Thermal Management for 6G Module Using Vapor Chamber

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Outline

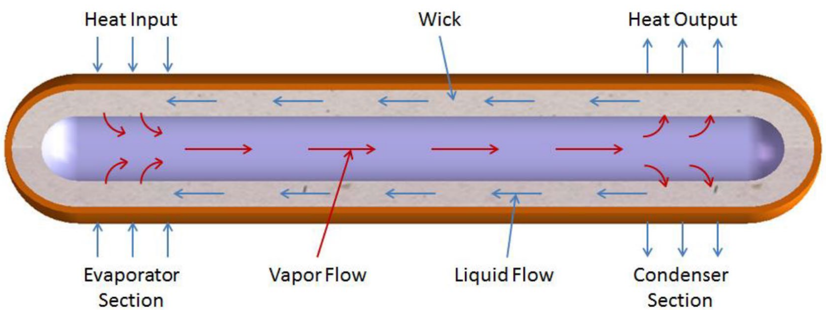
- Goals & Objectives
- Background Details
- Technical Approach
- Results
- Next Steps
- Summary

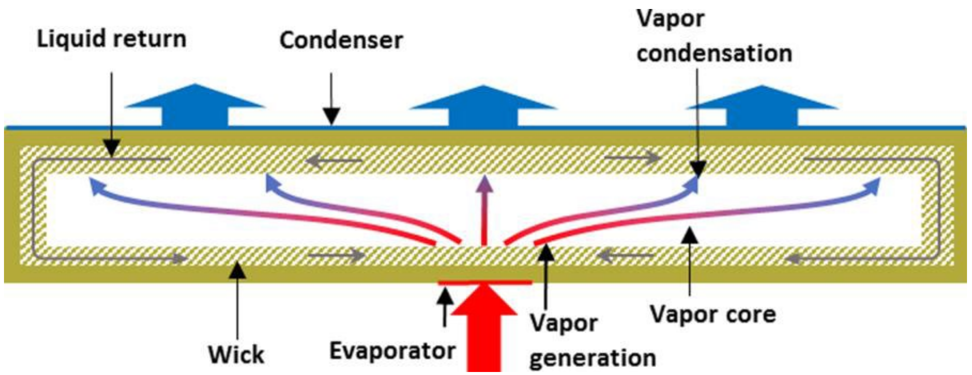
Goals and Objectives

- Study of using Vapor Chamber (VC) for thermal management of sub-THz RF Modules through modeling

- VC, similar to a flat heat pipe but different form factor, is a 2-phase cooling solution which transfers the heat through the phase change of liquid into vapor (evaporator) and back from vapor to liquid (condenser).

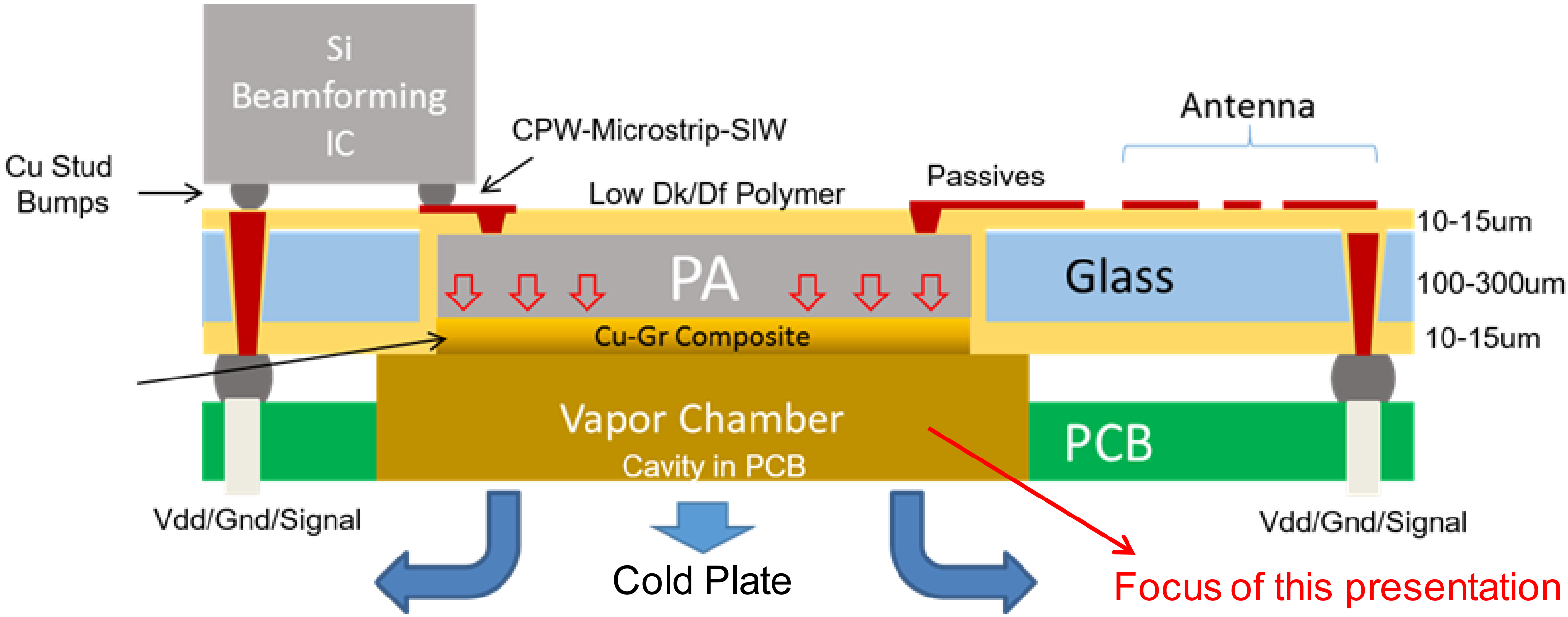
- Working principle of heat pipe and VC



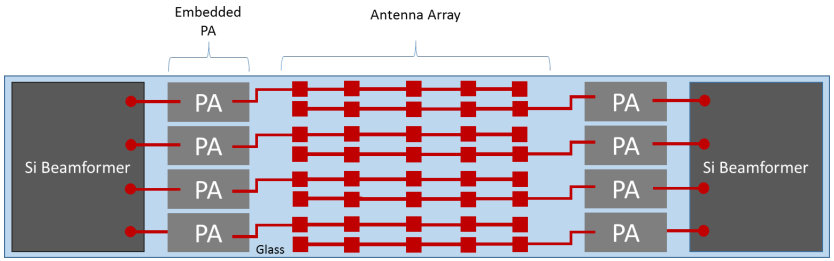


Background Details

- ❑ Use of Fan-Out Panel Level Packaging (FOPLP) for sub-THz RF Modules



- ❑ PA based on III-V has ~25% Efficiency
- ❑ PA heat flux 100W/cm^2 – 200W/cm^2
- ❑ VC proposed for thermal management



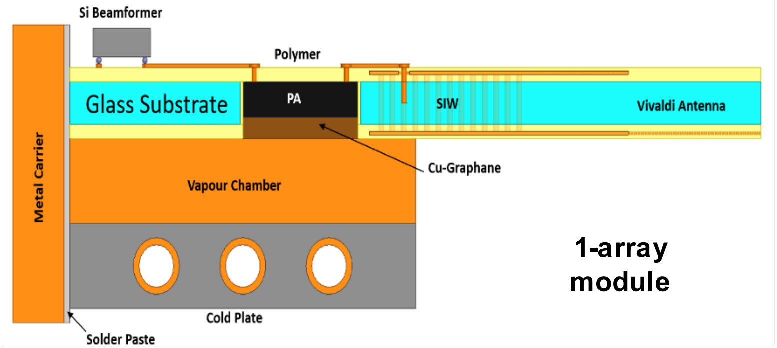
Technical Approach

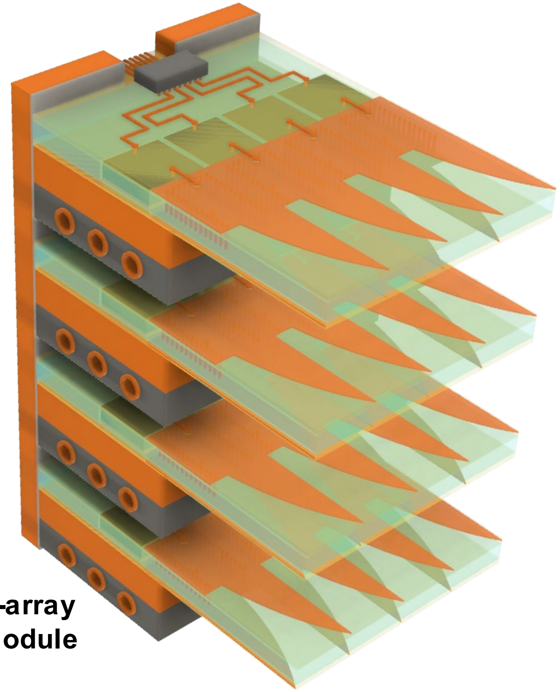
- Conduction-based model of VC

- Isotropic approach which treats the whole VC as a rectangular plate having an isotropic conductivity ($k_x = k_y = k_z = k_{vc}$);

- Orthotropic approach in which the effective thermal conductivity is assumed to be composed of two components: the straightforward conductivity (k_s) and the lateral conductivity (k_l). In this approach, $k_z = k_s$ and $k_x = k_y = k_l$.

- In this study, the VC was modeled with orthotropic approach in ANSYS Workbench using Steady State Thermal Module.





Technical Approach (Cont.)

Model Inputs

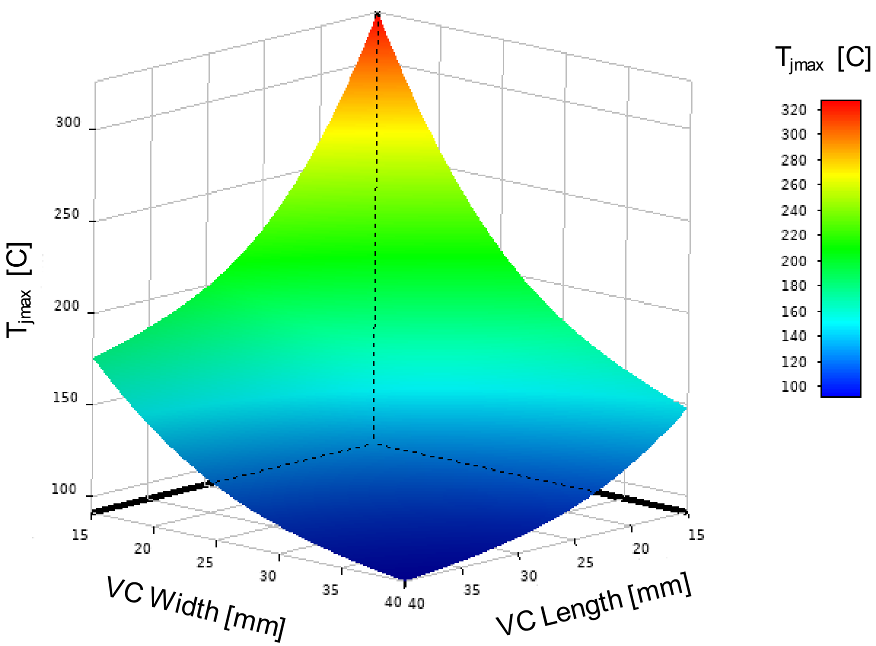
- Heat source size (PA module) = 10mm*10mm
- Heat flux of PA module = 100 W/cm^2 & 200 W/cm^2
- Heat transfer coefficient of the cold plate (1mm thick) = 1500 $[W/m^2.k]$
- Assumed values for thermal conductivities of VC: $k_x = k_y = 1500$ [W/m.k] and $k_z = 300$ [W/m.k]
- Assumed maximum junction temperature of PAs (T_{jmax}) = 100 $°C$
- Ambient temperature = 22 $°C$
- Typical range of the VC thickness is 1mm-1.5mm. Here, it is set to 1mm.
- The parametric analysis was conducted on dimensions of VC to keep T_{jmax} smaller than 100 $°C$

	Dielectric	PA	Glass	Cu-Gr Composite	Solder	Metal Carrier
Material	Resin Epoxy	Silicon	Glass	Copper	Tin	Copper
Isotropic Thermal Conductivity (W/m.K)	0.15	148	1.4	400	64	400

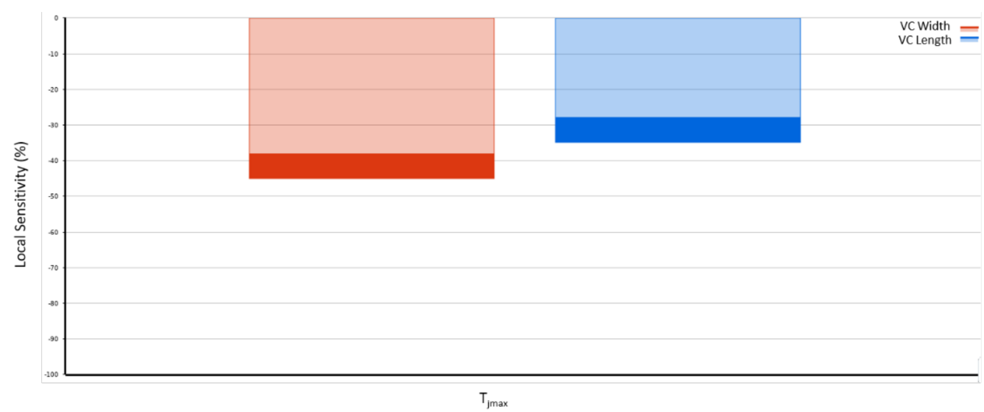
Preliminary Results

- Simulation results (Heat flux = 100 W/cm^2)

- To keep T_{jmax} smaller than 100 °C, both length and width of VC should be larger than 35.5 mm which give T_{jmax} equal to 100.15 °C.

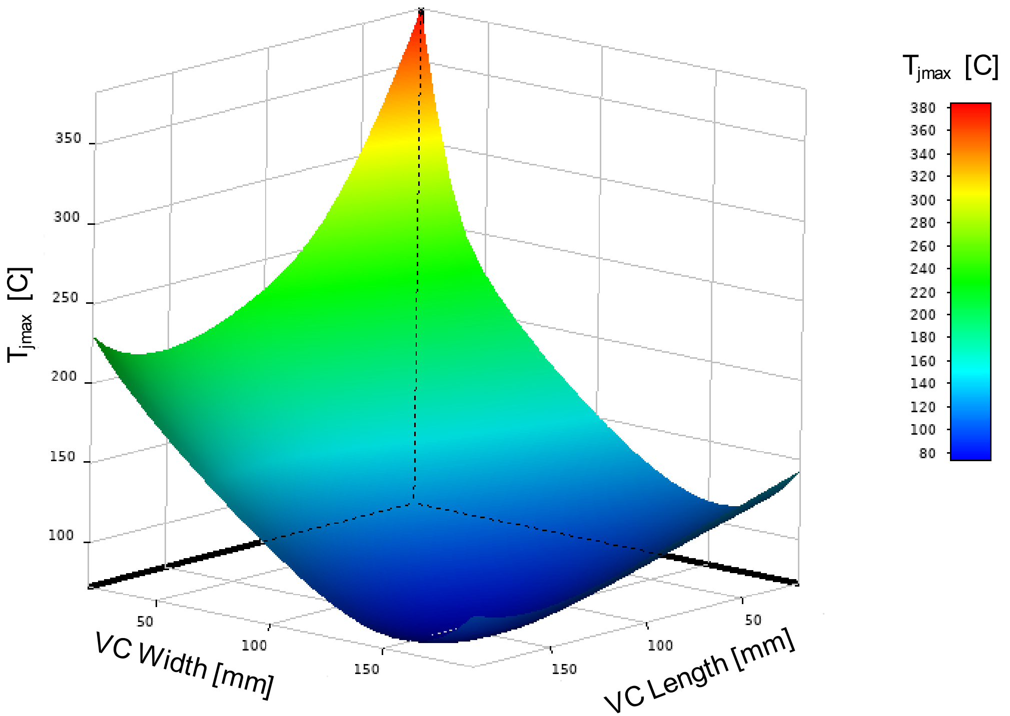


- Sensitivity analysis results show that T_{jmax} is more sensitive to VC width than its length.



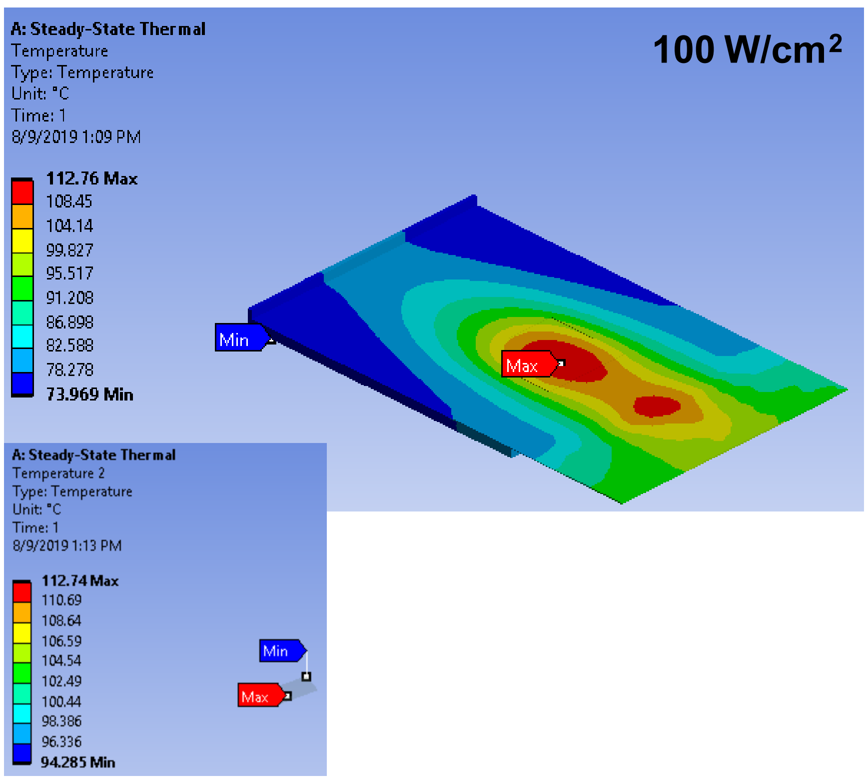
Preliminary Results (cont.)

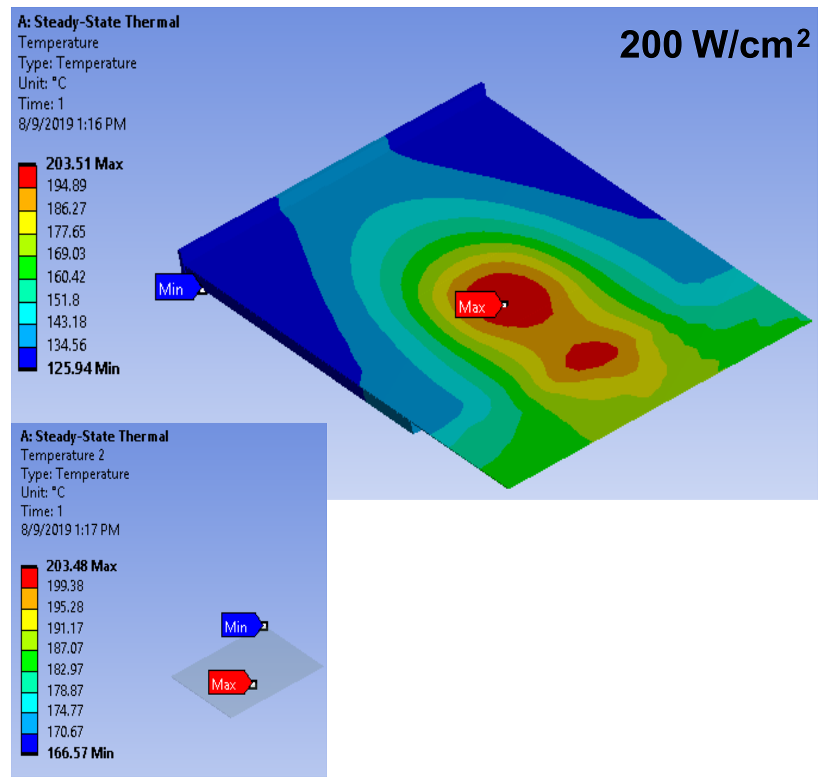
- ❑ Simulation results (Heat flux = 200 W/cm^2)
  - After optimization, the length and width of VC are determined as 158.87 mm and 156.96 mm which gives T_{jmax} equal to 72.402 °C.



Preliminary Results (cont.)

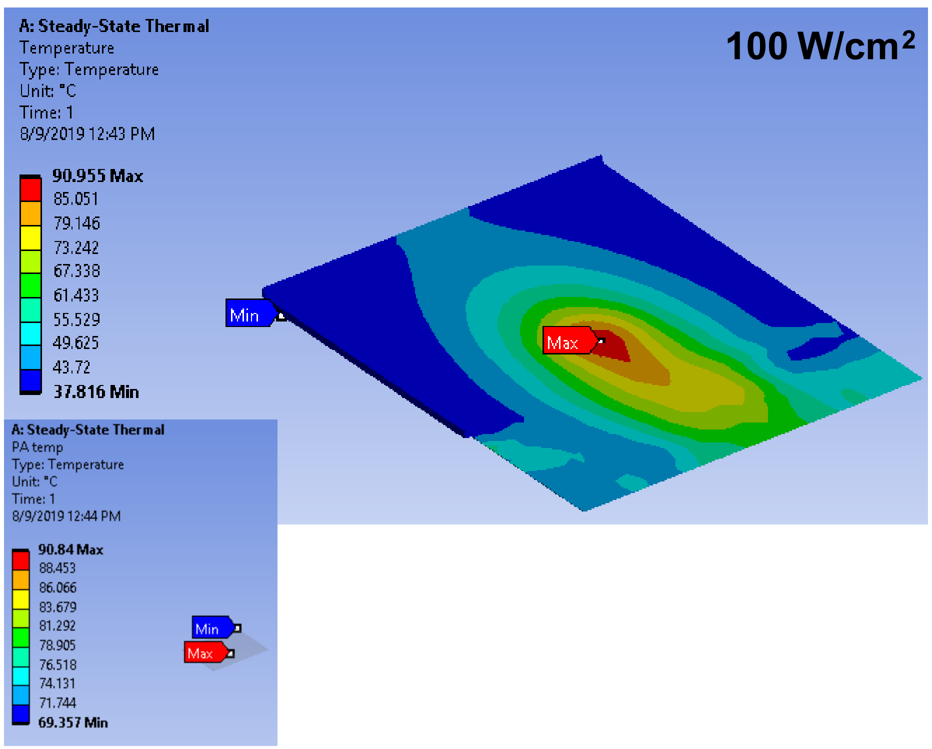
- Simulation results for 1 array
  - Glass panel size: 50mm*30mm*100um
  - VC Size: 35mm*30mm*1mm
  - Heat flux of PA = 100 W/cm^2 & 200 W/cm^2

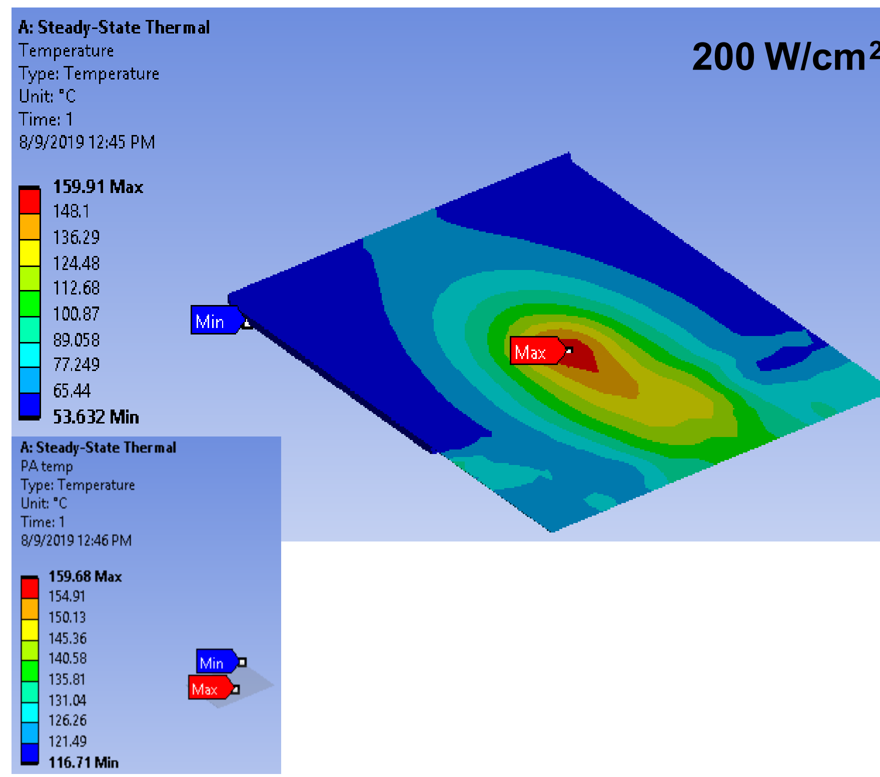




Preliminary Results (cont.)

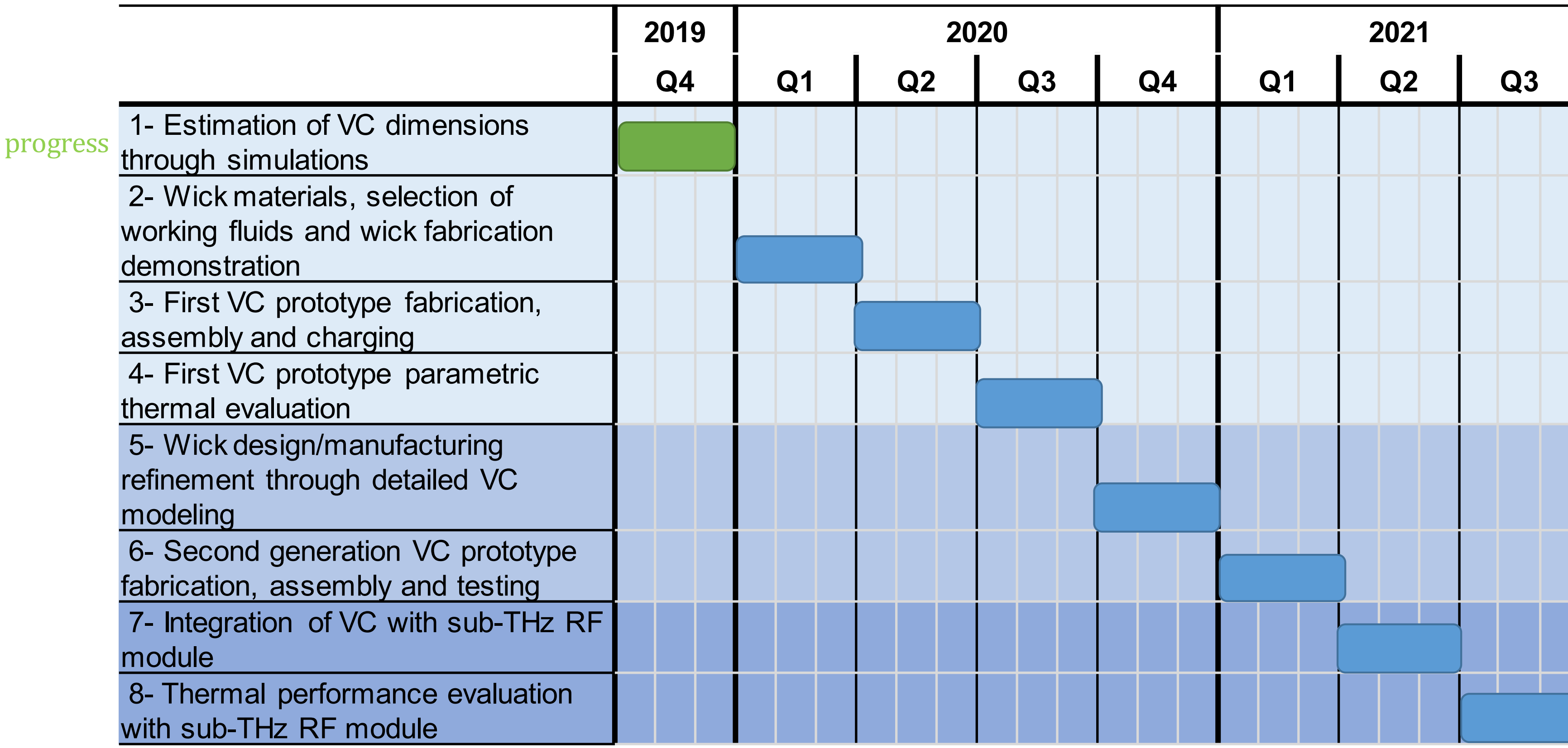
- Simulation results for 1 array
  - Glass panel size: 80mm*50mm*100um
  - VC Size: 50mm*50mm*1mm
  - Heat flux of PA = 100 W/cm^2 & 200 W/cm^2





Next Steps

- Goal is to use rigorous thermal modeling to design, fabricate and characterize the vapor chamber over the next two years by 2021.



Summary

- Effectiveness of VC for thermal management of 6G module was proved through the simulation results in ANSYS Workbench.

- Finding the right dimensions of VC considering the size and heat flux of the heat source along with the liquid convection from cold plate can lead to an efficient thermal management solution for future 6G module.

- For the heat flux of 100 W/cm^2, the parametric study showed that both length and width of VC should be larger than 35.5 mm to keep the PA junction temperature below 100 $°C$.

- Using optimization approaches, for the heat flux of 200 W/cm^2, the length and width of VC are determined as 158.87 mm and 156.96 mm to keep the PA junction temperature below 100 $°C$.