Thermal Management for 6G Module Using Vapor Chamber

Students: Nahid Aslani Amoli, Lydia Mele and Madeline Parnall (UG)
Faculty: Prof. Madhavan Swaminathan and Prof. Yogendra Joshi

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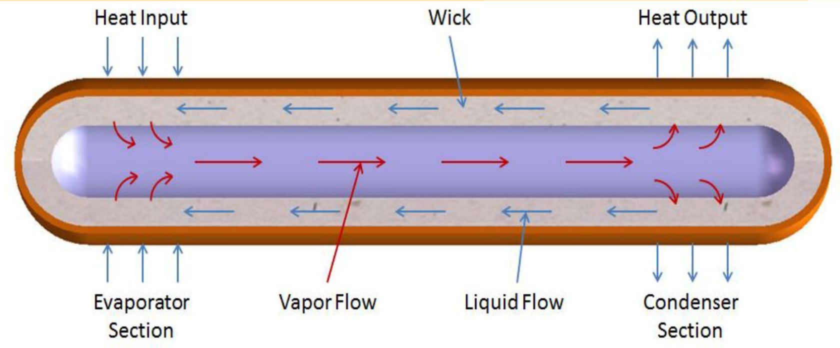
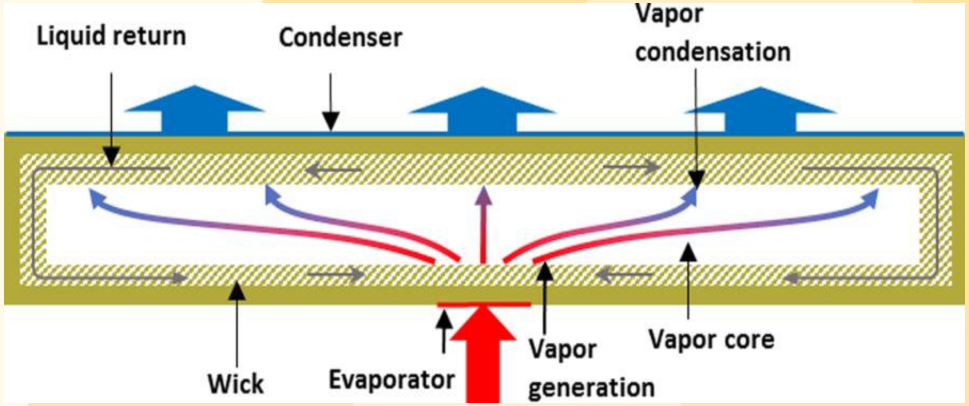
1. Research Objective

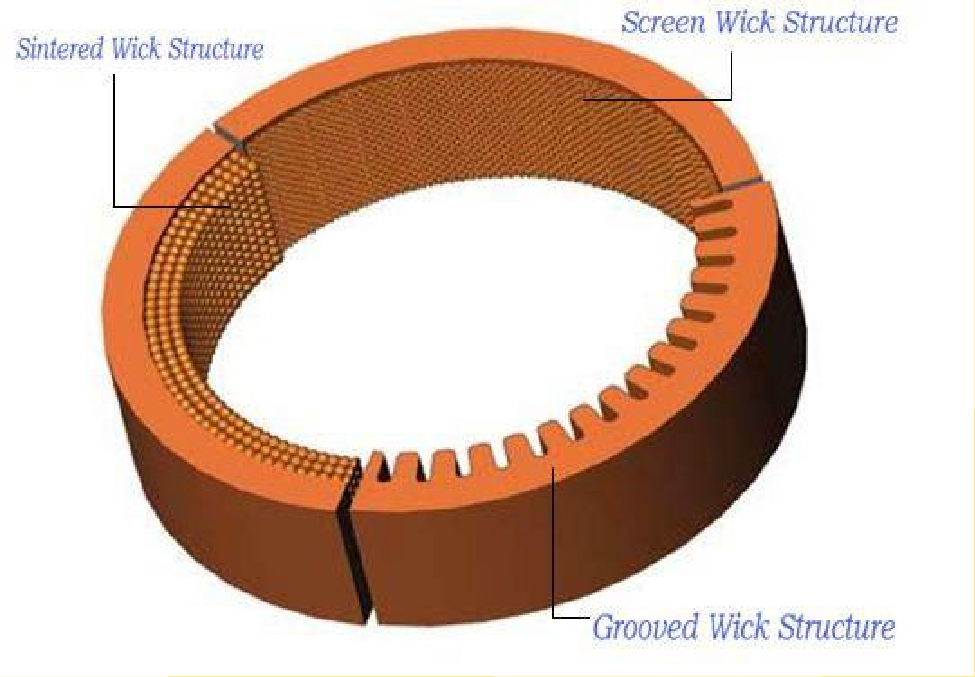
- Study of using Vapor Chamber (VC) for thermal management of sub-THz RF modules through modeling in ANSYS Workbench
- VC is a 2-phase cooling solution which has the same working principle as heat pipes.
- Heat pipes have a limitation of only 1-D heat flow while VC can provide multidirectional heat flow.
- They both use a medium such as water or any other fluid to transfer the heat from one point to the other.





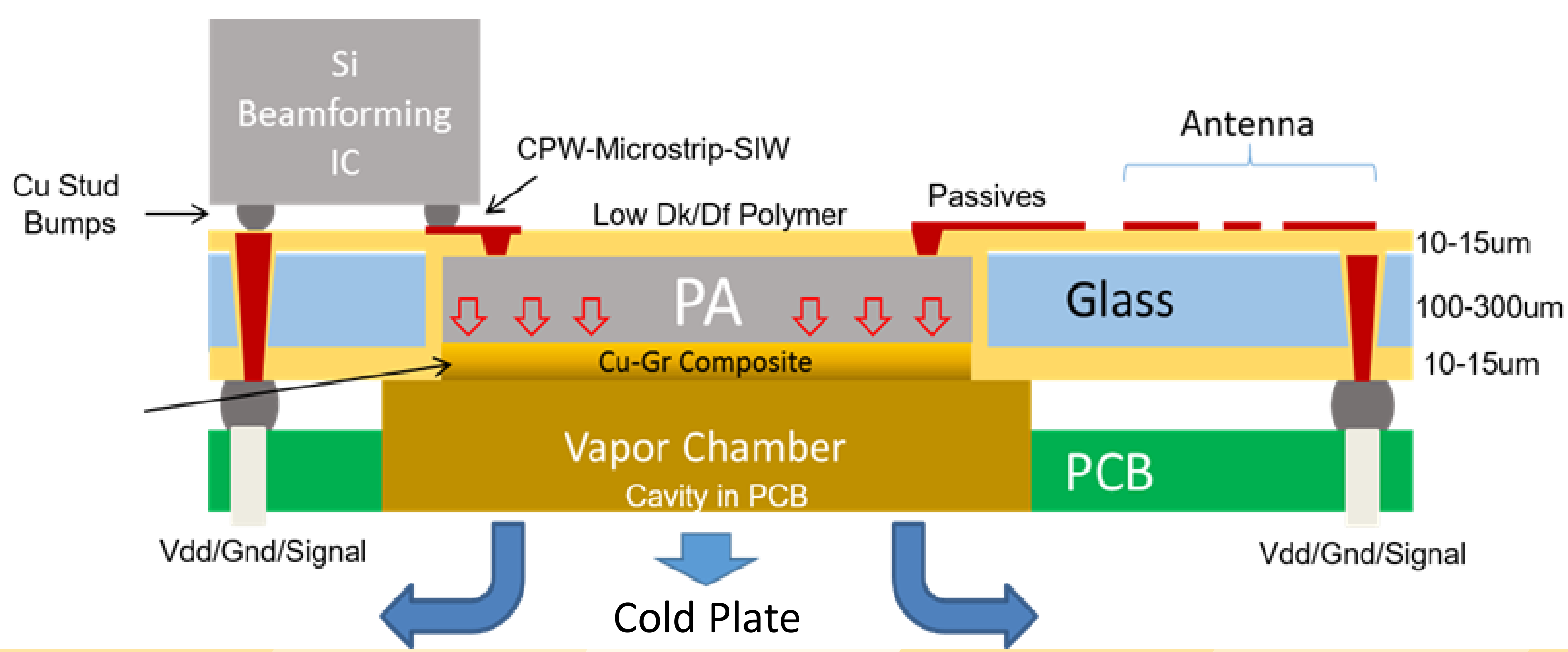
2. Configuration of VC

- The performance of a heat pipe and vapor chamber depends on several factors, one of which is the nature of the wick structure.
- To optimize the thermal performance of these devices requires wick structures that can provide high capillary pressure, high permeability and yet still offer low resistance to fluid flow.
- Types of wick structures:

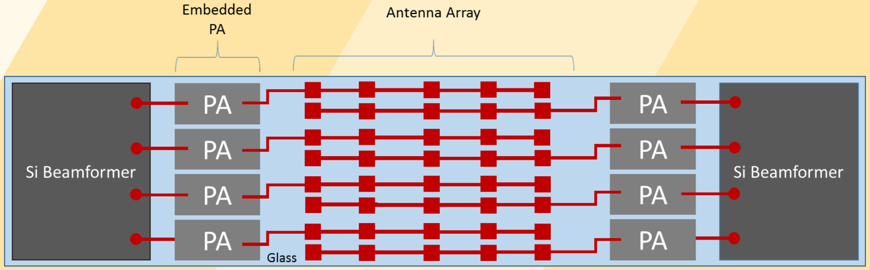


3. Background Details

- 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



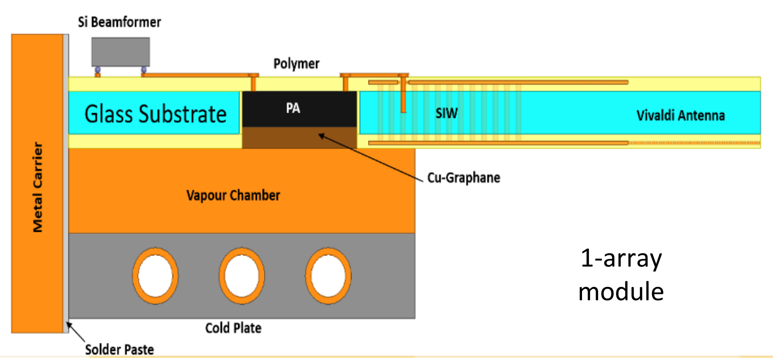
4. Technical Approach

- Conduction-based model of VC

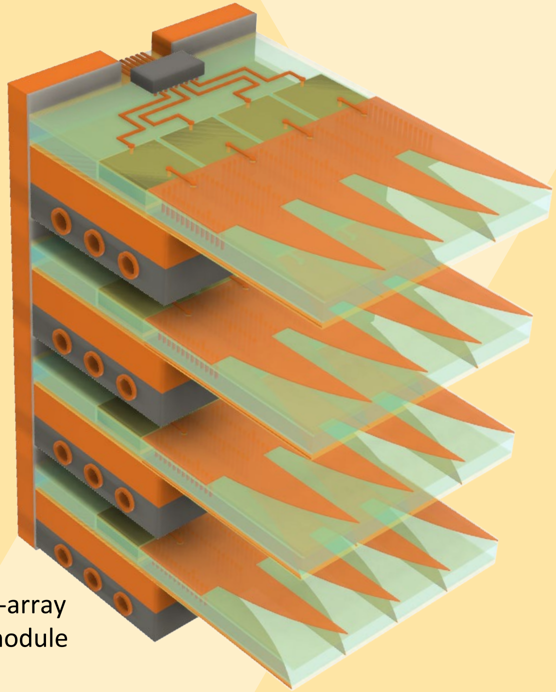
- Isotropic approach which treats the whole VC as a rectangular plate having an isotropic conductivity ($k_x = k_y = k_z = k_{vc}$);

- 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 research, the VC was modeled with orthotropic approach in ANSYS Workbench using Steady State Thermal Analysis module.



1-array module



4-array module

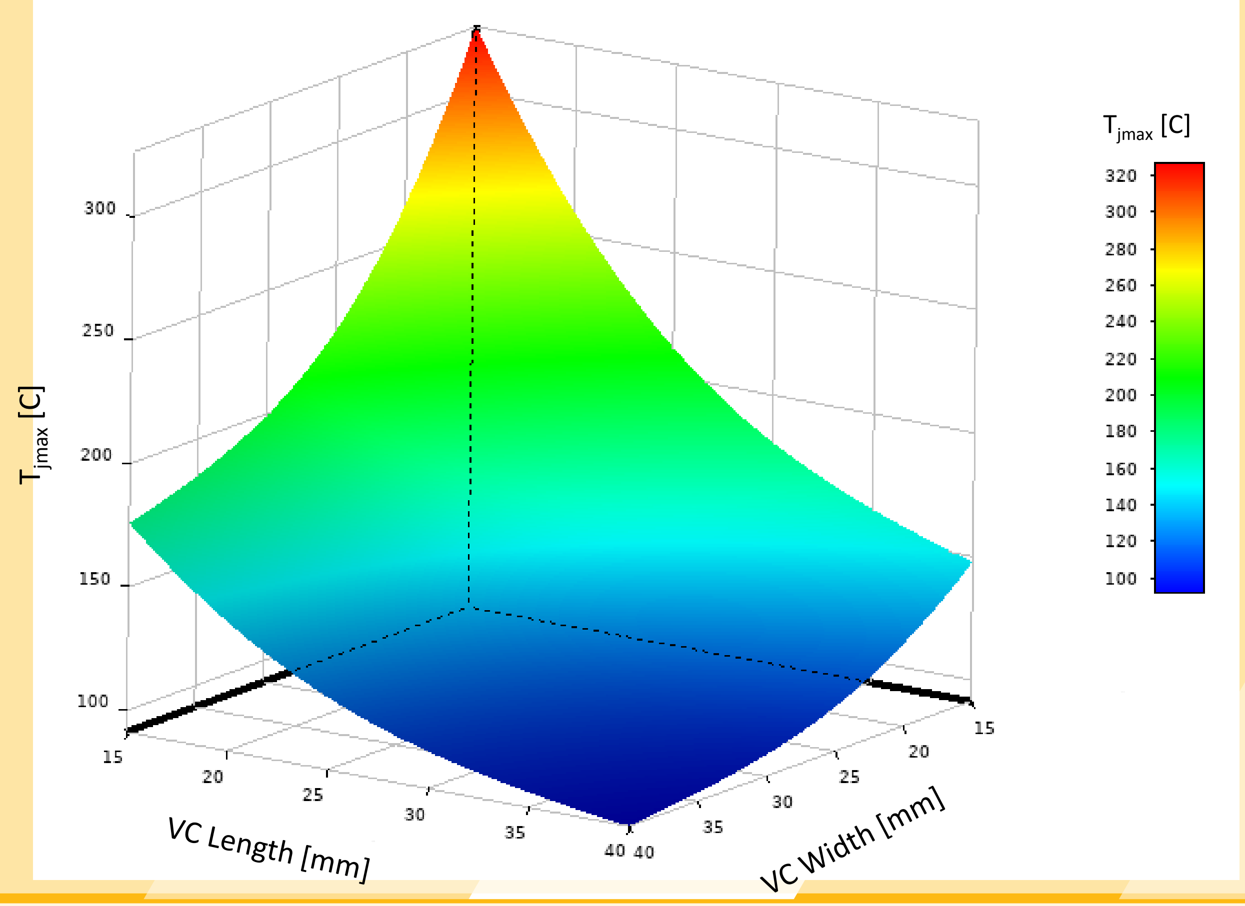
5. Model Inputs

- 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

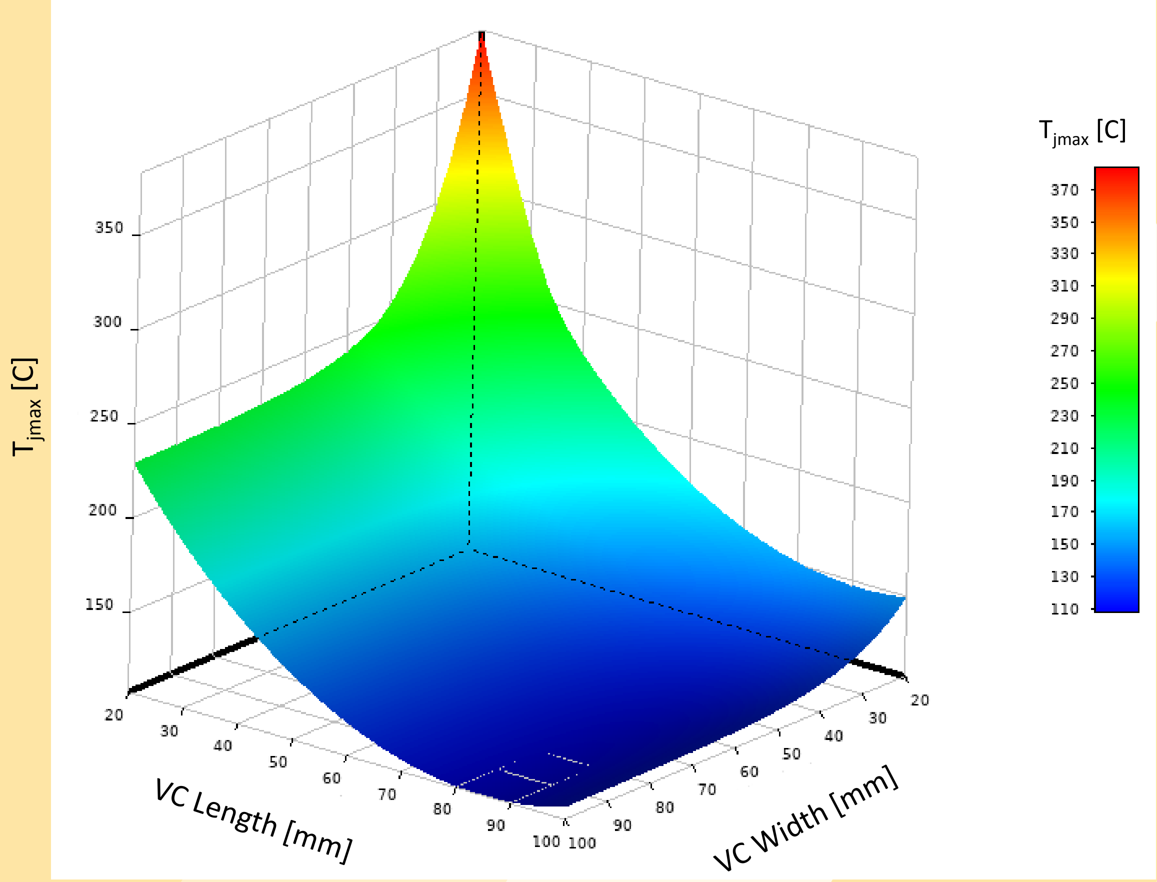
6. Preliminary Results

- Maximum junction temperature of PA versus length and width of VC for heat flux = 100 W/cm^2
  - To keep T_{jmax} smaller than 100 C, length and width of VC should be larger than 40 mm.



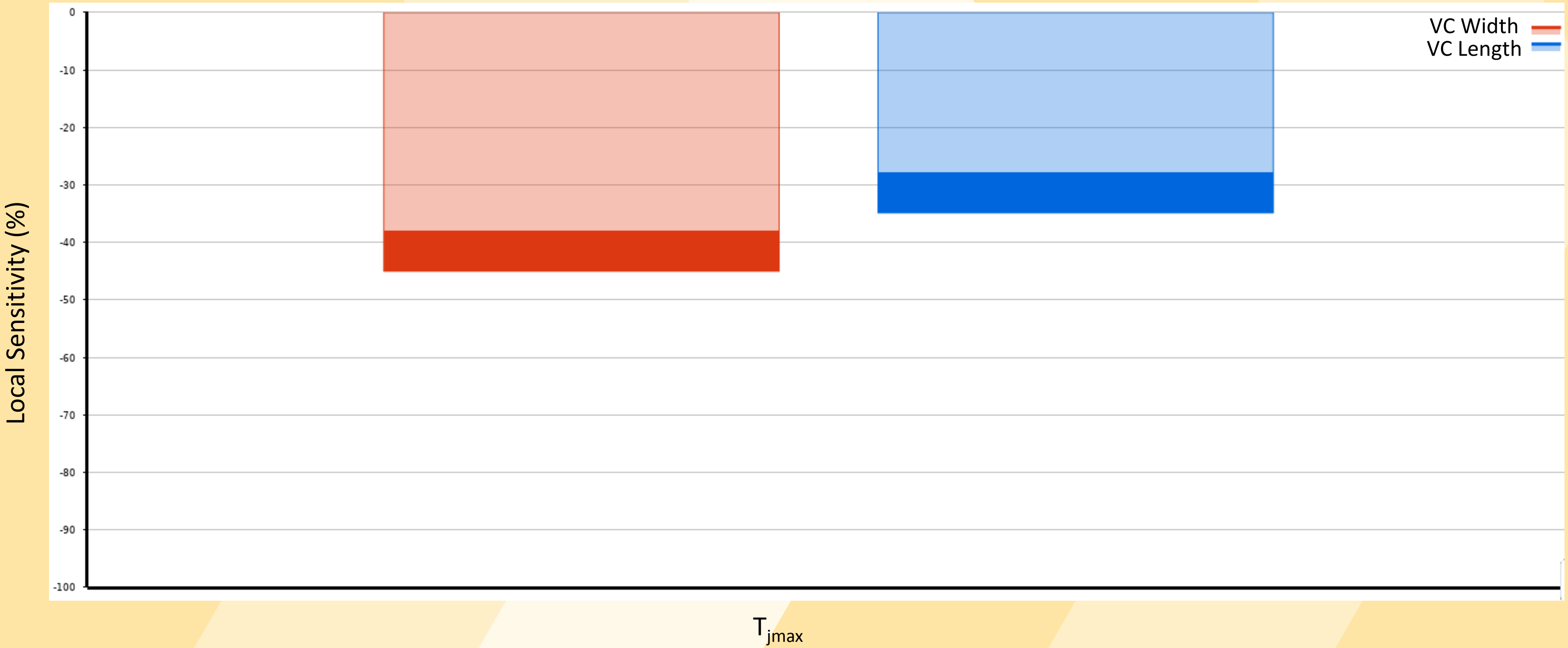
7. Preliminary Results

- Maximum junction temperature of PA versus length and width of VC for heat flux = 200 W/cm^2
  - To keep T_{jmax} smaller than 100 C, length and width of VC should be larger than 120 mm.



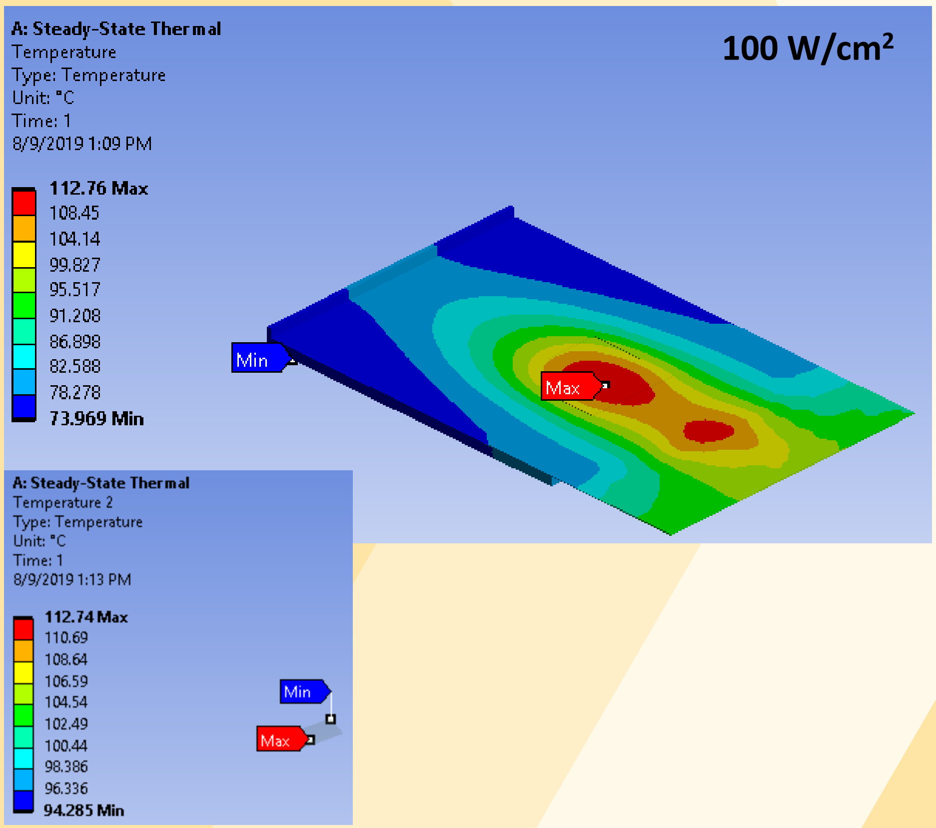
8. Sensitivity Analysis Results

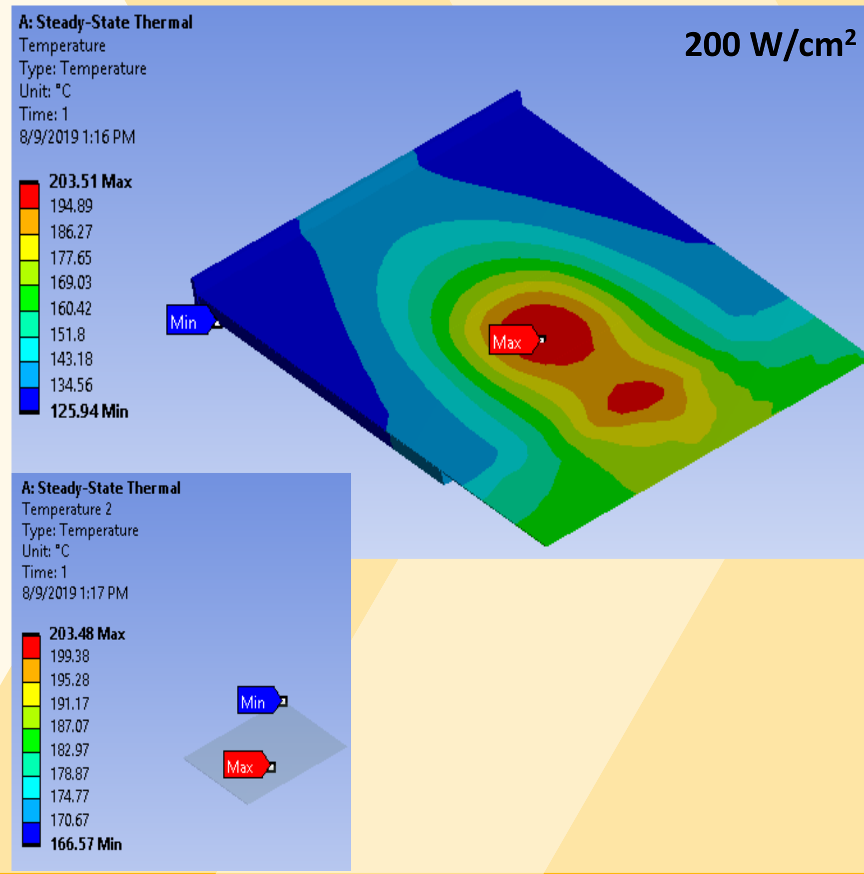
- Sensitivity analysis of T_{jmax} versus length and width of VC for heat flux = 100 W/cm^2
- It shows that T_{jmax} is more sensitive to VC width than its length.



9. Temperature Contour for 1 Array

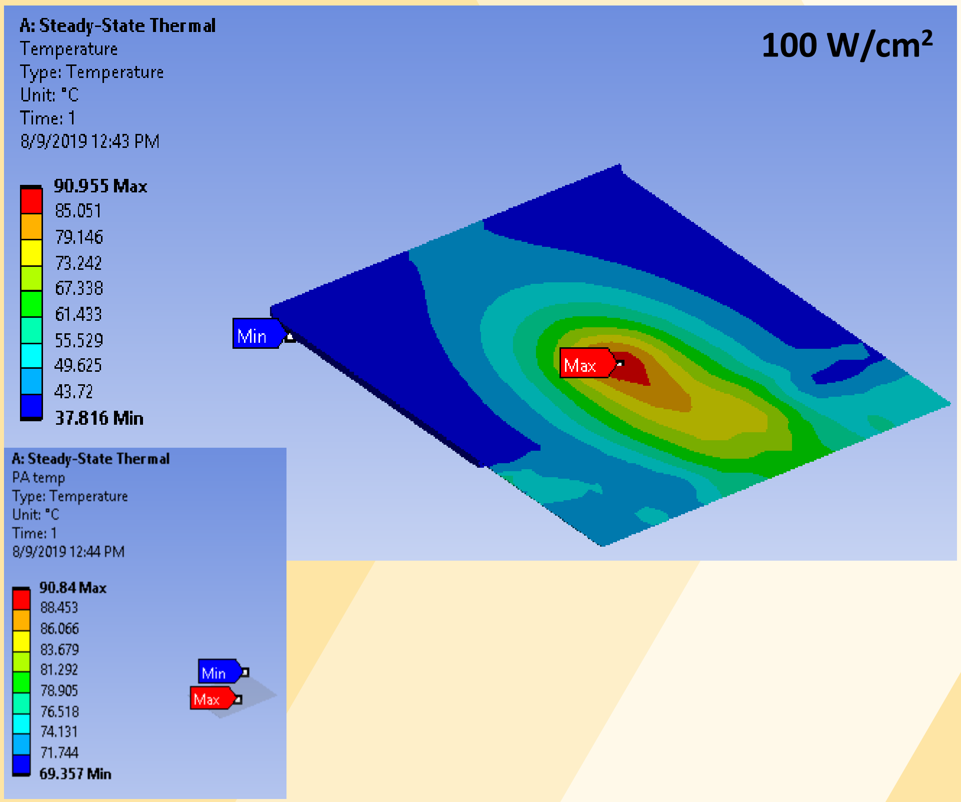
- Glass panel size: 50mm*30mm*100um
- VC Size: 35mm*30mm*1mm
- Heat flux of PA = 100 W/cm^2 & 200 W/cm^2

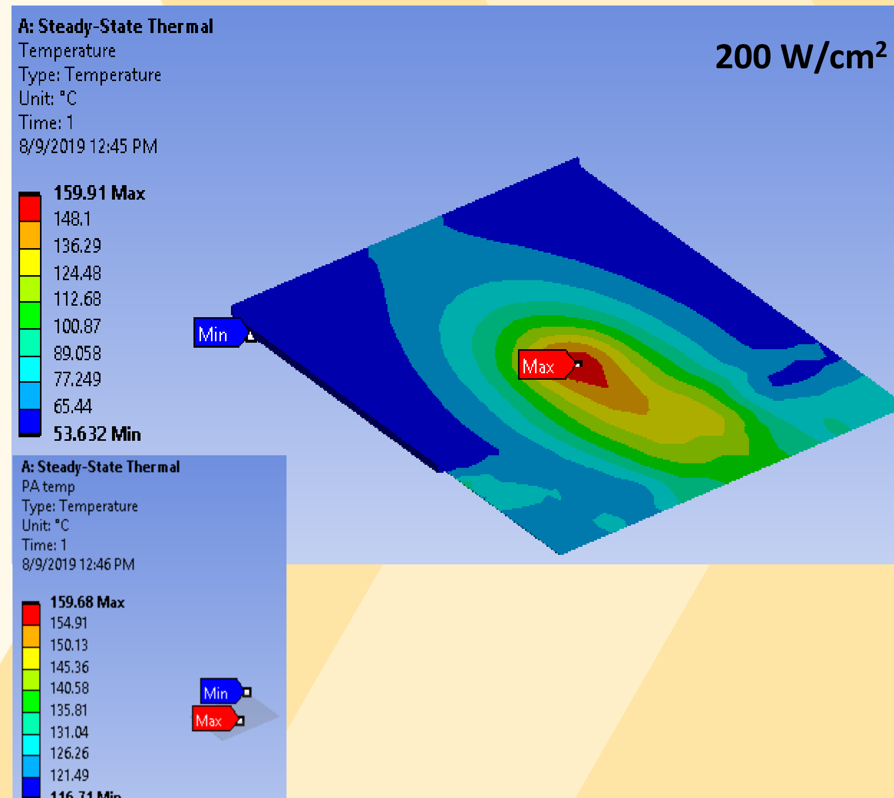




10. Temperature Contour for 1 Array

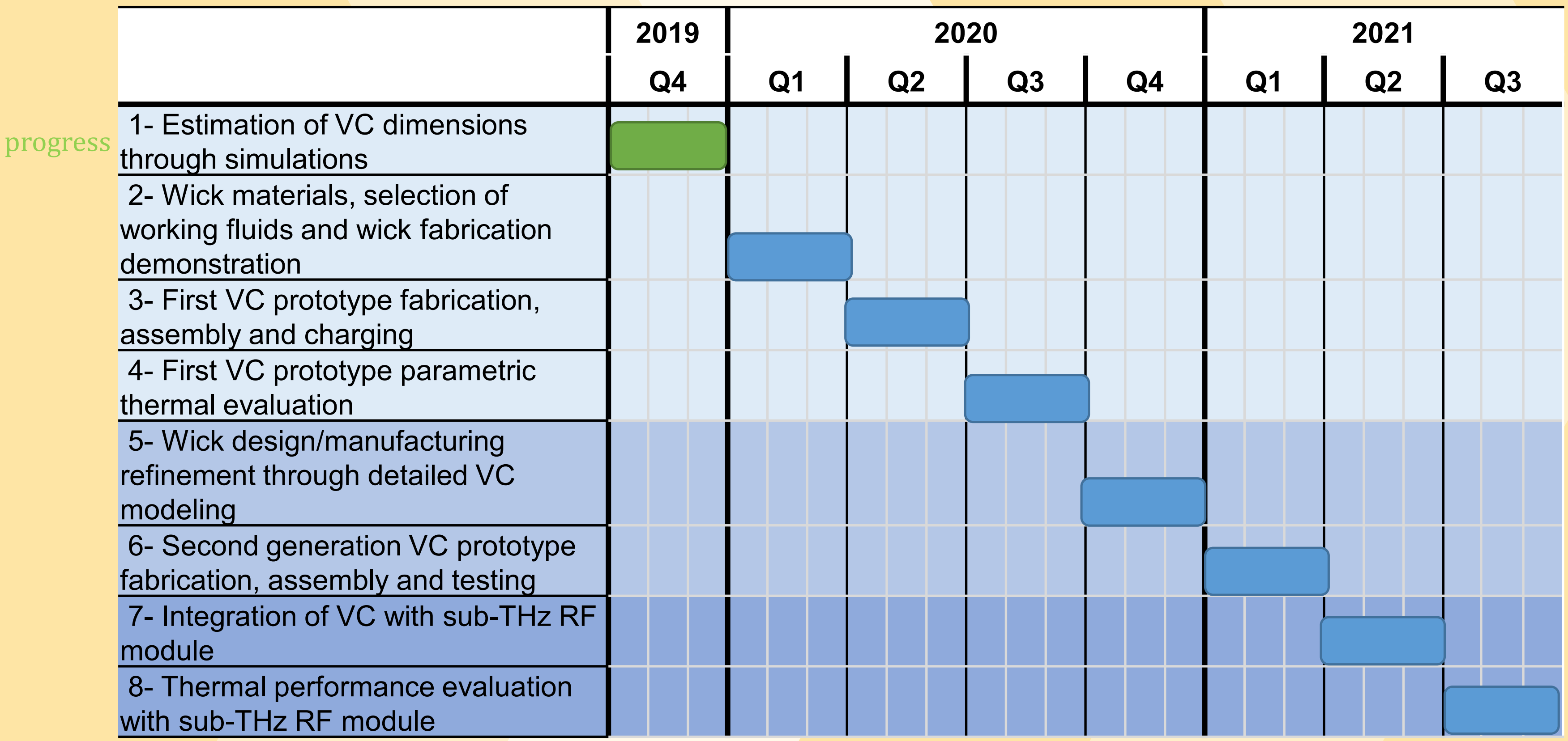
- Glass panel size: 80mm*50mm*100um
- VC Size: 50mm*50mm*1mm
- Heat flux of PA = 100 W/cm^2 & 200 W/cm^2





11. Schedule of Project

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



12. 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 simulation results showed that the length and width of VC should be larger than 40 mm to keep the PA junction temperature below 100 degree C.
- From the simulation results, for the heat flux of 200 W/cm^2 , the length and width of VC should be larger than 120 mm to keep the PA junction temperature below 100 degree C.