Temperature measurements of cooling foam apparatus

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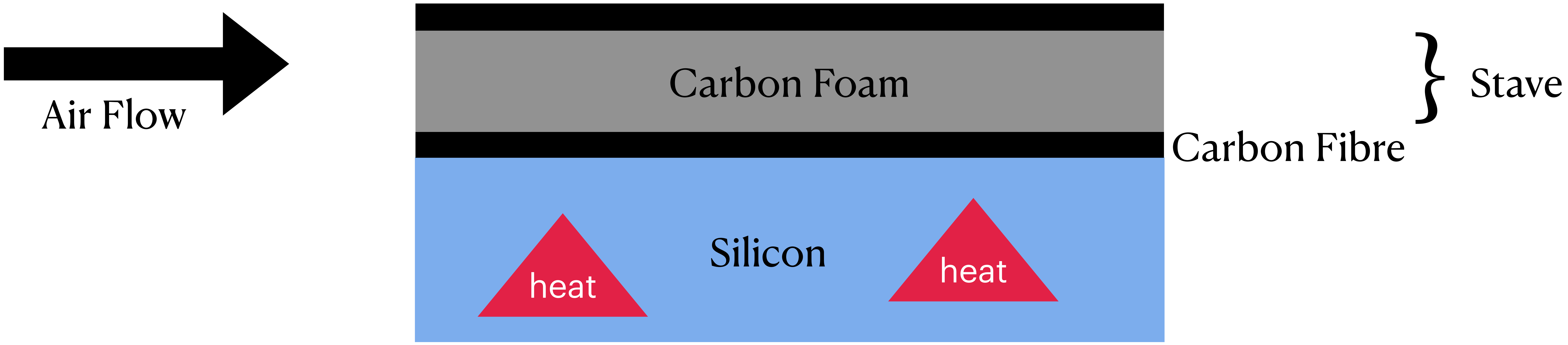
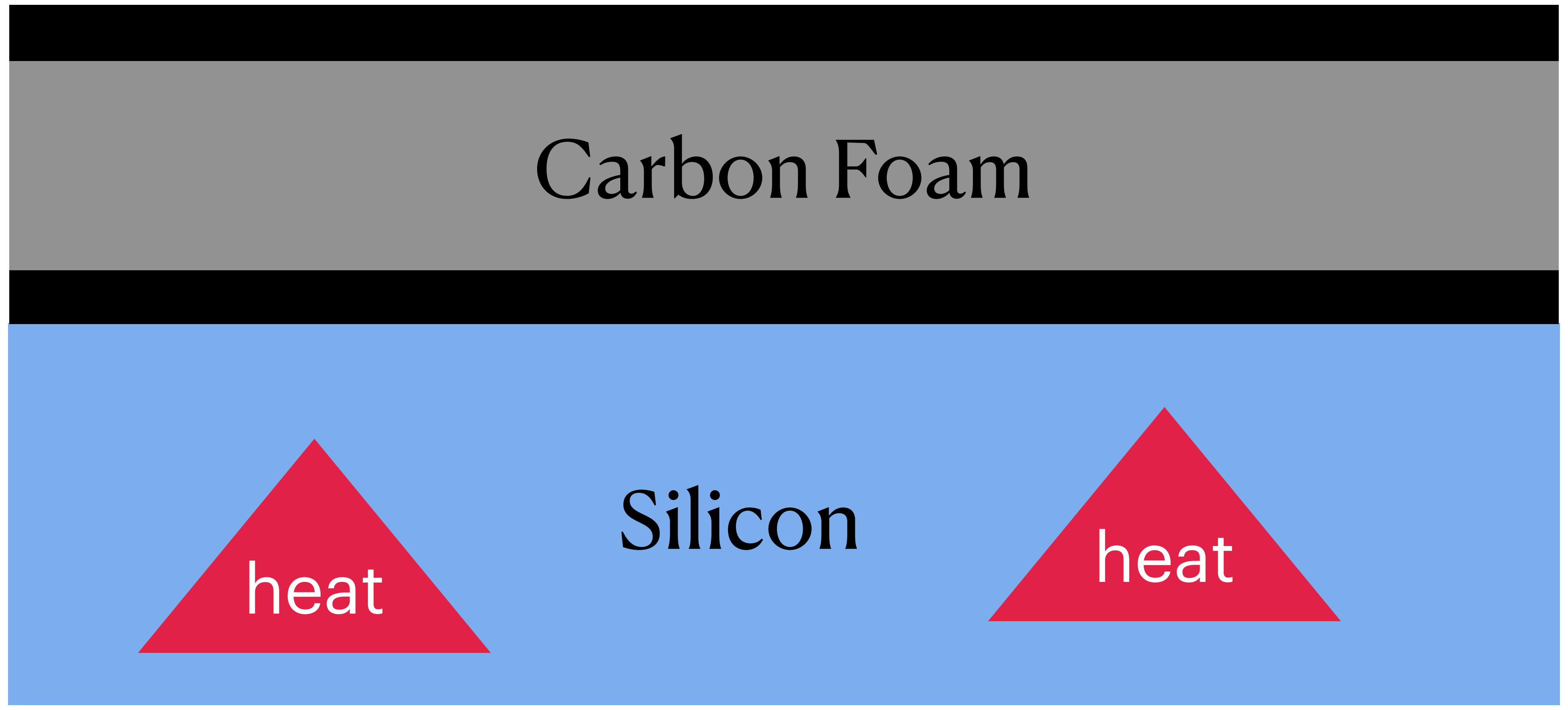
Staves

- To reduce material budget, want to explore air cooling
- Use carbon foam staves to direct air cooling through internal structure.
- Need to understand how airflow and temperature changes as air travels through the stave.
- Apply heat to stave as stand in for silicon, and direct air through the foam.

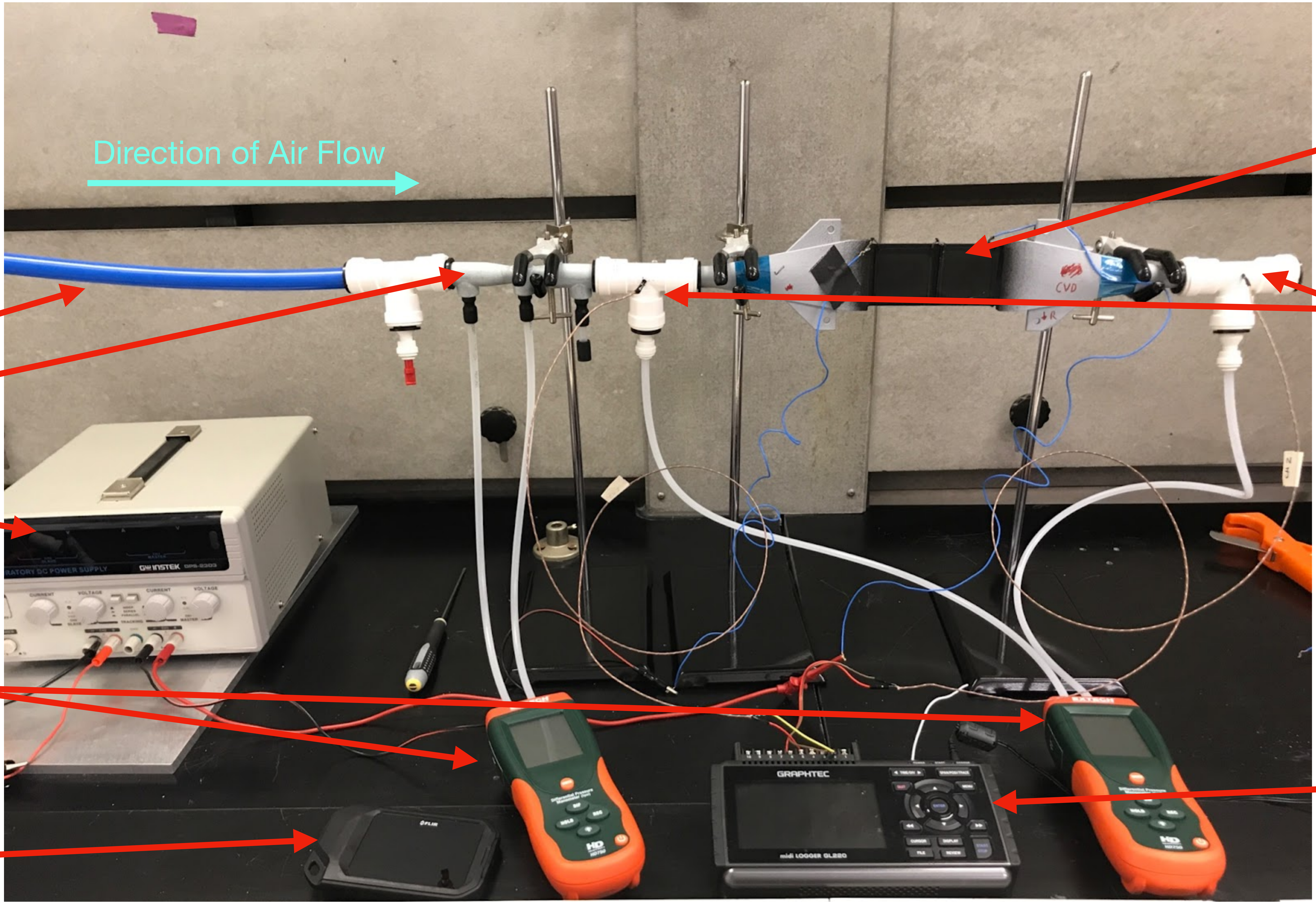


Staves

- Which stave would be best?
- Needs to work across a range of power domains (sensors span a range of power domains)
- How is heat distribute along the staves as we apply air cooling?
- Rough Goal: $\Delta T < 10^{\circ}$ C for a one metre stave
- Things we can manipulate:
  - Foam thickness
  - Porosity
  - Length

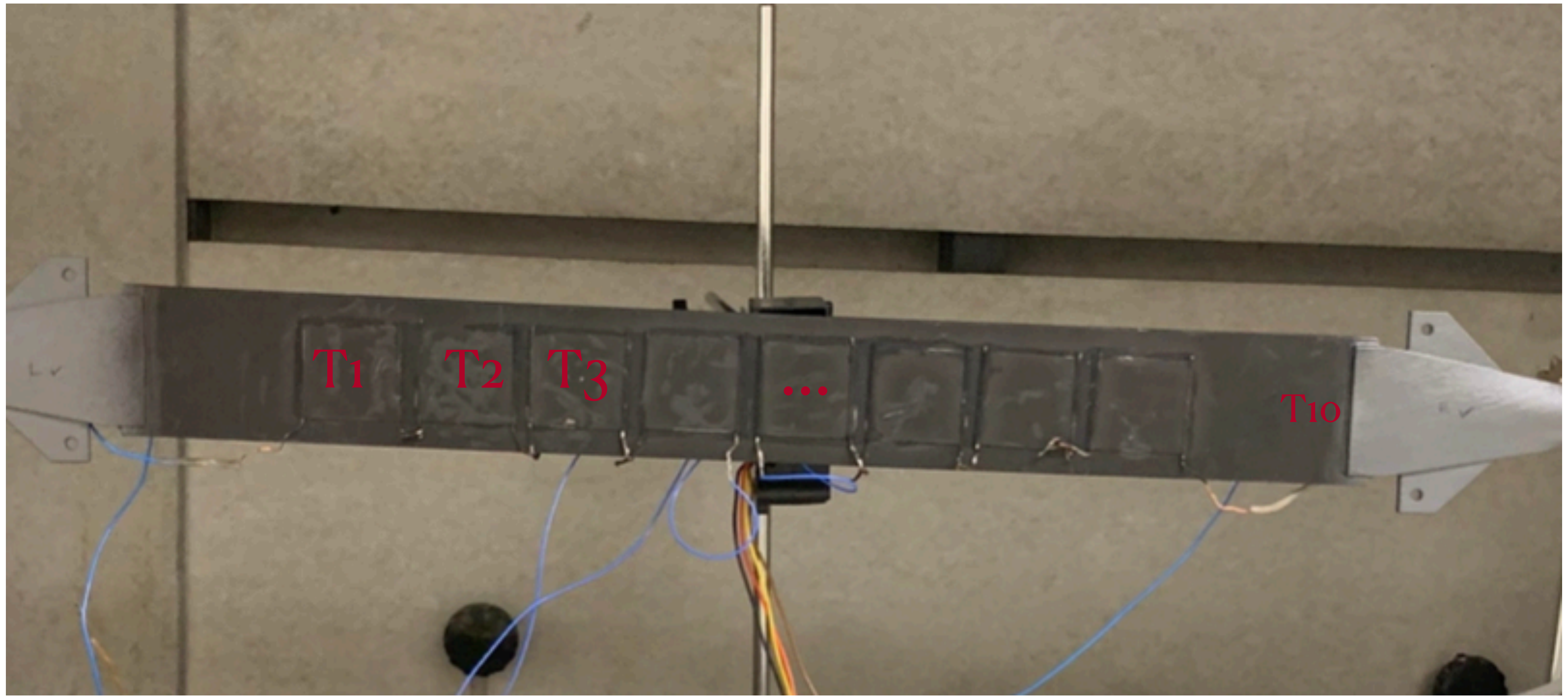


Setup


Direction of Air Flow
Stave w/ carbon foam pieces
Air Flow
Venturi
Thermocouples
Power Supply
Manometers
DAQ
FLIR camera

Procedure

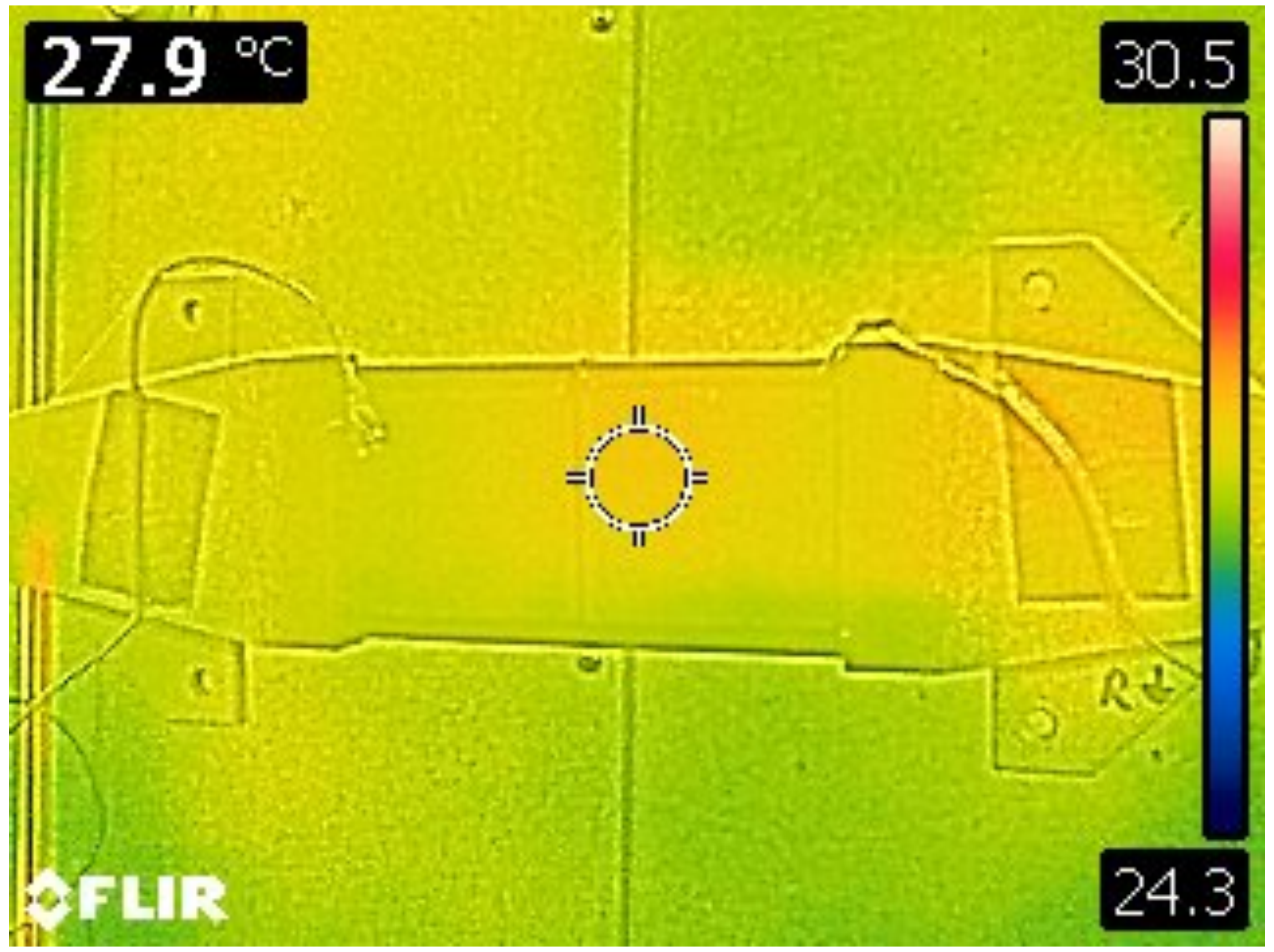
- Apply different voltages across stave. Take temperature measurement with infrared thermometer across 10 locations down the stave. Record pressure change at end of stave.
- Apply faster flow rate to stave. Repeat.
- Compare to different materials.



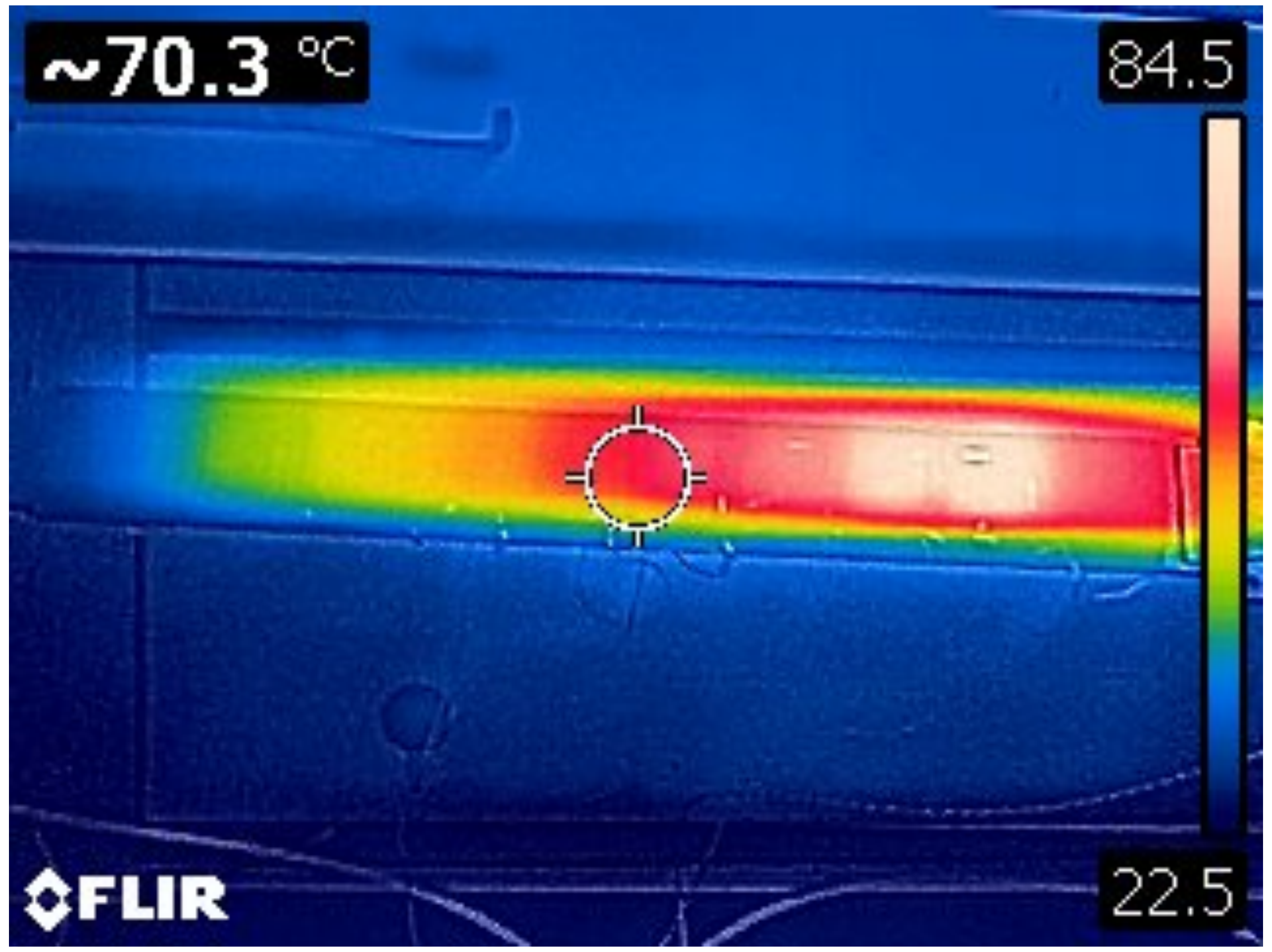
$z = 0$ cm $\qquad z = 50$ cm

Procedure

- We care about the change in temperature relative to temperature before we applied heat.
- Take a “dark temperature.” dT is then the difference between bright and dark temperatures.
- Measure *T* across the stave to see how heat changes as a function of length.



Dark Temperature

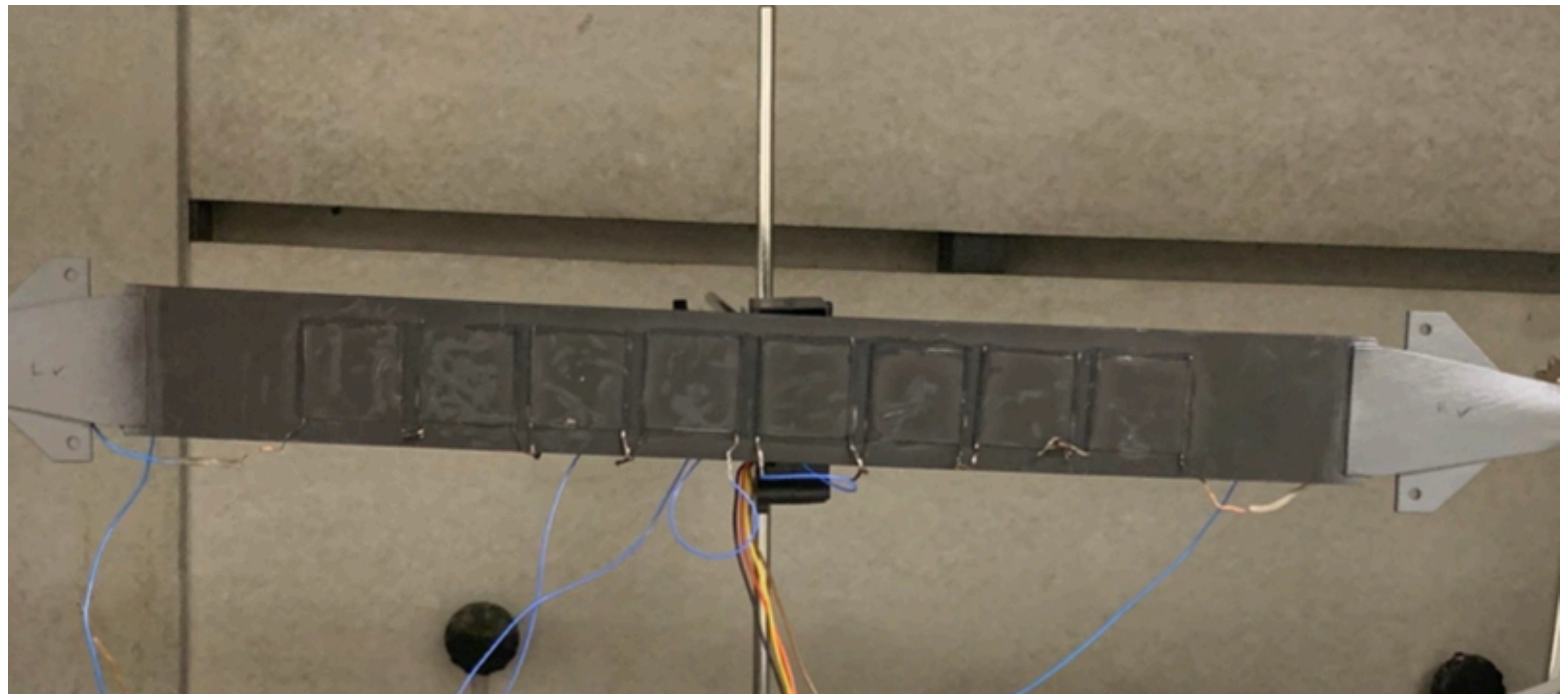


Bright Temperature

Short and Long Stave

- Earlier, work was shown on 'short' staves.
- Longer staves will be needed in practice.,
- Measurements of short staves are only an average of the whole material.
- Measurements of longer staves allow us to map the temperature gradient more thoroughly.

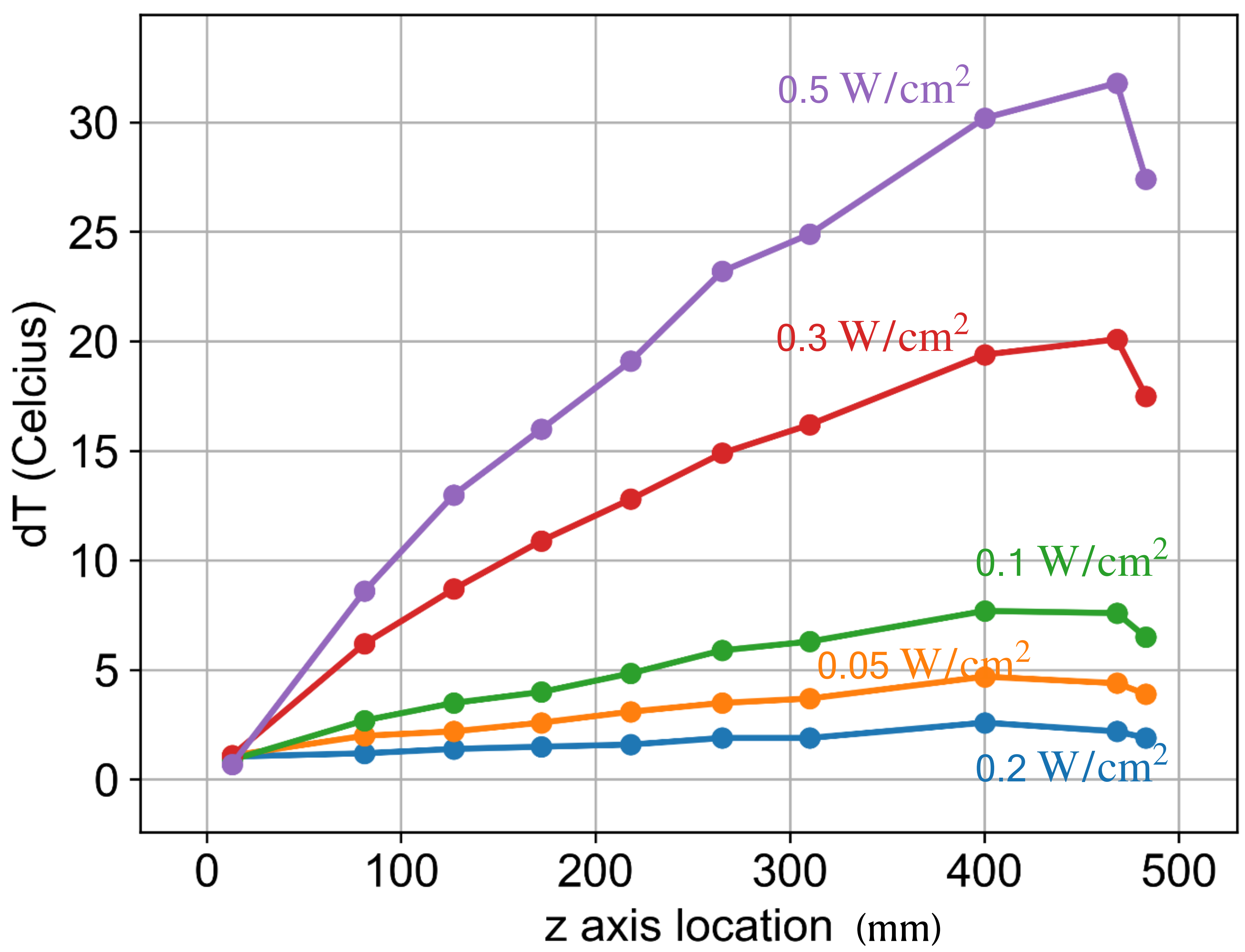
Short Stave


Long Stave

Results

3.0 cfm, RVC Foam

Heat gradient across long RVC stave



Ideal :

$\Delta T < 10^\circ$ C

for a one metre stave

- For power densities up to 0.10 W/cm^2, $\Delta T < 10^\circ$ C

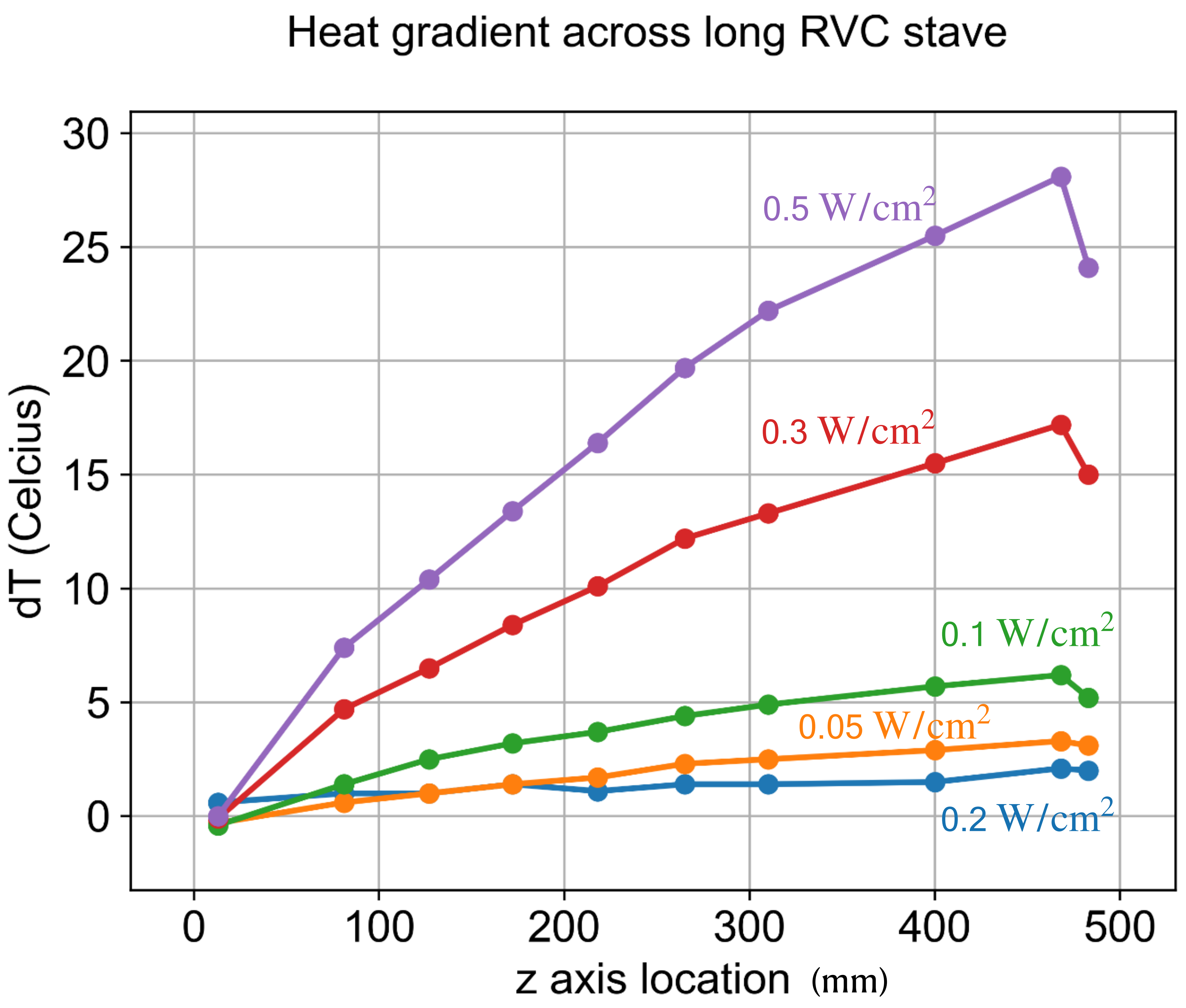
Results

3.4 cfm, RVC Foam

Ideal :

$\Delta T < 10^{\circ}$ C

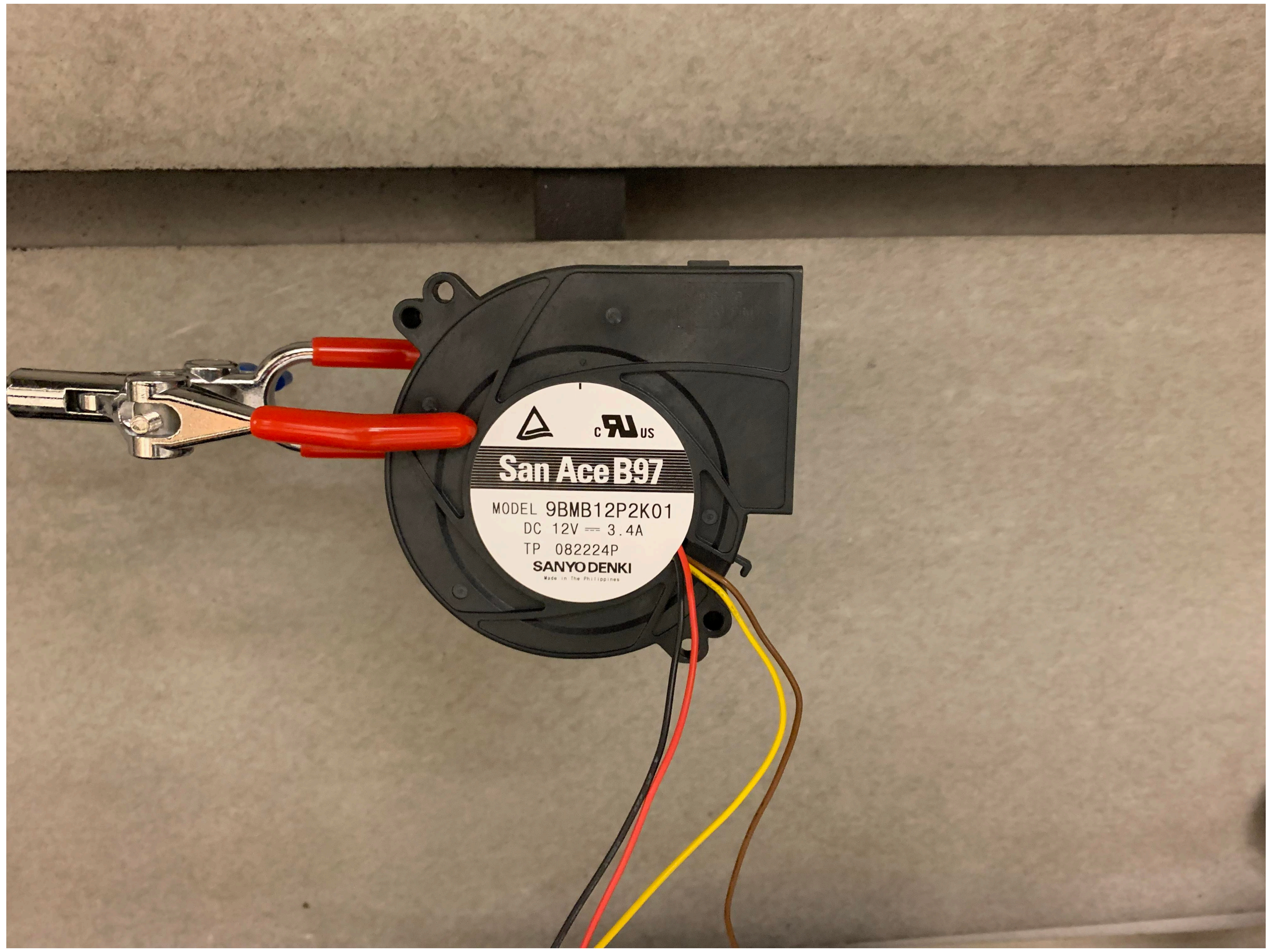
for a one metre stave



- For power densities up to 0.10 W/cm^2, $\Delta T < 10^{\circ}$ C
- We see that the higher flow rate indeed leads to lower temperatures across the same power densities

Status and Next steps

- Workflow has been established for 0.5 m stave and taking and analysis is underway
- House air doesn't get to high enough flow rate.
- Solution: new fan.
- Different materials in 0.5 m length.
- Error estimations.



Conclusion

- Data taking and analysis in progress.
- Current material (RVC) doesn't provide sufficient cooling for power densities above 0.10 W/cm^2.
- Need to explore new materials. CVD foam in shorter lengths has shown sufficient cooling.