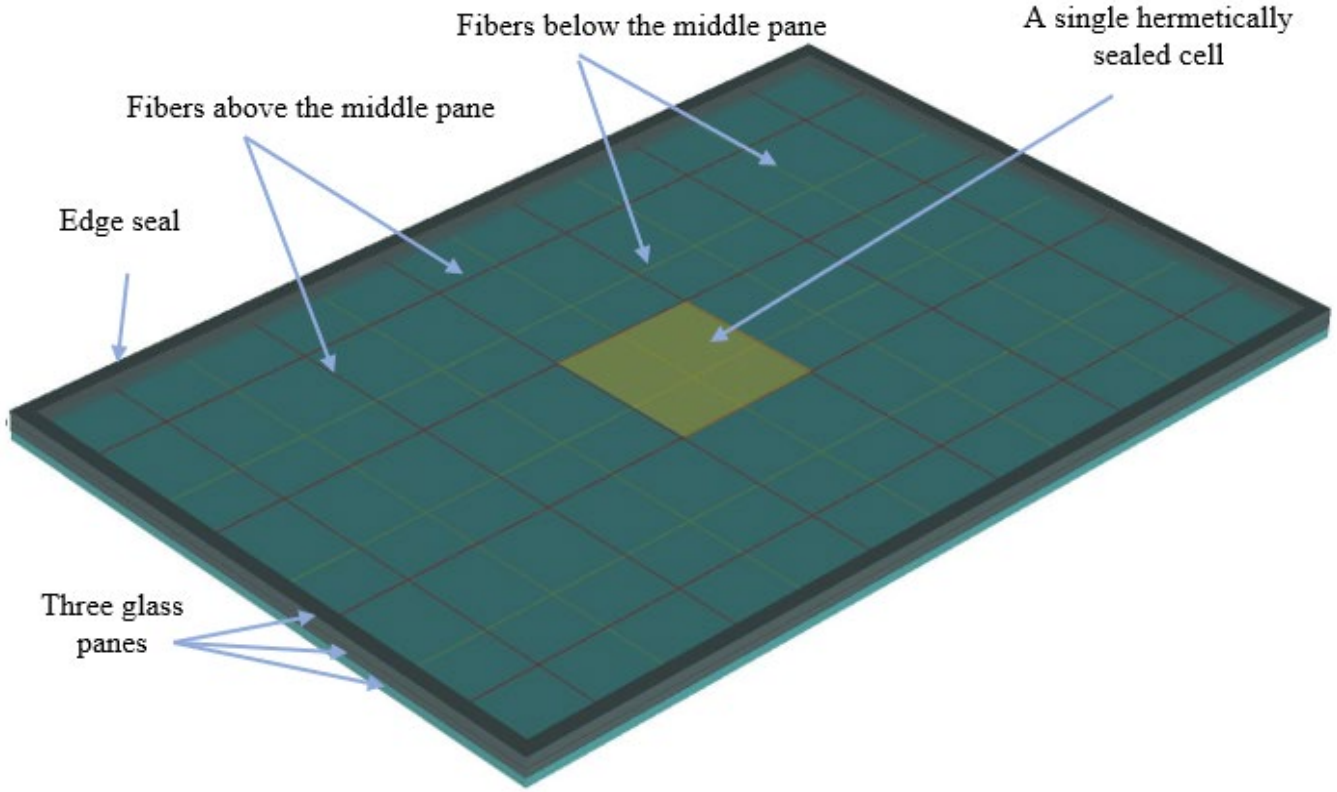
VacuGlass: Low-cost, Reliable, High Performance Vacuum Insulated Glazings (VIGs)



University of Maryland, Dept. of Mechanical Engineering
Jungho Kim (Professor) and Ratnesh Tiwari (Assistant Research Professor)
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Project Summary

Timeline:

Start date: March 1, 2019

Planned end date: April 30, 2022

Key Milestones

- Demonstrate R10 insulation and vacuum retention; March 2020
- Vacuum retention in 12” x 12” sample, reliability test setup completed. R10 insulation; Mar 2021

Budget:

Total Project $ to Date:

- DOE: $543,627
- Cost Share: $117,804

Total Project $:

- DOE: $902,567
- Cost Share: $225,642

Key Partners: None

Project Outcome:

- Develop high-performance vacuum insulated glass (VIG) which can be used as a direct replacement for single pane window and other IGUs.

Team

Jungho Kim
Professor

Ratnesh Tiwari
Assistant Research Professor

Dept. of Mechanical Engineering, U. of Maryland

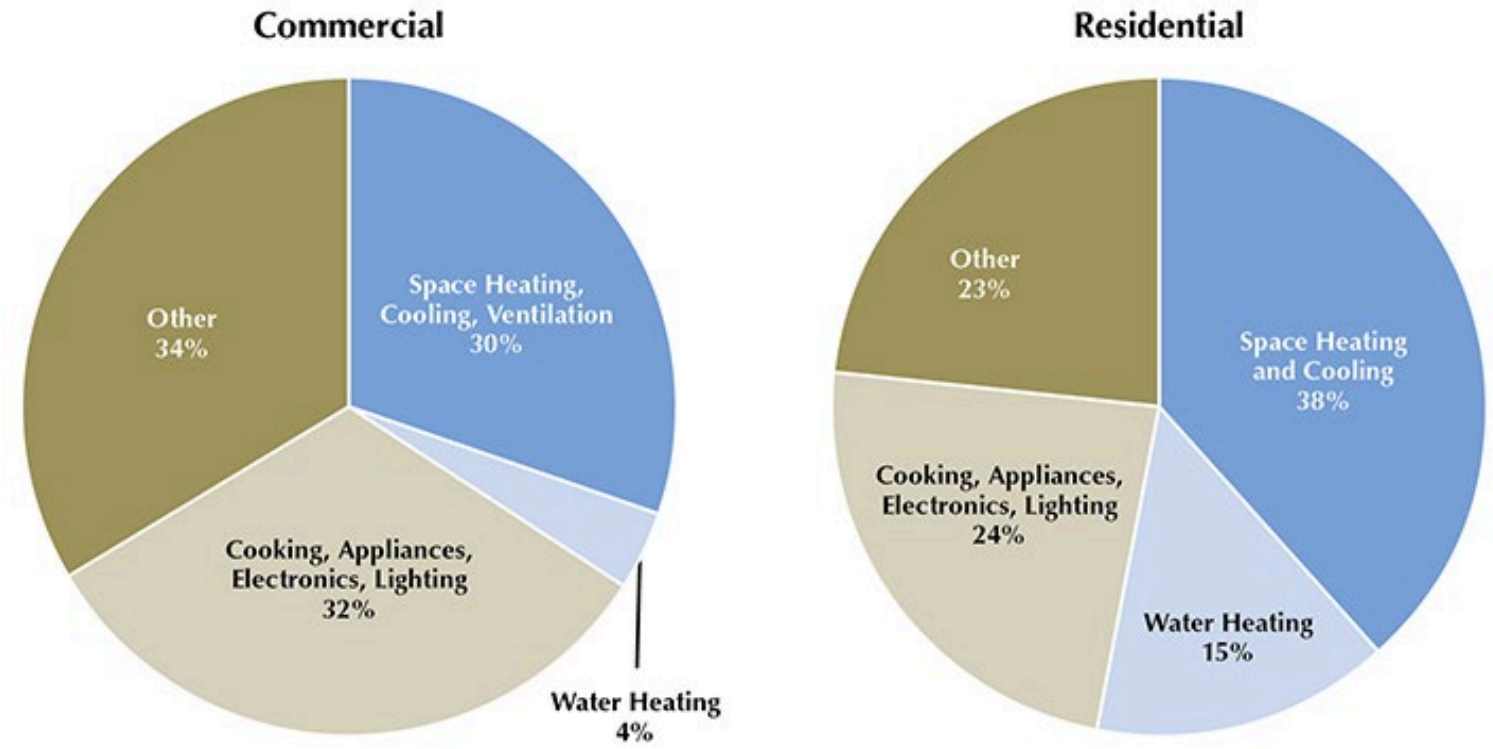
Challenge and Impact

Heat loss through windows:

7% total US carbon emission

$7.8 billion/year

Energy Use in US Buildings (35% of US CO_2 Emissions)



US Energy Information Administration, Annual Energy Outlook 2018, www.eia.gov/outlooks/aeo

GOAL: CUT ENERGY LOSS THROUGH WINDOWS BY >75%

Challenge: Window Performance

Walls of your home: R-20 to R-30

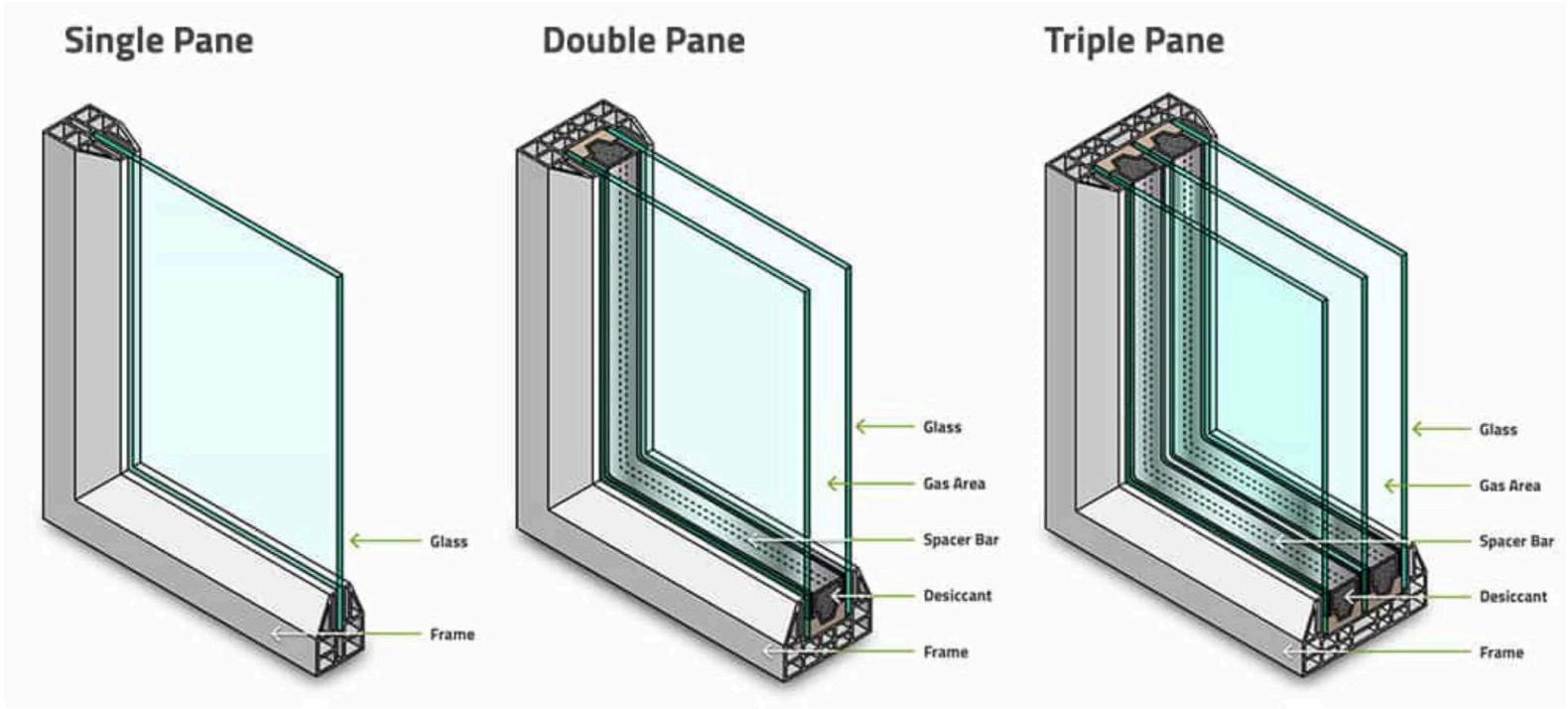


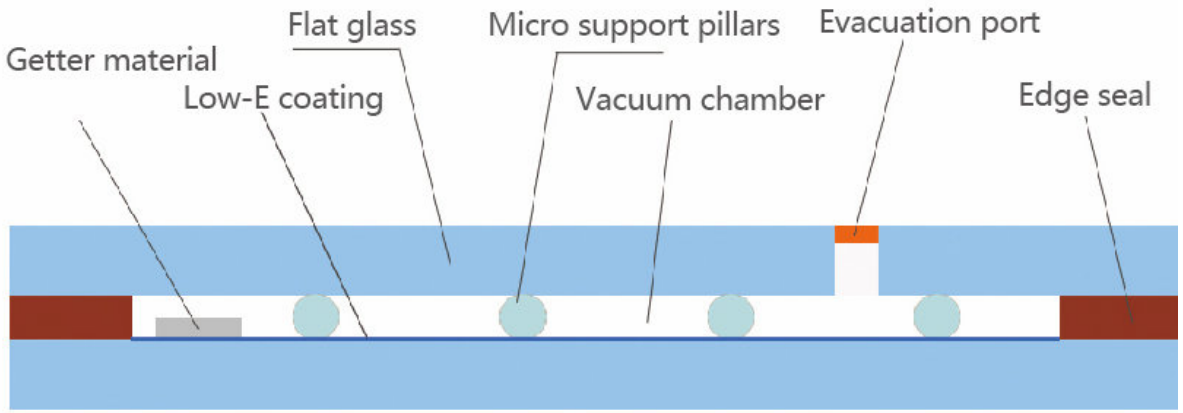
Image: brennancorp

R-1

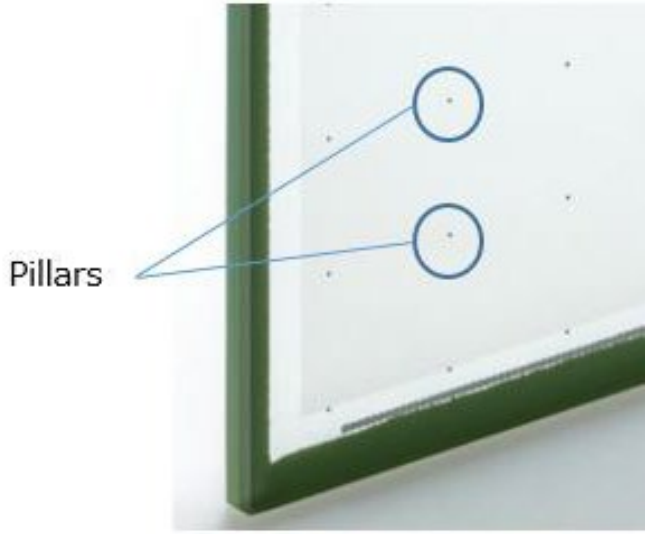
R-2 to R-4

R-7

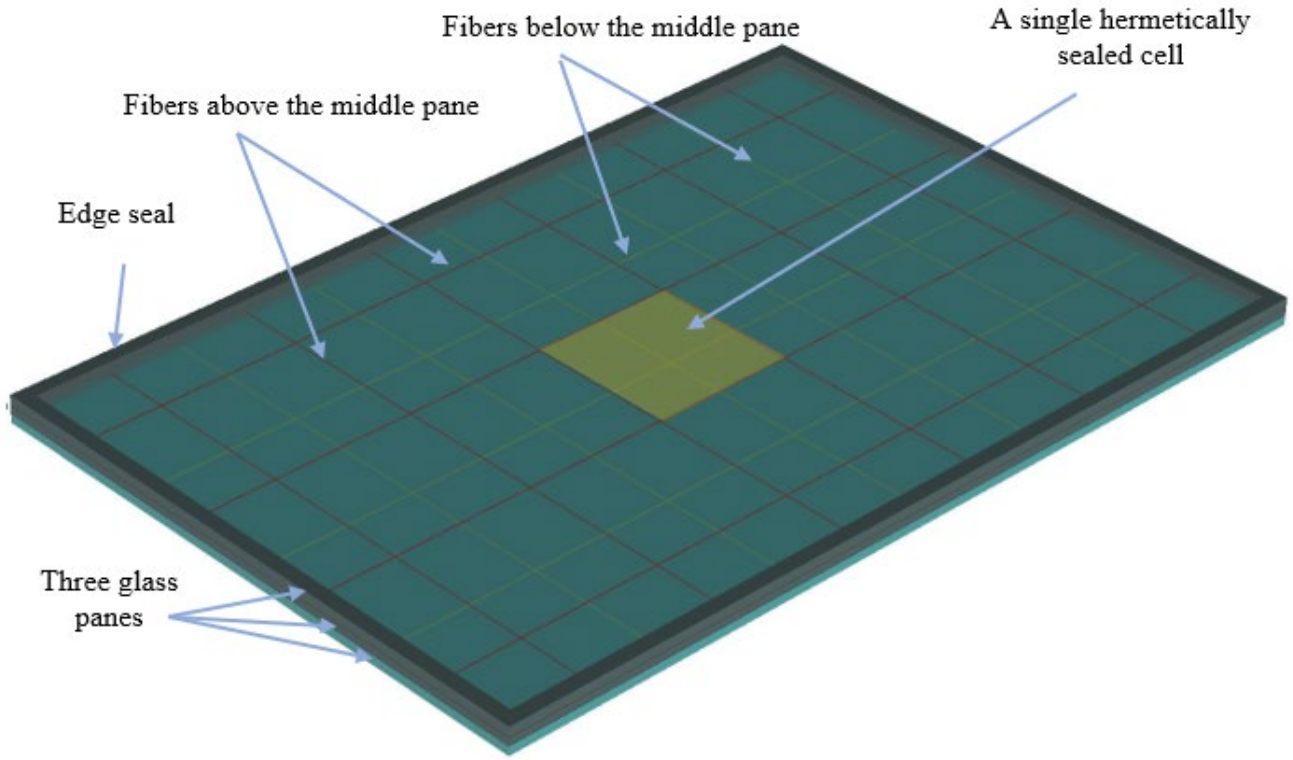
Current VIG Technology

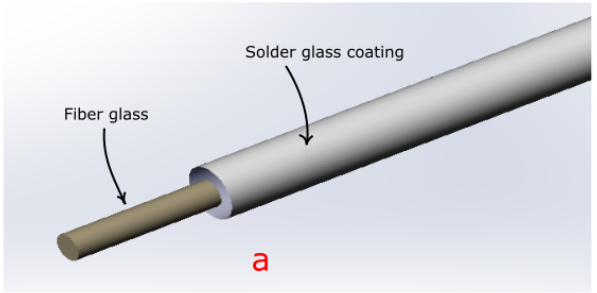


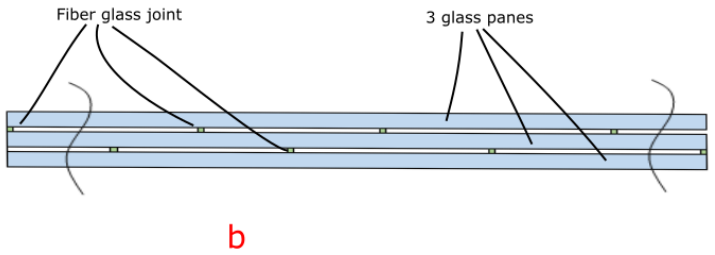
Vacuum insulating glass structure diagram



Approach: Triple Pane VIG Technology







Advantages:

- Many individually sealed cells
- Seal redundancy
- Distributed stresses
- Can cut larger panes to size
- Thin window

Disadvantages:

- High cost?

Progress: Thermal Simulations

Base Case Geometry:

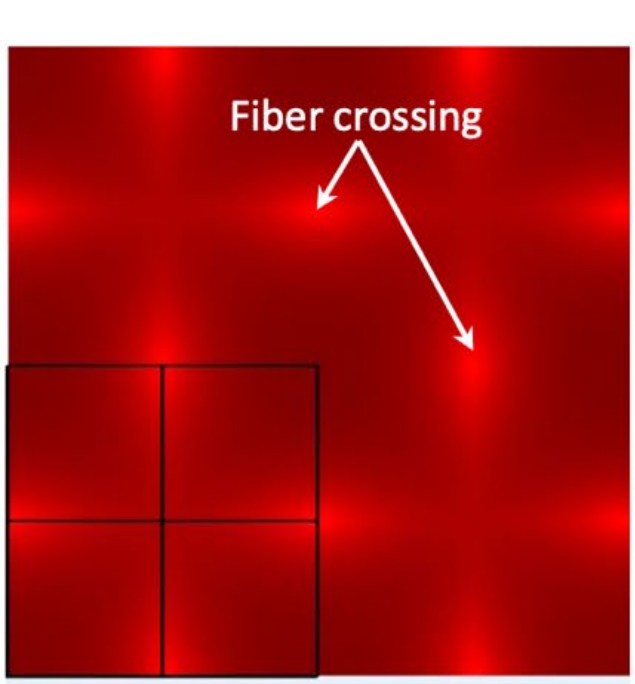
Inner and outer glass: 5.7 mm thick

Middle glass: 1.1 mm thick

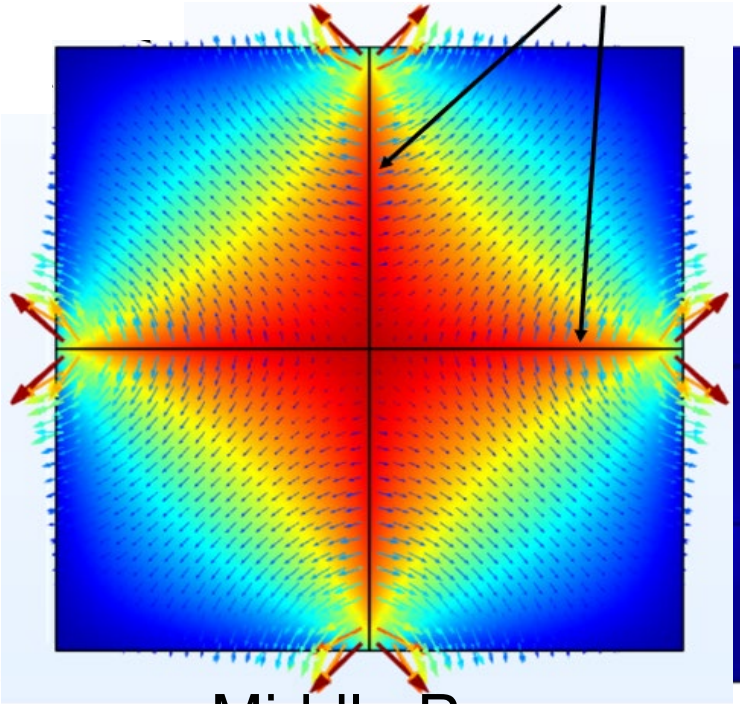
Fibers: square cross section 0.3 mm spaced 150 mm apart

Emissivity: 0.022 on surfaces 2 and 5 with other surfaces 0.88

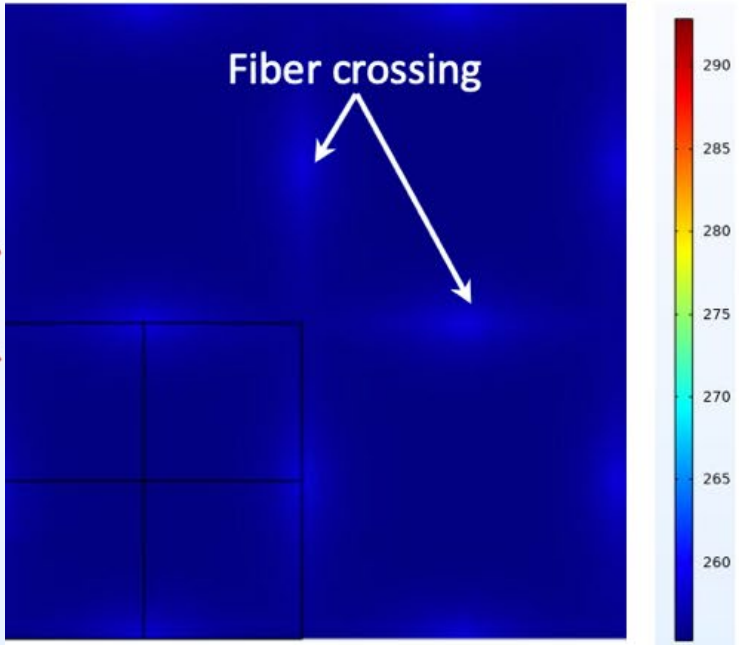
R-11.2



Hot pane

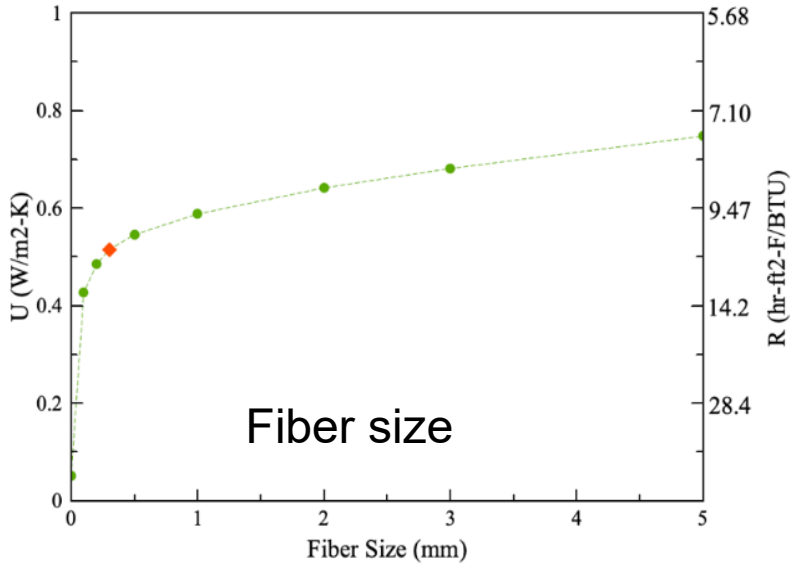


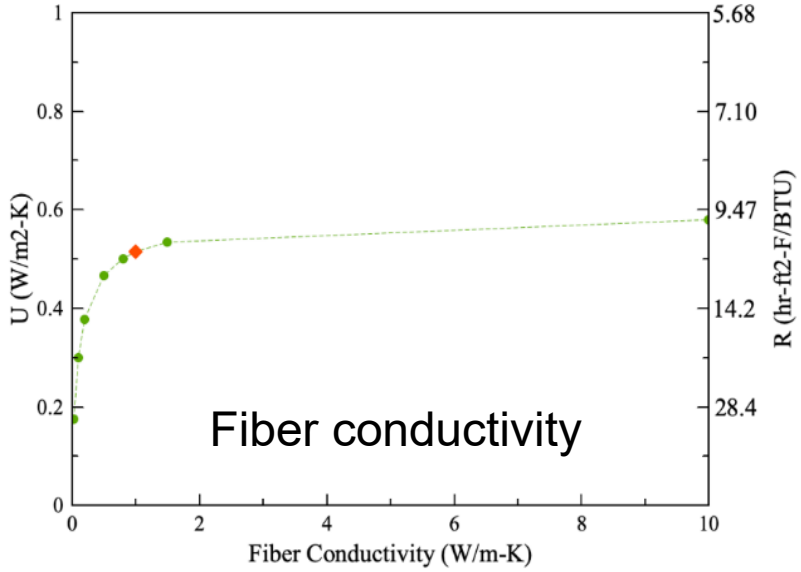
Middle Pane

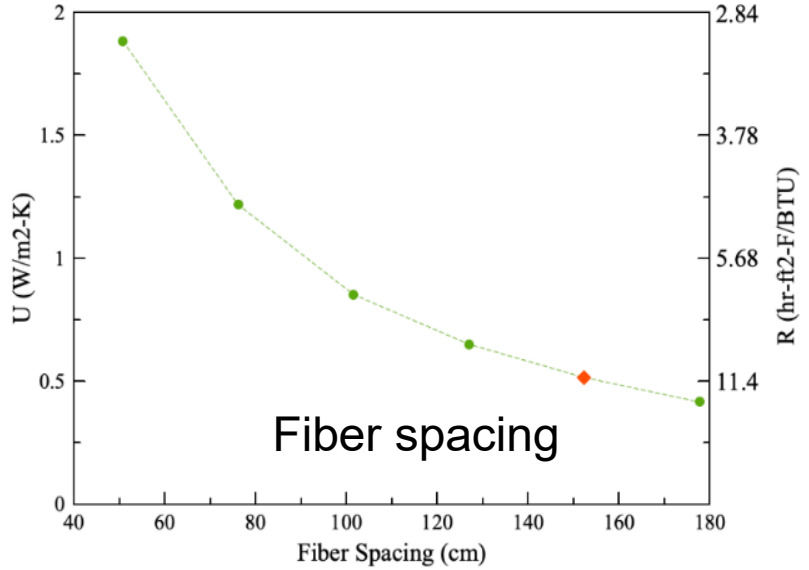


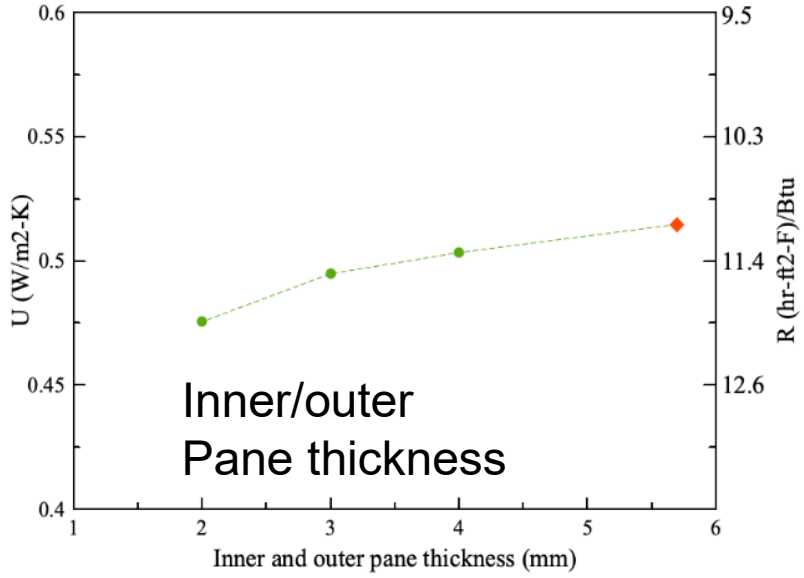
Cold Pane

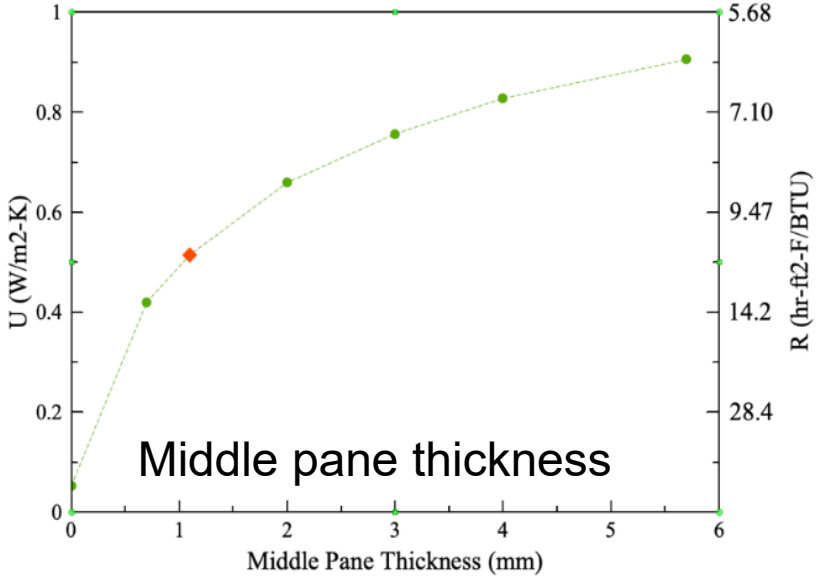
Progress: Thermal Simulations

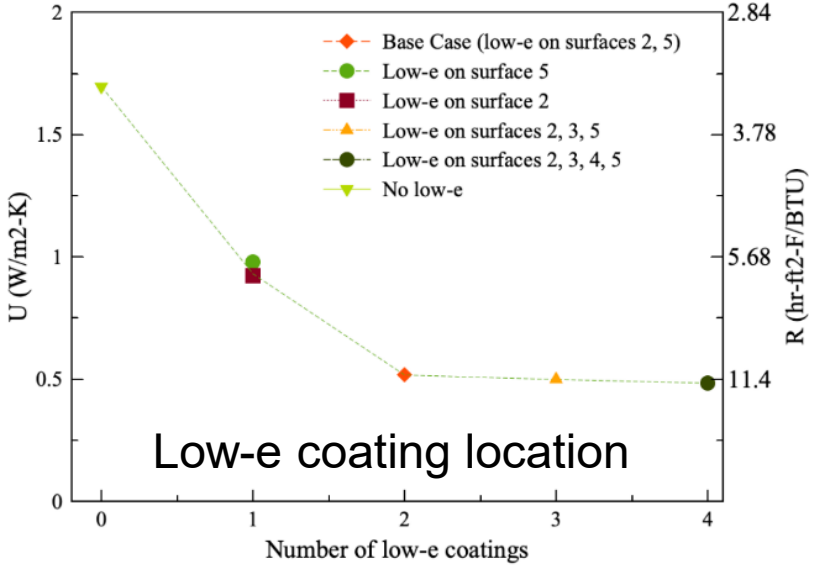




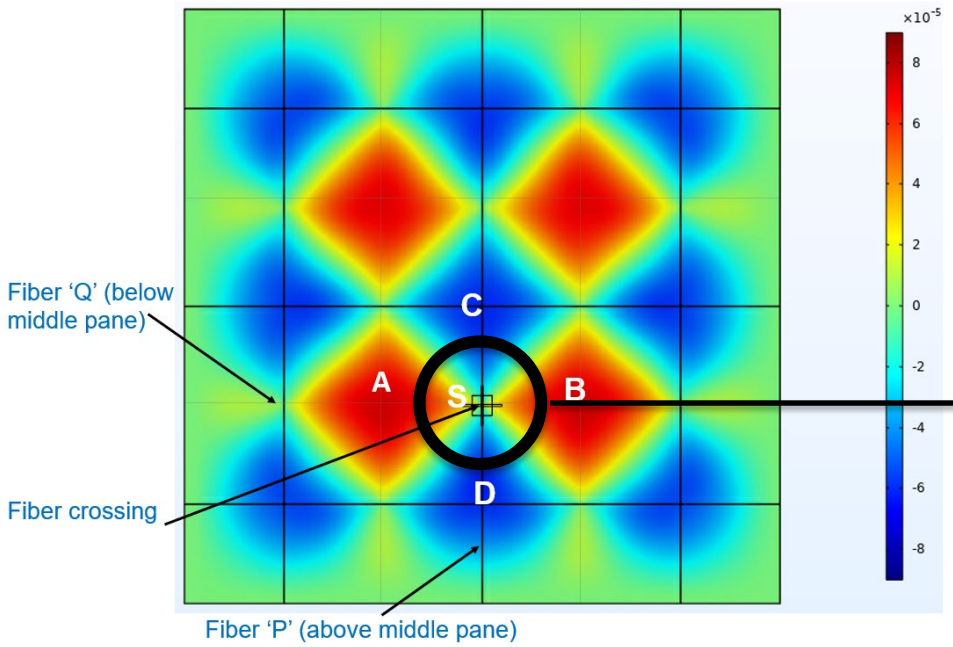


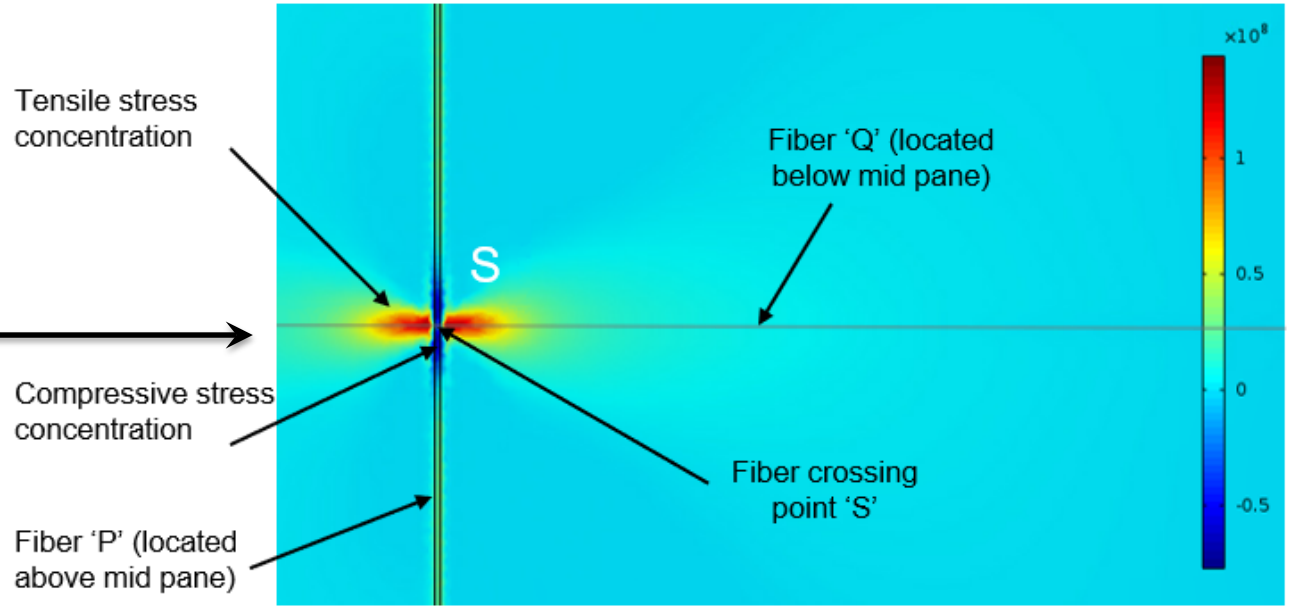






Progress: Stress Analysis Results

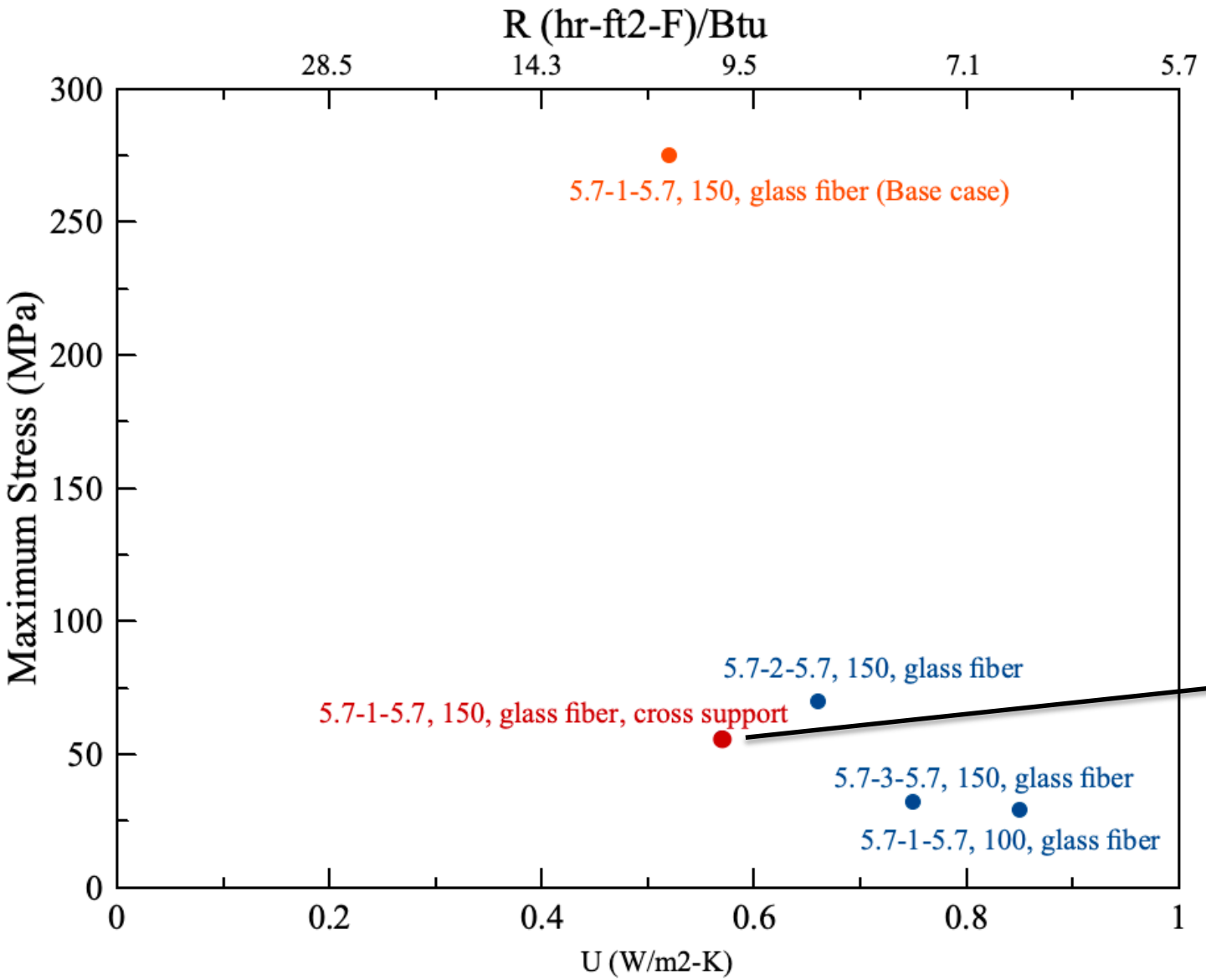


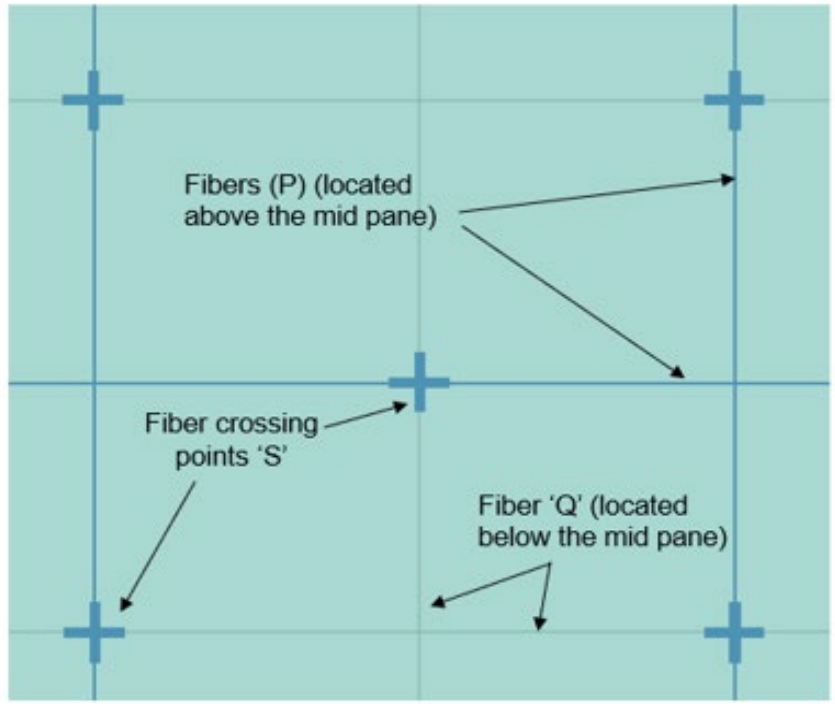


Deflection of the middle pane

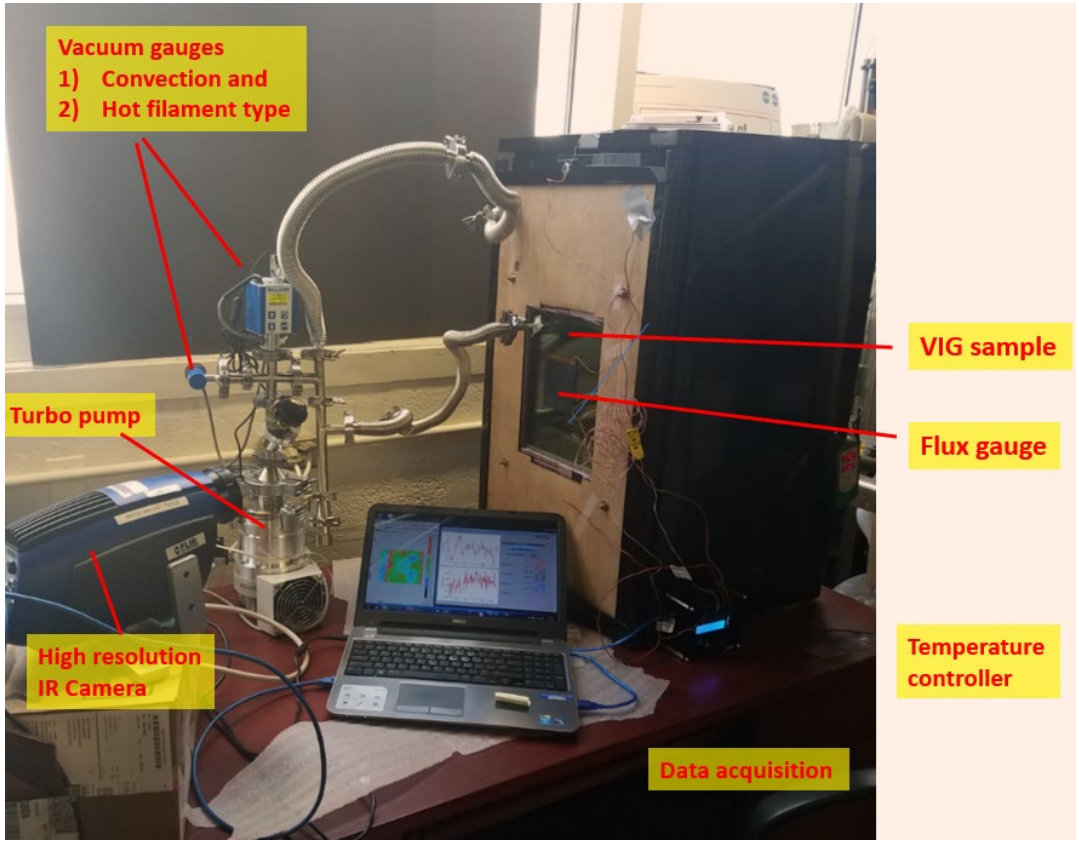
Stress concentration in the middle pane

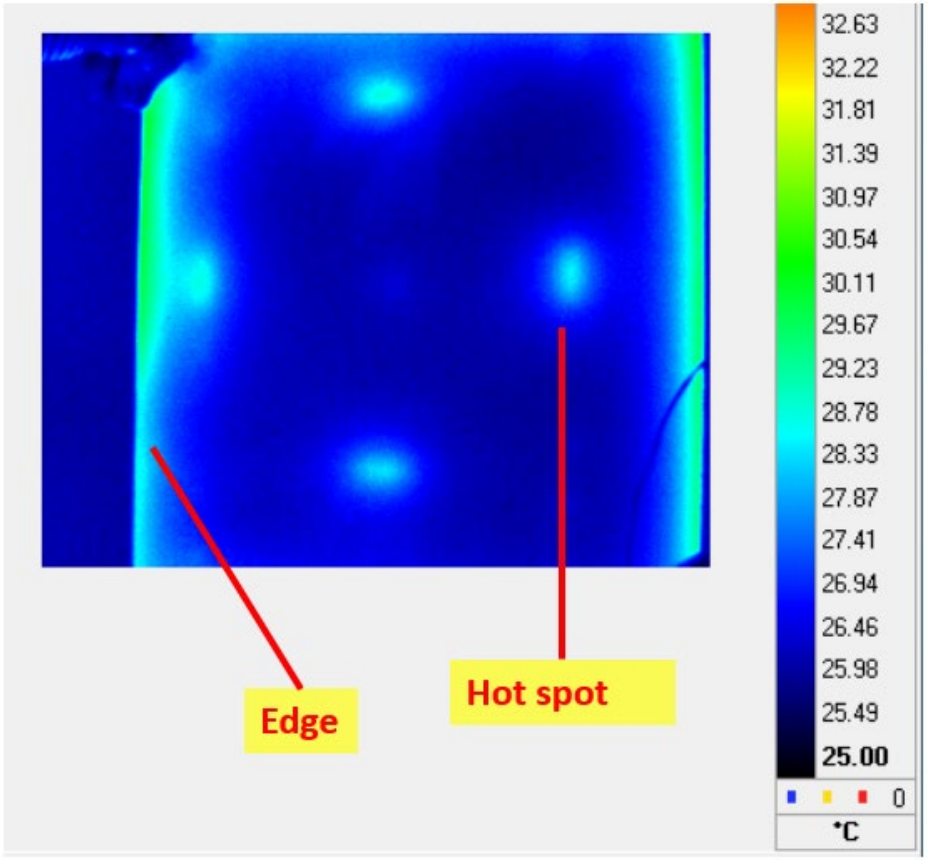
Progress: Thermal and Stress Analysis





Progress: Experimental Results for TPVIG





Measured center of Glass **R-value = 13.2**

Simulations

Experiment

Progress: Refocus Research to Address VIG Problems

TPVIG Pros:

- Demonstrated High R-value
- Reliable seal
- Less stresses

Drawbacks:

- Lines are visible
- Manufacturability issues
- Higher stresses in the middle pane need thin tempered glass

Progress: Challenges for VIGs

High cost

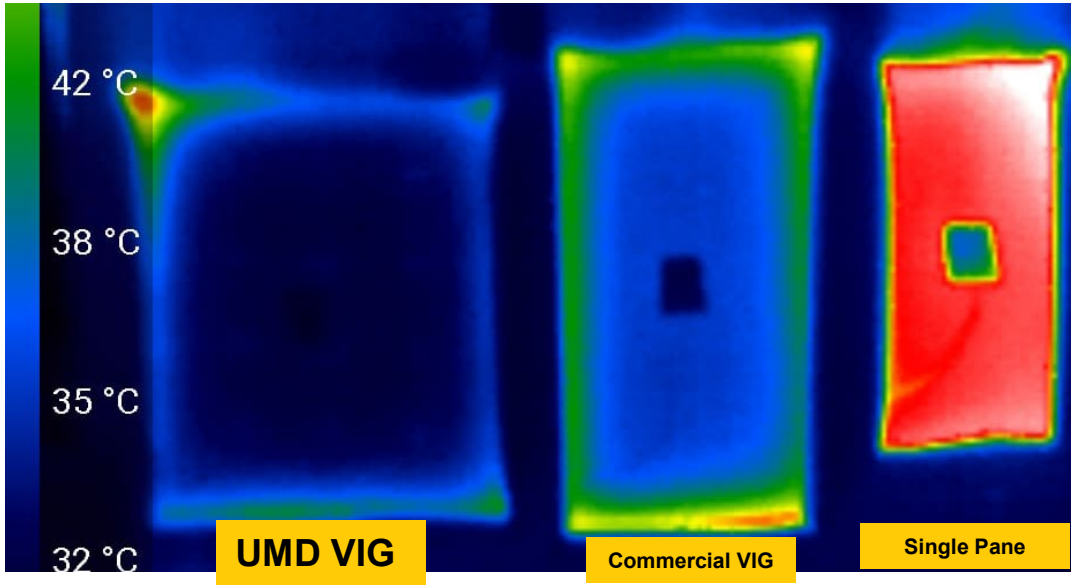
- Low throughput at temperatures (400-500C)
- ~ $20-$40/ft^2

Large thermal stresses on the seal

- Temperature differential between inside and outside panes

Progress: Metal Seals

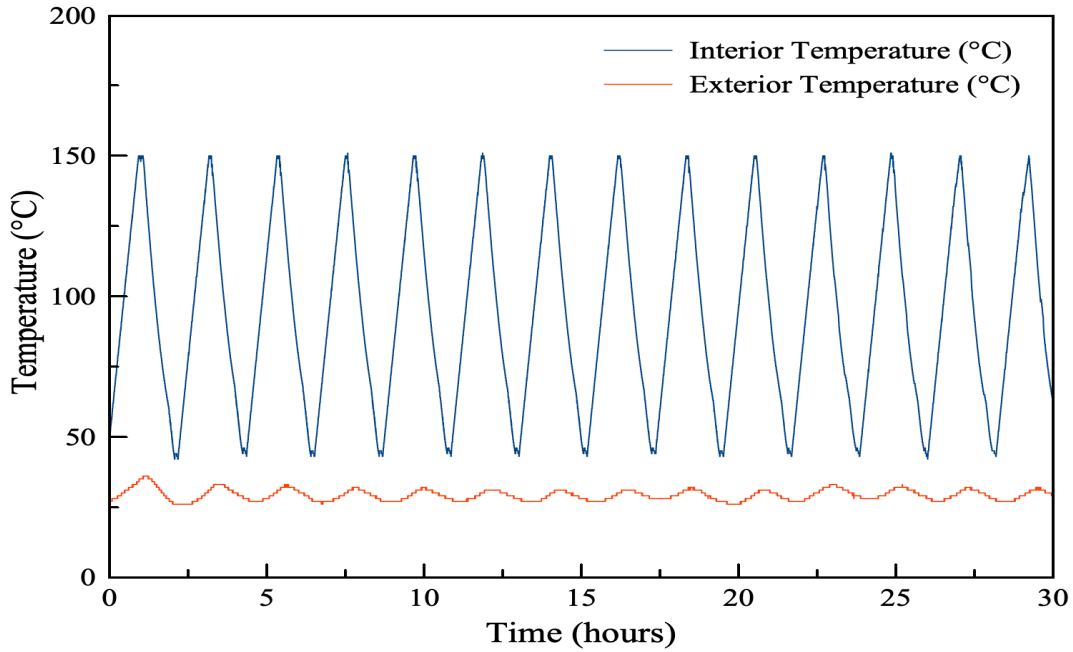
- Low temperature sealing
- Flexible seal hence minimal seal stress
- Low cost



Progress: Reliability Testing

- Accelerated thermal cyclic testing as per ISO 19916-1
- Thermal cycling between 25C and 150C
- Completed more than 500 cycles
- Currently making 14”x20” windows to send out for third party testing

Thermal cycle testing example.



Stakeholder Engagement

- Customer validation (I-corps)
- State of Maryland commercialization grant
- Discussion with possible first market partners in place
- Discussion with manufacturing partners
- Identifying buildings to demonstrate the VIGs

Remaining Project Work

- Further reliability testing
- Third party inspection
- Manufacturing analysis
- Setup a small-scale demonstration line

Thank You !

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REFERENCE SLIDES

Project Budget

Project Budget: Total budget of $1.12M (no change)

Variances: Glass coated fiber concept was modified and hence the budged was reallocated to creating low temperature seal.

Cost to Date: $661,431

Additional Funding: We received MII funding $115K (frit paste development and commercialization)

Budget History					
5/1/2019– FY 2020 (past)		FY 2021 (current)		FY 2022 – 4/30/2022 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$461,469	$126,849	$342,475	$77,008	$98,623	$21,785

Project Plan and Schedule

Project start : 5/1/2019

Project end: 4/30/2022

◆ **Completed on time**

◆ **Late ompletion**

		CY1			CY2				CY3				CY4
		Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1
PAST WORK													
Q2 Milestone	Assess thermal performance of TPVIGs to determine if it has the potential to achieve an average center of glass U value <0.1 Btu/hr-ft2-°F.												
Q3 Milestone	Select the solder glass material for bonding, and other grid materials for a sealed TPVIG if appropriate.												
Q4 Milestone	Demonstrate the sealing of a small, representative coupon without vacuum using multiple cells created between the panes using frit												
Go/No Go year 1	**Successful creation of initial proof of concept TPVIG with vacuum retention: The proof of concept shall achieve an overall U value <0.1 Btu/hr-ft2-°F.**												
Q2 Milestone	Literature review on VIGs and bonding methods completed, and journal paper submitted												
Q3 Milestone	Technoeconomic cost model completed												
Q4 Milestone	Full window thermal modeling results Completed												
Go/No Go year 2	**Successful vacuum retention between 10-3 - 10-4 torr within a 12”x10” prototype VIG. Thermal cycle test rig designed, fabricated, and qualified. The entire TPVIG shall achieve an overall U value <0.1 Btu/hr-ft2-°F measured in accordance with industry acceptable standards or in collaboration with NREL. Stretch goal of a R13 (U value <0.077 Btu/hr-ft2-°F) whole TPVIG.**												
CURRENT WORK													
Q2 Milestone	Thermal cycle test results completed												
Q3 Milestone	Send out VIG samples for independent third-party testing in accordance with testing requirements established in Task 9												
Q4 Milestone	Design optimization completed												
Q1 Milestone	Technology to market analysis completed and industry partner identified. Submit report showing potential for mass production, including yield, cost and capital expenses.												

Completed

Planned

Project Plan and Schedule

- Project original initiation date & Project planned completion date: 5/1/2019 to 4/30/2022
- Schedule and Milestones:
- Explanation for slipped milestones and slips in schedule
- Go/no-go decision points
- Current and future work