can frame be?





Laser beams

Available for stiffening (white indicates required clear aperture)

Total thickness? (including stiffeners) as large as 7.5 cm (5 cm preferred)

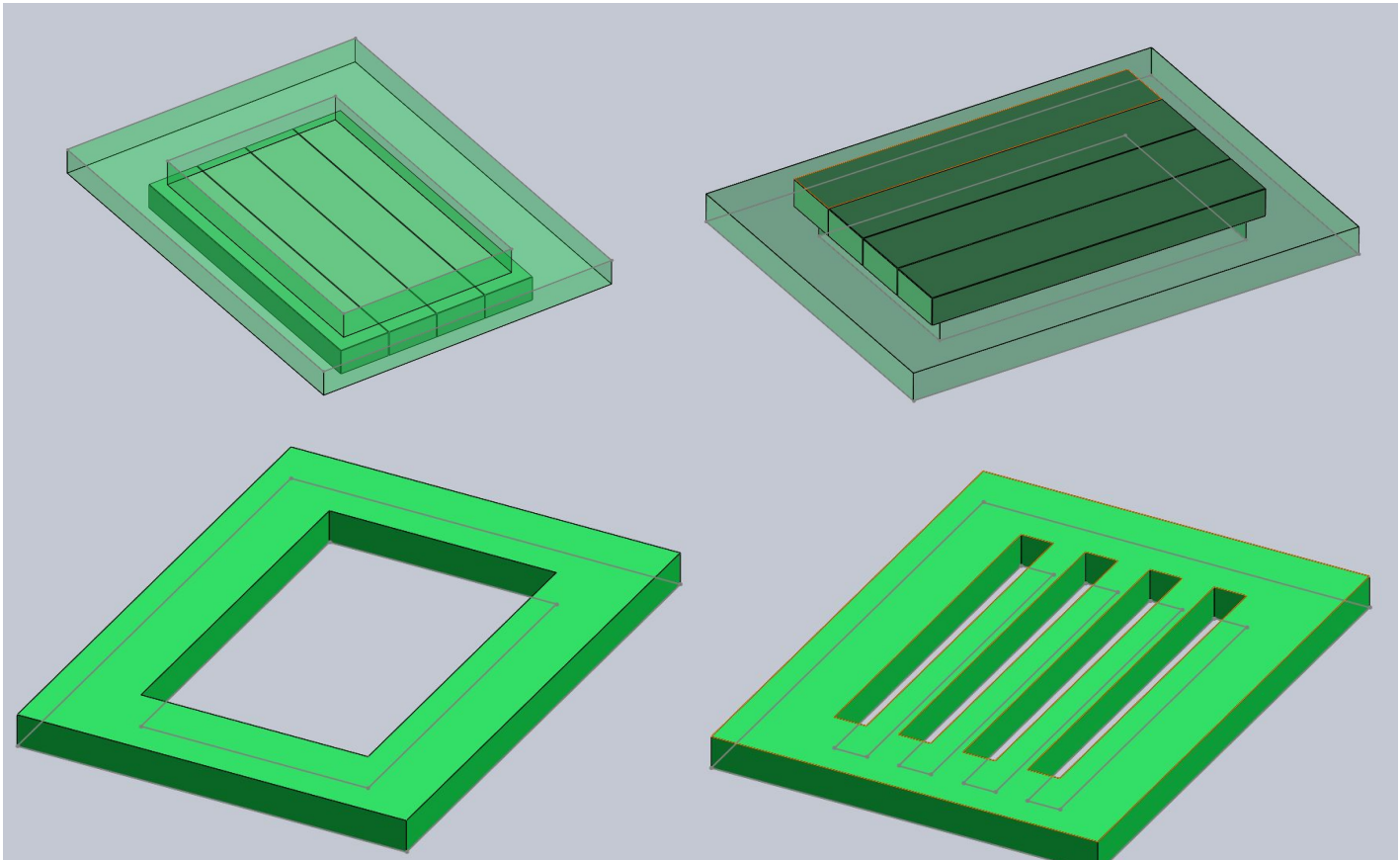
Quick Recap of Questions & Concerns

- UHV-compatible epoxy?
  - Masterbond LIGO-approved epoxy, maybe others too
- Structural integrity/strength
  - Epoxy strength seems promising
  - More tests to be done
- Epoxy to fill gaps from chamfers at boundaries between panels
  - ITO deposition on epoxy is possible
  - Cut extra epoxy material with razor blade and (possibly) perform polishing
- Thermal expansion mismatches between panels, panels & frame, epoxy & panels/frame
  - At least two panels of SF57HTULTRA “good” glass (for laser transmission)
  - Could make other panels of ordinary SF57. Exact thermal match to “good” glass (just lower purity)
  - Soda-lime float glass also good thermal match

Quick Recap of Questions & Concerns

- Availability of materials?
  - SF57HTULTRA available in panel size
  - SF57 available in panel size, maybe also in frame size
  - Soda-lime glass available in frame size
- How to assemble for max flatness on electrode surface?
  - Lay down the electrode side first and then glue the rest onto the electrode pieces
- Questions we have:
  - How large an opening for fluorescence collection optics?
  - How thick can frame be?

Small-scale prototypes & tests



Step 1: Find really flat surface (granite, ~1 micron flat)

- http://precisiongraniteusa.com/
- 12”x18” at 1 micron flatness
- 24”x48” at 4 micron flatness (1 micron possible with customized plate)

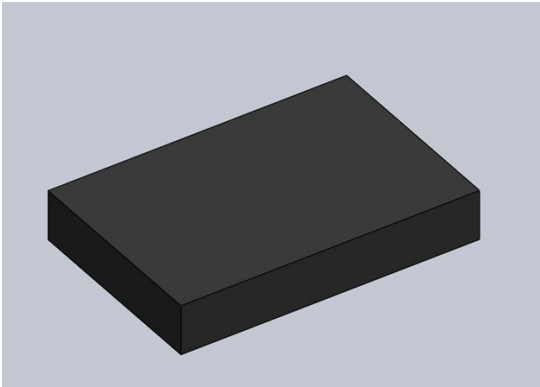
0-LEDGE

2-LEDGE

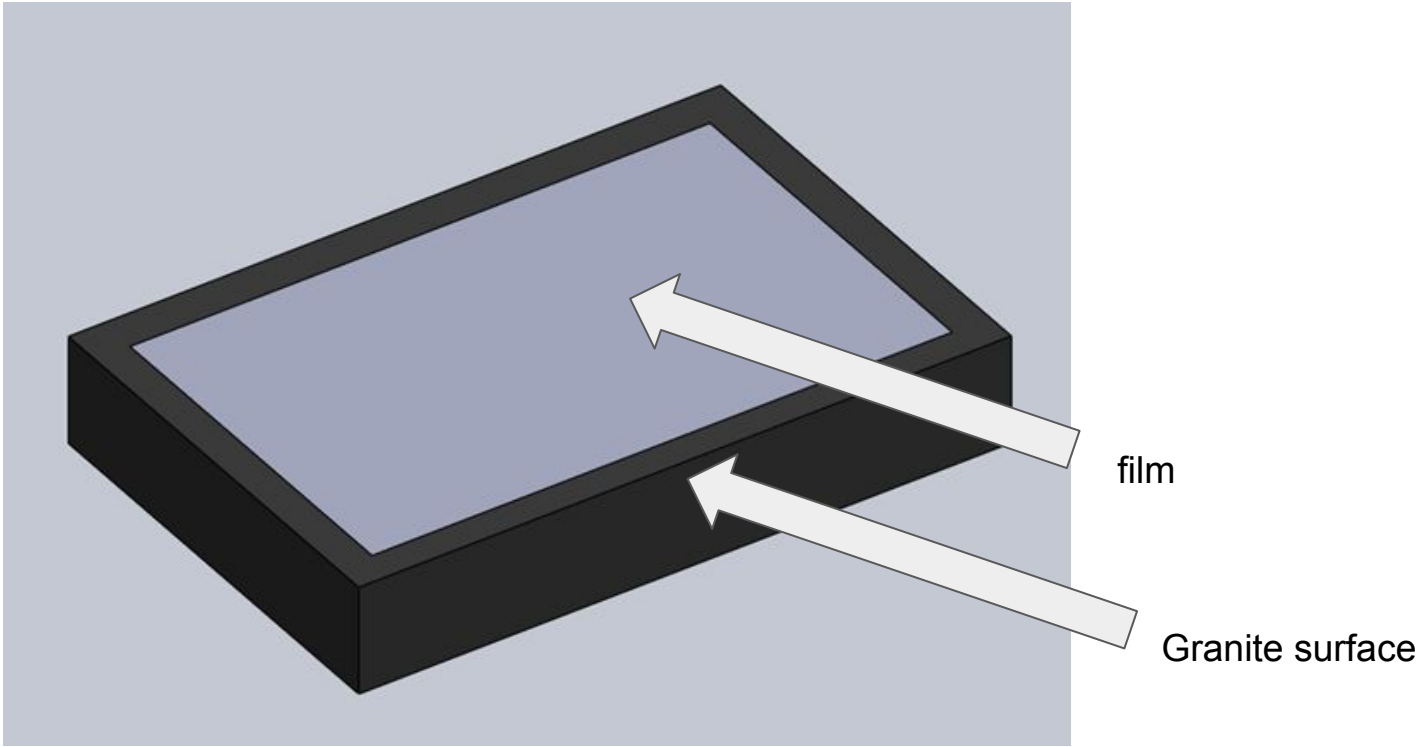
4-LEDGE

SURFACE PLATES AA GRADE (LABORATORY)

SIZE INCHES W x L x T	0-LEDGE $	0-LEDGE Item#	2-LEDGE $	2-LEDGE Item#	4-LEDGE $	4-LEDGE Item#	OVERALL ACCURACY	REPEAT READING	SHIP WT LB
8 x 12 x 2	132.00	8x12x2-AA0	N/A		N/A		.000050"	.000035"	28
9 x 12 x 3	155.00	9x12x3-AA0	N/A		N/A		.000050"	.000035"	40
12 x 12 x 3	177.00	12x12x3-AA0	N/A		N/A		.000050"	.000035"	54
12 x 18 x 3	219.00	12x18x3-AA0	256.00	12x18x3-AA2	292.00	12x18x3-AA4	.000050"	.000035"	81
18 x 18 x 4	376.00	18x18x4-AA0	434.00	18x18x4-AA2	488.00	18x18x4-AA4	.000050"	.000035"	156
18 x 24 x 4	462.00	18x24x4-AA0	508.00	18x24x4-AA2	582.00	18x24x4-AA4	.000075"	.000035"	208
24 x 24 x 4	630.00	24x24x4-AA0	678.00	24x24x4-AA2	728.00	24x24x4-AA4	.000075"	.000045"	278
24 x 36 x 6	944.00	24x36x6-AA0	1,017.00	24x36x6-AA2	1,114.00	24x36x6-AA4	.0001"	.000045"	601
24 x 48 x 6	1,305.00	24x48x6-AA0	1,389.00	24x48x6-AA2	1,584.00	24x48x6-AA4	.000150"	.000045"	802
30 x 48 x 6	1,654.00	30x48x6-AA0	1,775.00	30x48x6-AA2	1,874.00	30x48x6-AA4	.000175"	.000045"	1,002
36 x 36 x 6	1,379.00	36x36x6-AA0	1,516.00	36x36x6-AA2	1,662.00	36x36x6-AA4	.000150"	.000045"	902
36 x 48 x 6	1,930.00	36x48x6-AA0	2,052.00	36x48x6-AA2	2,316.00	36x48x6-AA4	.0002"	.000045"	1,203



Step 2: A flat film to prevent scratching



Film candidates

- Flat at least up to 2.5 microns

Clear Moisture-Resistant Polyester Film

Widely used as packaging, this polyester film absorbs almost no moisture and resists swelling in wet environments. It is also known as PET and PETE.

Film

- Color: Clear
- Temperature Range: -50° to 300° F
- Tensile Strength: 8,960 psi (Good)
- Impact Strength: 0.7 ft.-lbs./in. (Poor)
- Hardness: Rockwell R125 (Hard)
- For Use Outdoors: No

Thick.	Thick. Tolerance	Wd.	10 ft. Lg.		25 ft. Lg.	
				Each		Each
0.0005"	-0.0001" to 0.0001"	27"	8567K102	$6.12	8567K104	$12.25

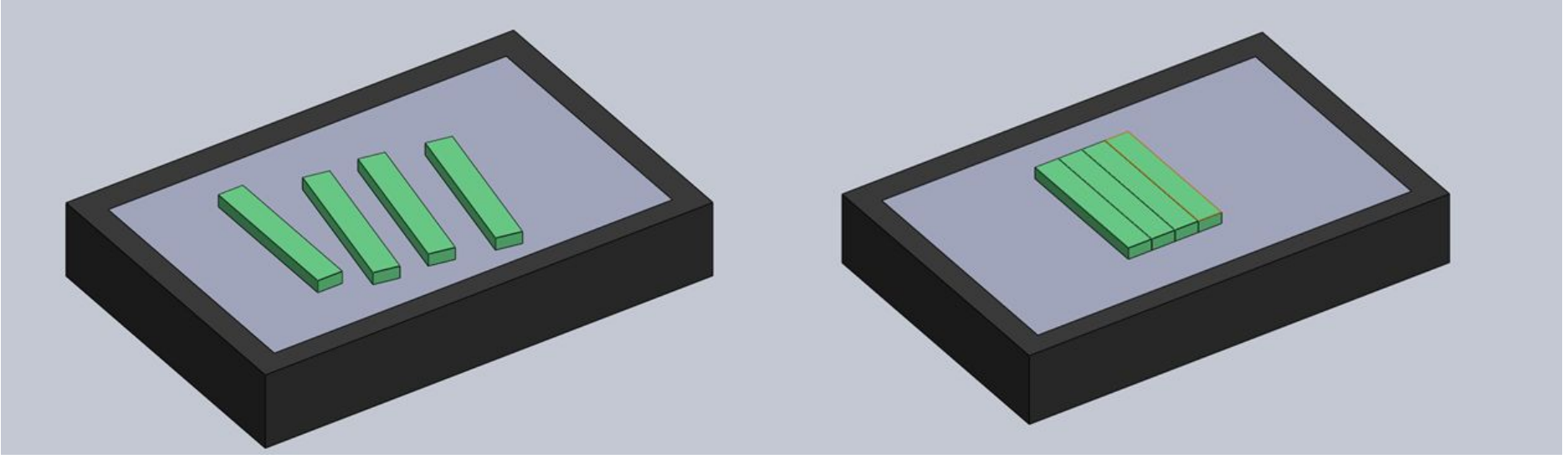
Low-Carbon Steel Sheets and Bars

Sheets

Thick.	Thick. Tolerance	Yield Strength, psi	Hardness	Specifications Met		Each
7" × 10ft.						
0.001"	-0.0001" to 0.0001"	44,000	Rockwell B90 (Medium)	ASTM A109	6544K831	30.24
0.004"	-0.0005" to 0.0005"	44,000	Rockwell B90 (Medium)	ASTM A109	6544K861	22.24
0.007"	-0.0008" to 0.0008"	44,000	Rockwell B90 (Medium)	ASTM A109	6544K891	30.12

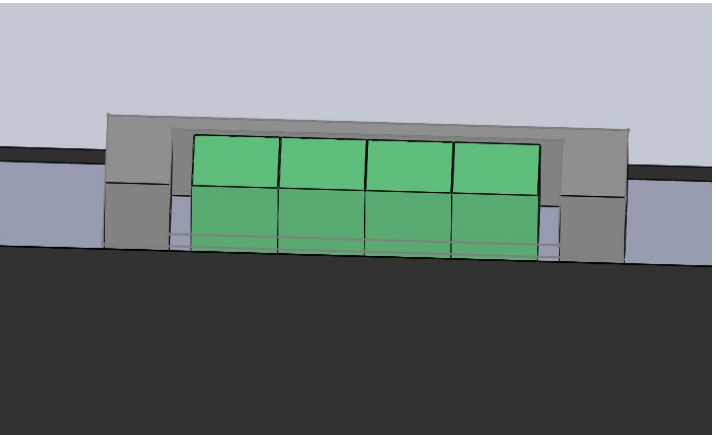
Step 3: Electrode side facing the flat surface & align

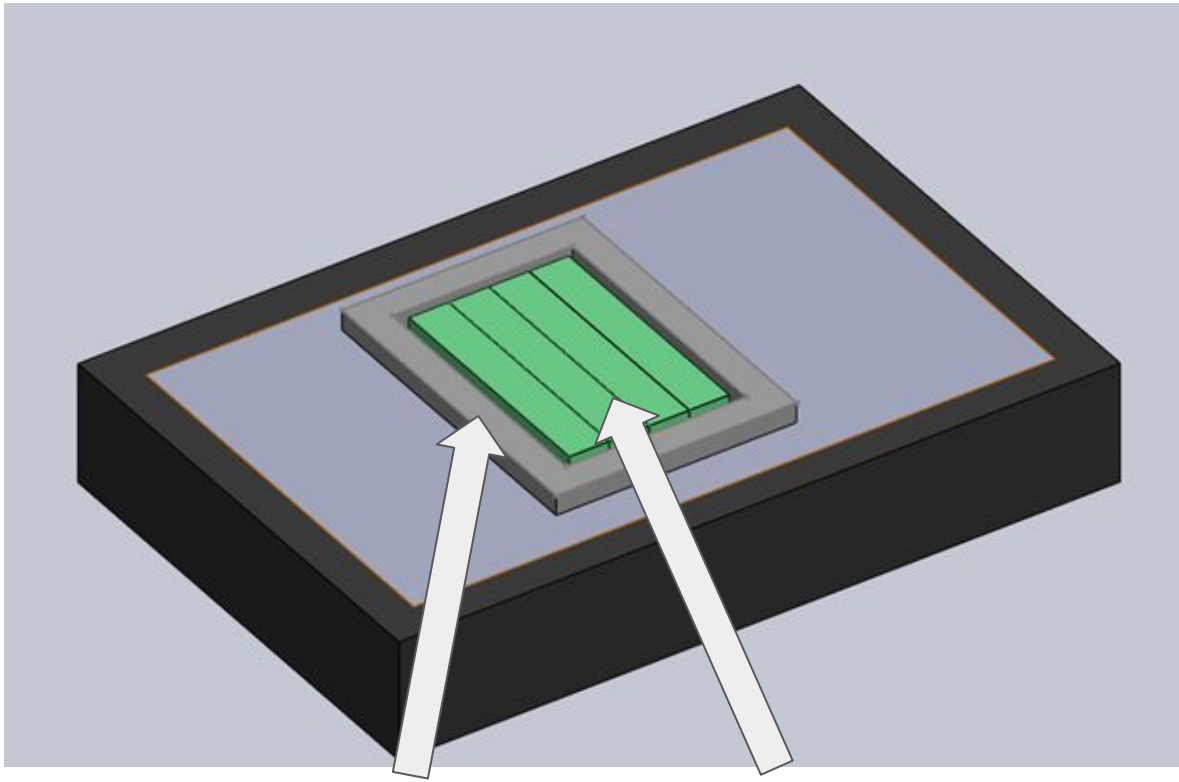
ITO deposition only after the full assembly



Step 4: Steel spacer frame for bond line thickness

- Apply epoxy
- ~100 microns thick
- Epoxy UHV compatible
- Work 4K to 149 C

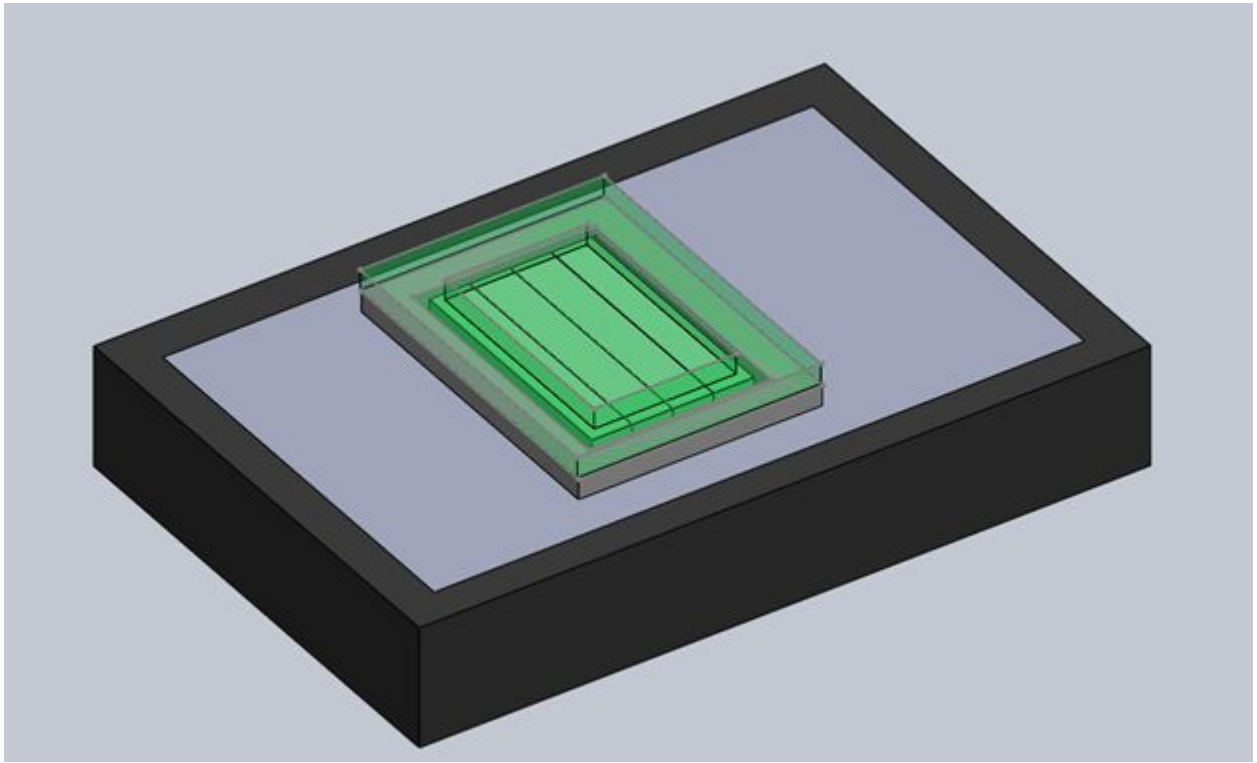




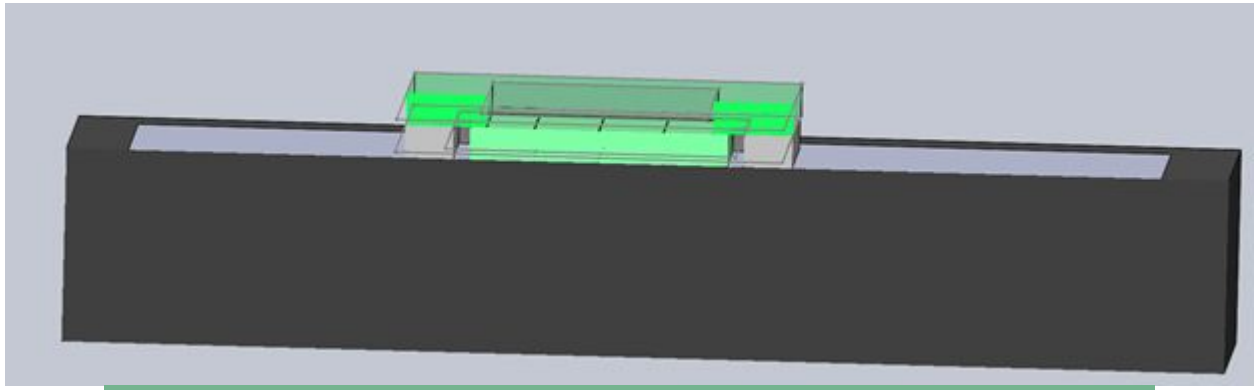
Steel Spacer Frame

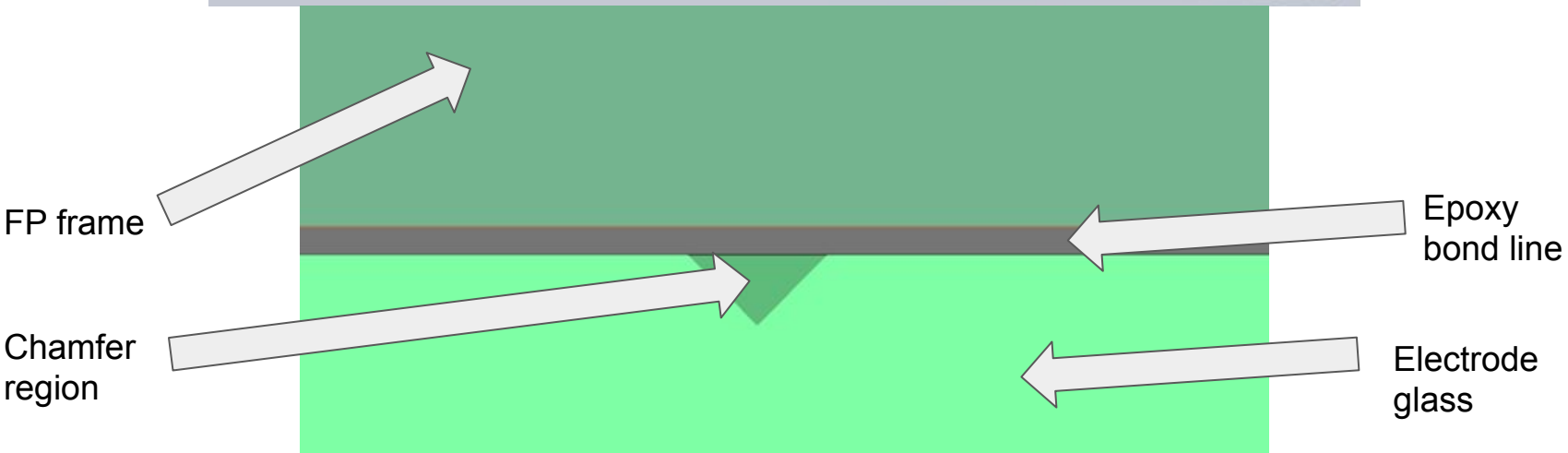
Electrodes (epoxy side)

Step 5: Lay the glass frame onto the electrodes

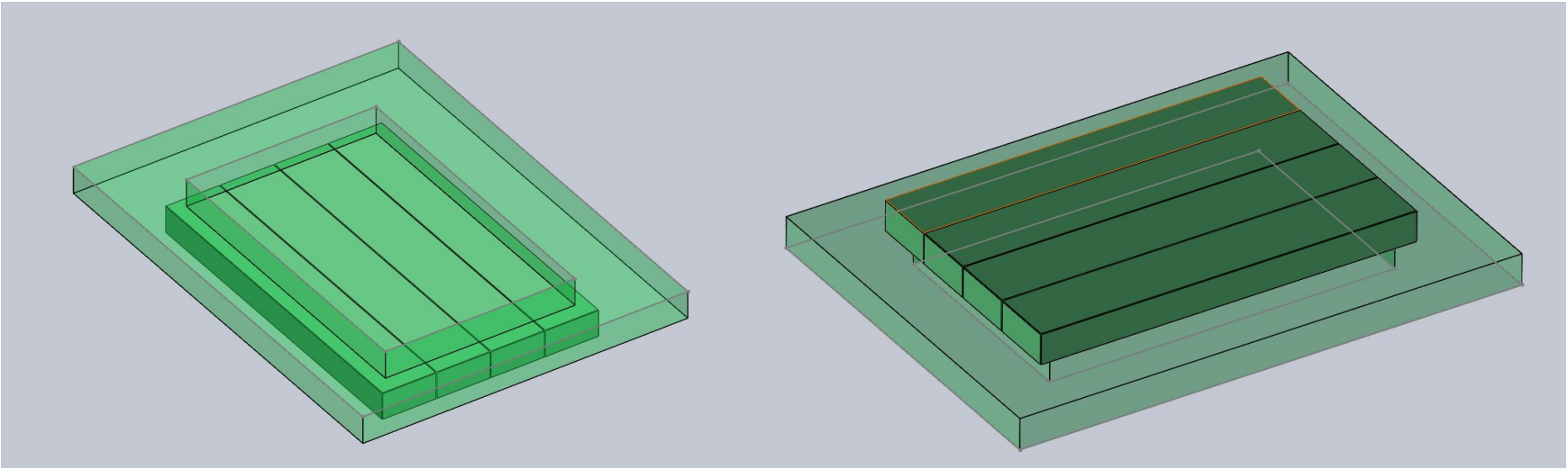


Zoomed in view at the joint



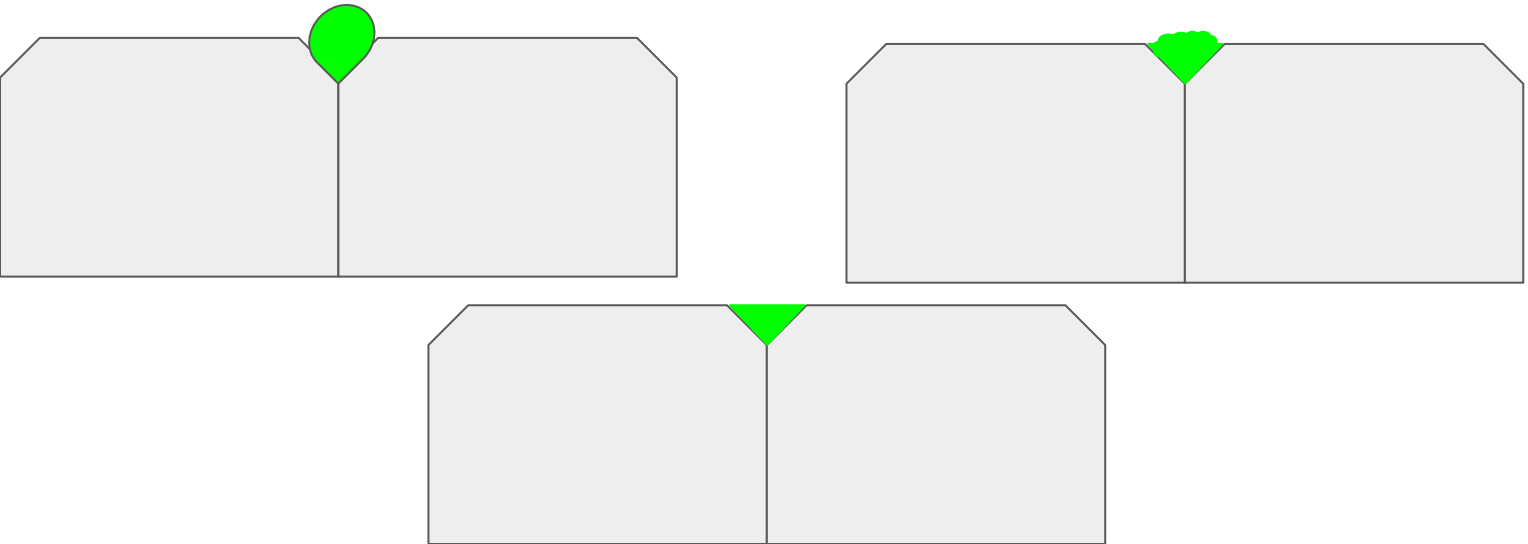


Step 6: Wait for epoxy to cure, flip to reveal electrode surface



Step 7: Hand polish joint area

1. Overfill the chamfer
2. Use softer razor blade to cut extra materials
3. Hand polish joint area
4. Then check using microscope



Next Steps & Remaining Questions

- Assembly of test field plate
- Epoxy at the chamfer polish and microscope test
- Epoxy tensile shear lap strength:
  - Strength testings between just two big glass plates
  - Tilt assembly as in actual setup and put weights on the panels
- ITO deposition and microscope test
- Flatness test with interferometer and a reference flat surface.
- Geometric constraint? (Optical opening? Thickness of frame?)