$La_5Ca_9Cu_{24}O_{41}$ Layers as 1D Heat Spreaders for Thermal Management Solutions

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Overview

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- Thermal Management Problem

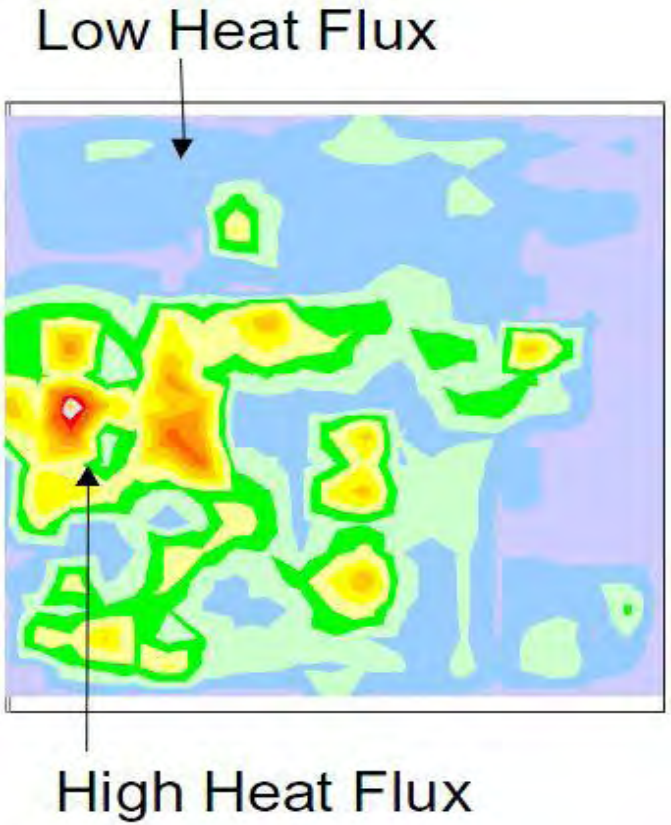
& Solution – The Idea

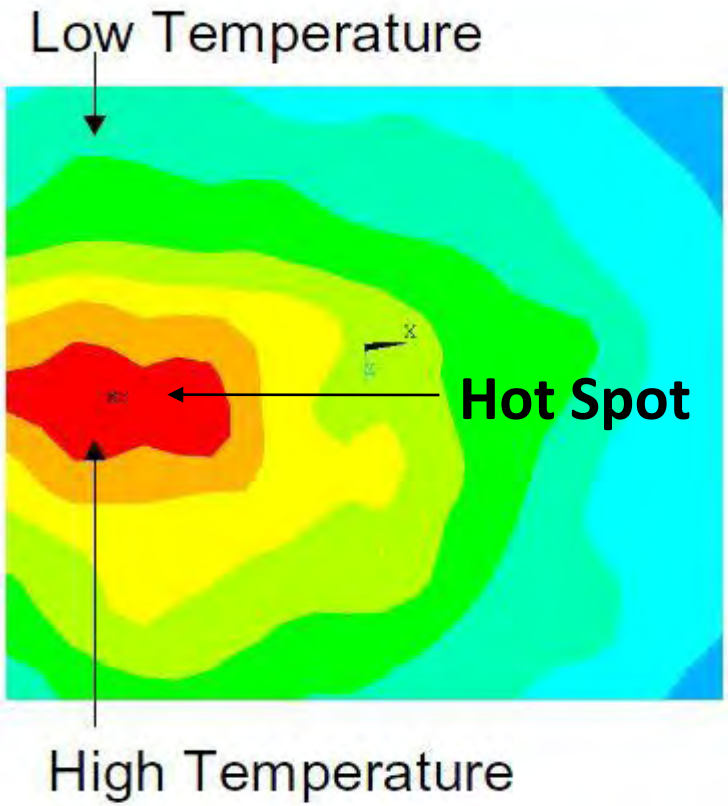
- The $La_5Ca_9Cu_{24}O_{41}$ material

- Equations
- Set up problem, Mesh & Results

- Conclusions

Thermal Management Problem



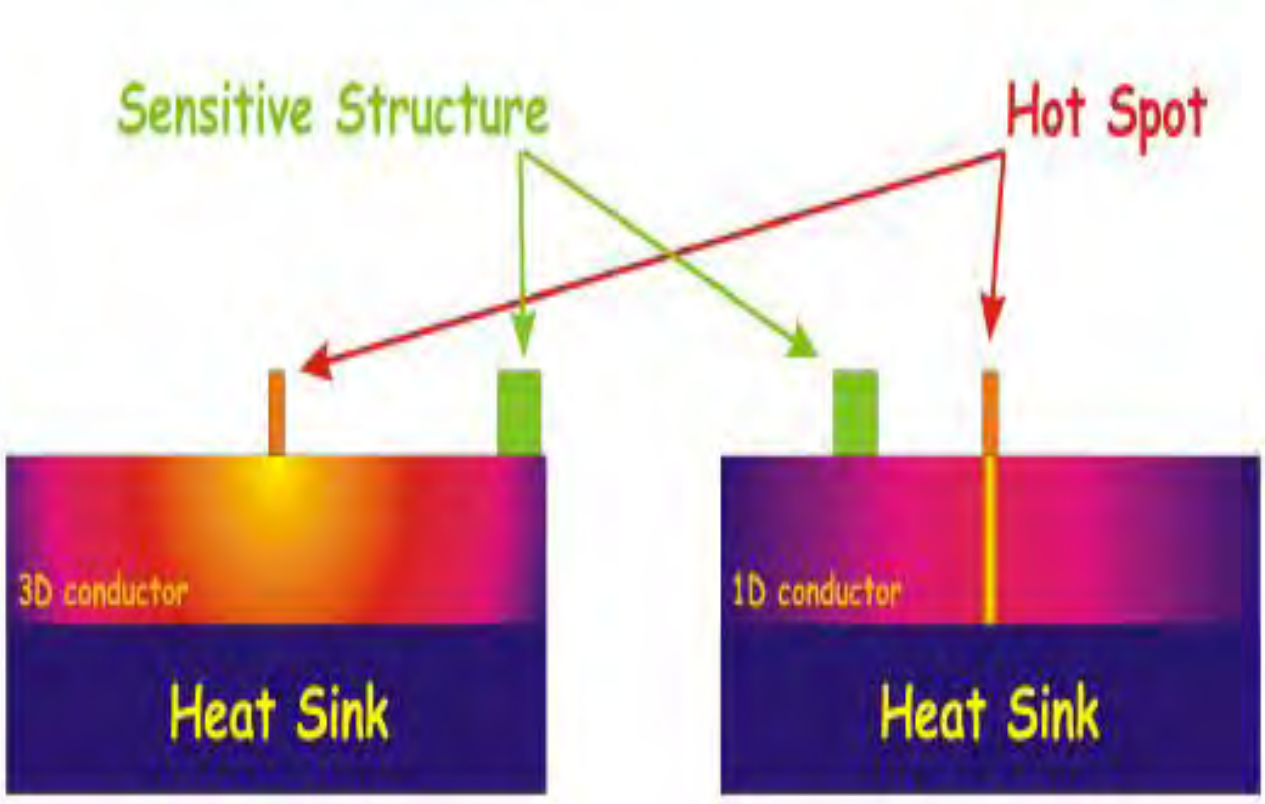


- Operating System → Flux Spots, Hot Spots

- Operating at high T → more possibilities to failure

R. Viswanath et al., *Intel Technology Journal*, Q3, 2000

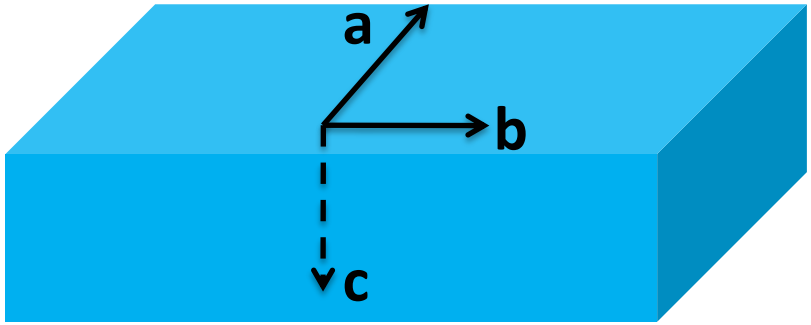
Thermal Management Solution – The Idea



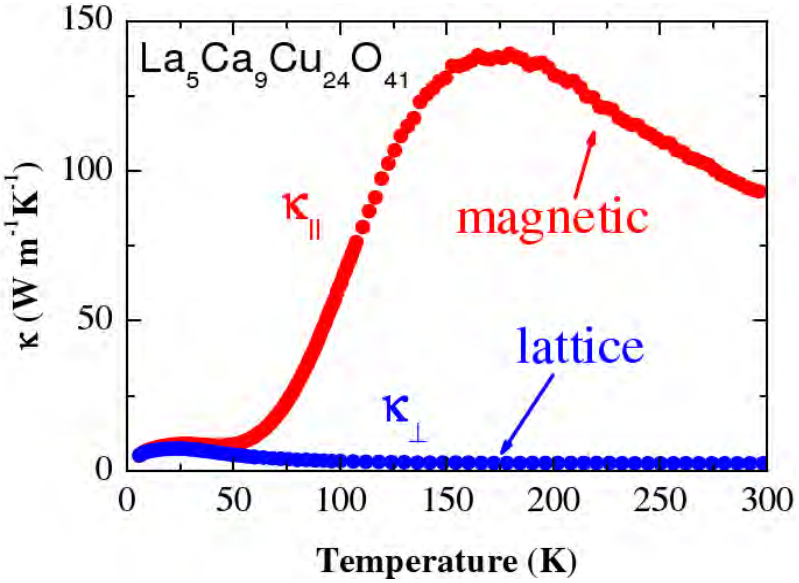
The $La_5Ca_9Cu_{24}O_{41}$ material

Thermally Conducting but electrically insulating

$La_5Ca_9Cu_{24}O_{41}$ layer c-axis oriented :



Thermal Conductivity



at Room Temperature:

$\kappa_a = \kappa_b \approx$ **1 W/m·K**

&

$\kappa_c \approx$ **100 W/m·K**

C. Hess et al., *Physical Review B*, vol.64, 2001

Equations

The heat conduction was modeled by solving the steady state, two-dimensional heat conduction equation:

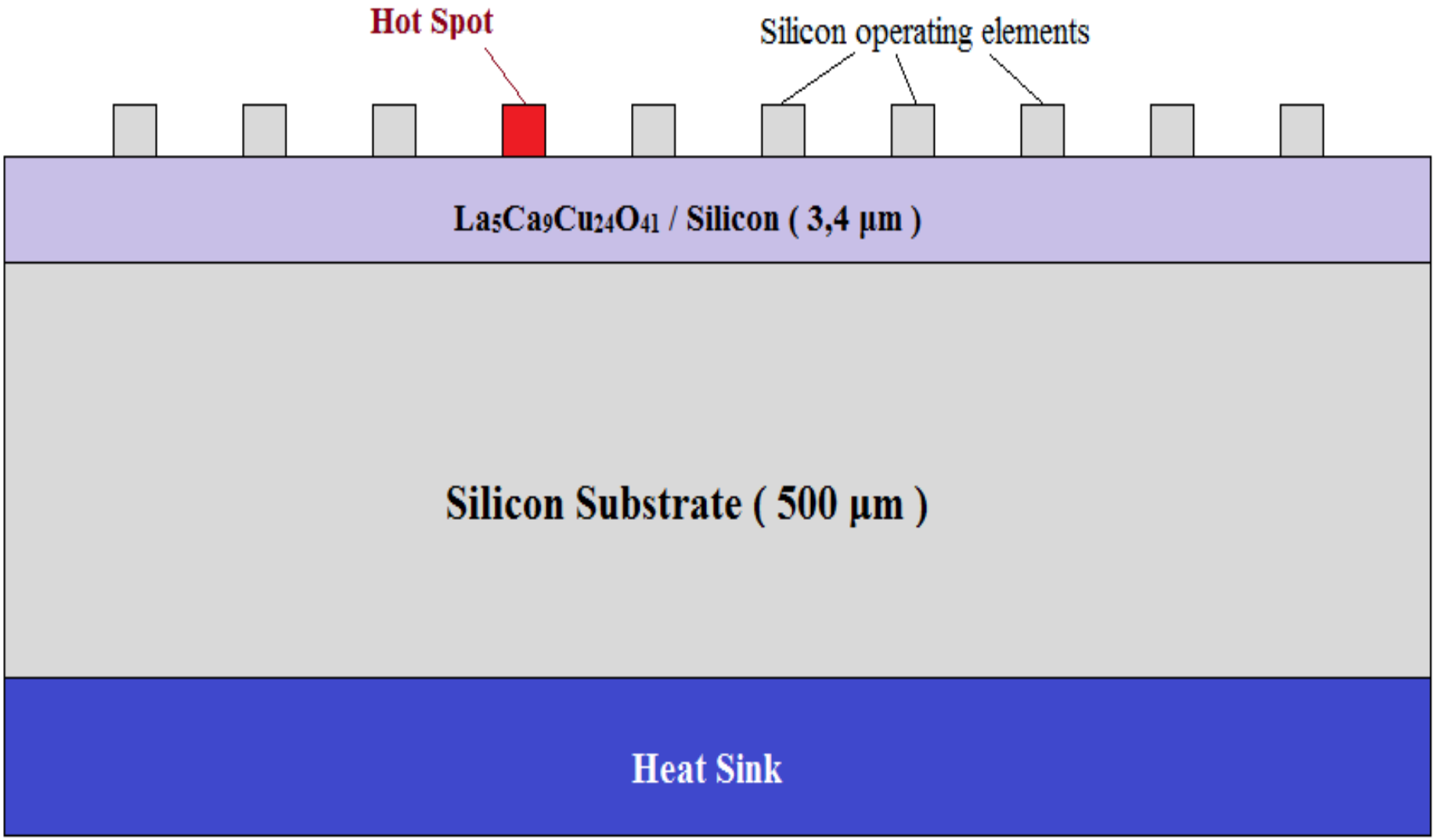
$$\frac{\partial}{\partial x}\left(\kappa_x \frac{\partial T}{\partial x}\right) + \frac{\partial}{\partial y}\left(\kappa_y \frac{\partial T}{\partial y}\right) = 0$$

A normal heat flux is applied at the top of the silicon operating elements using Fourier's law:

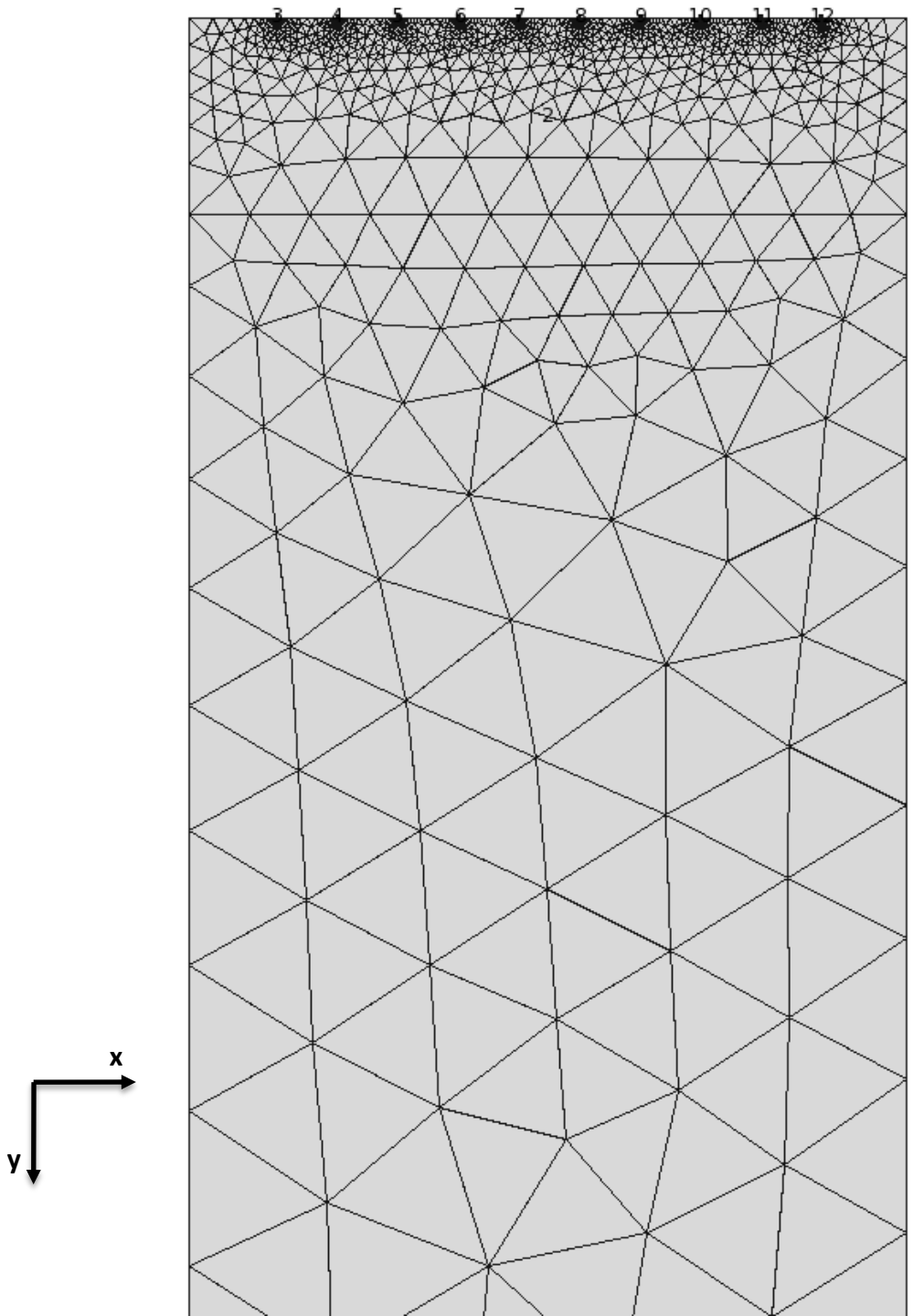
$$Q_y = -\kappa_y \left(\frac{\partial T}{\partial y}\right)$$

$\mathbf{Q_y}$ = heat flux
$\mathbf{T}$ = absolute temperature
$\boldsymbol{\kappa_x}$, $\boldsymbol{\kappa_y}$ = local values of thermal conductivity

Set up problem

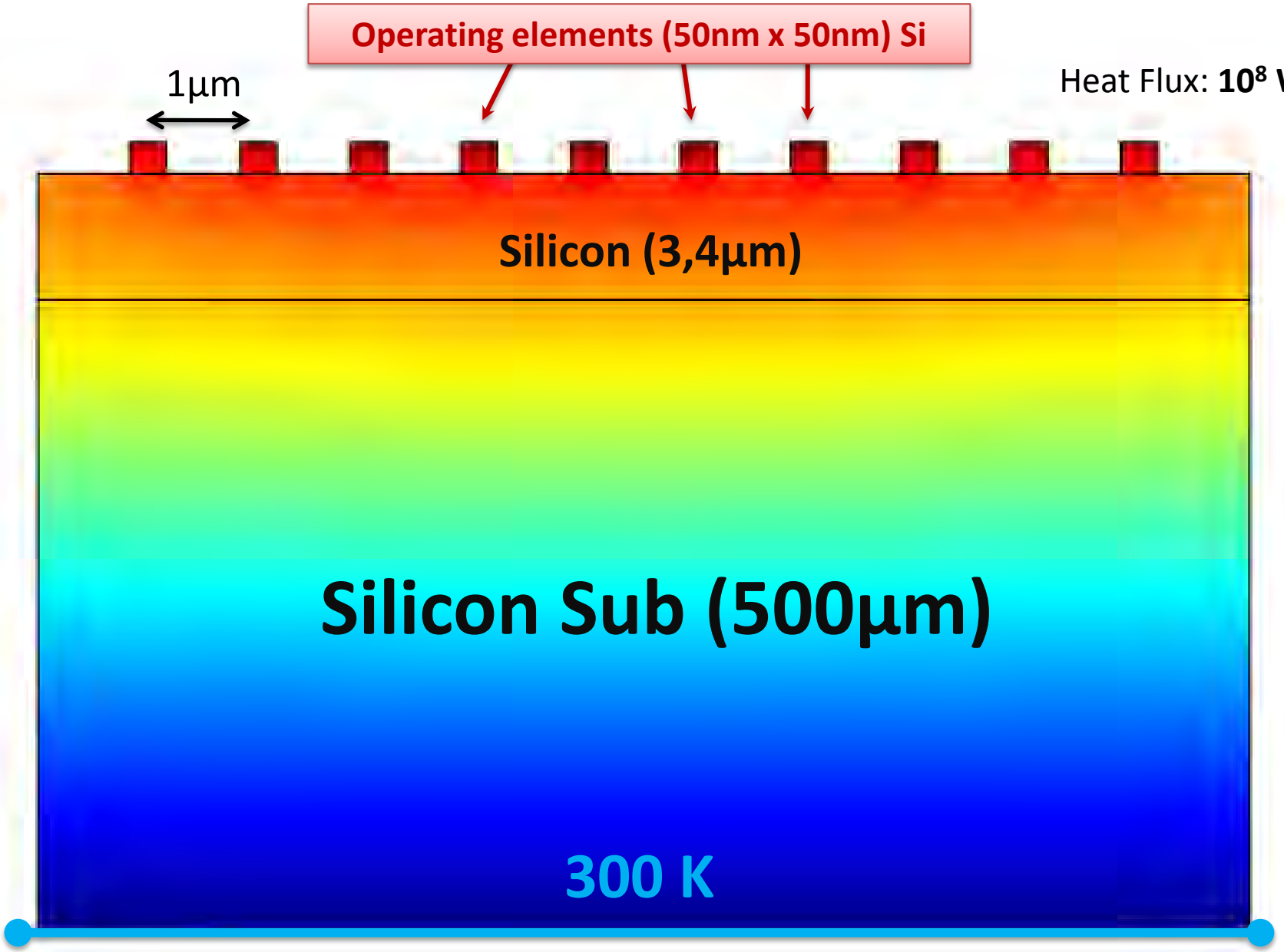


Mesh

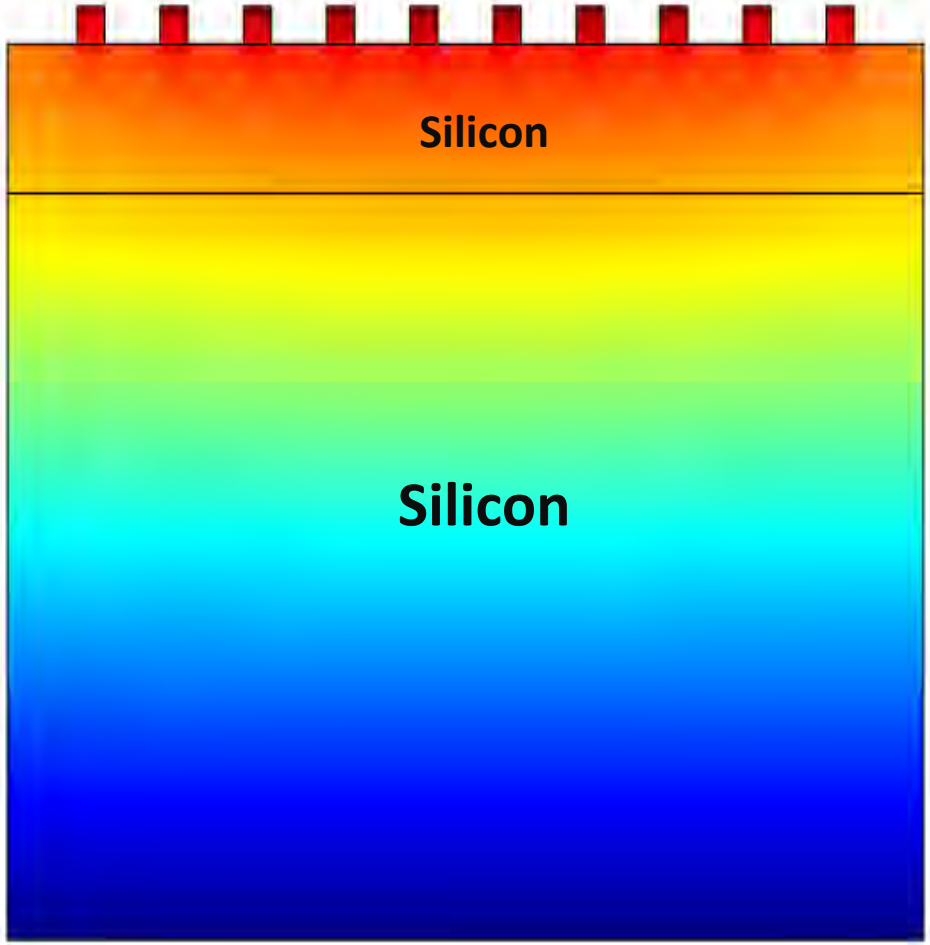


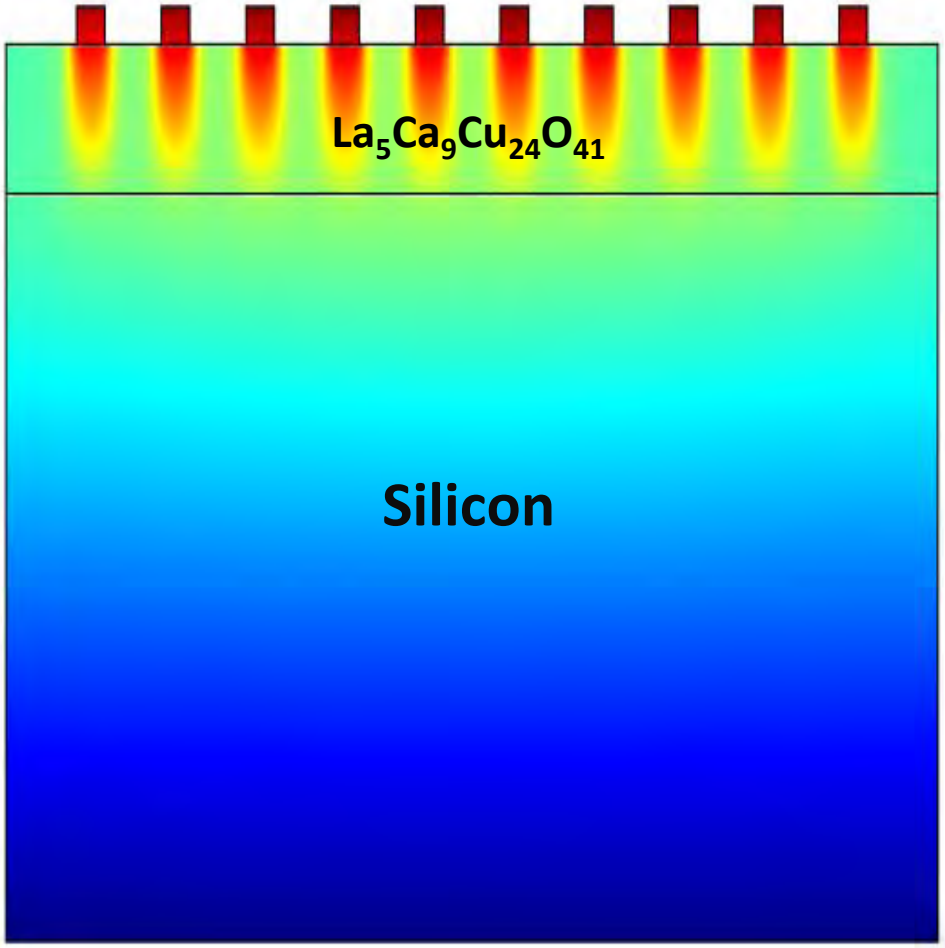
- Free Triangular
- 3074 elements

Set up problem

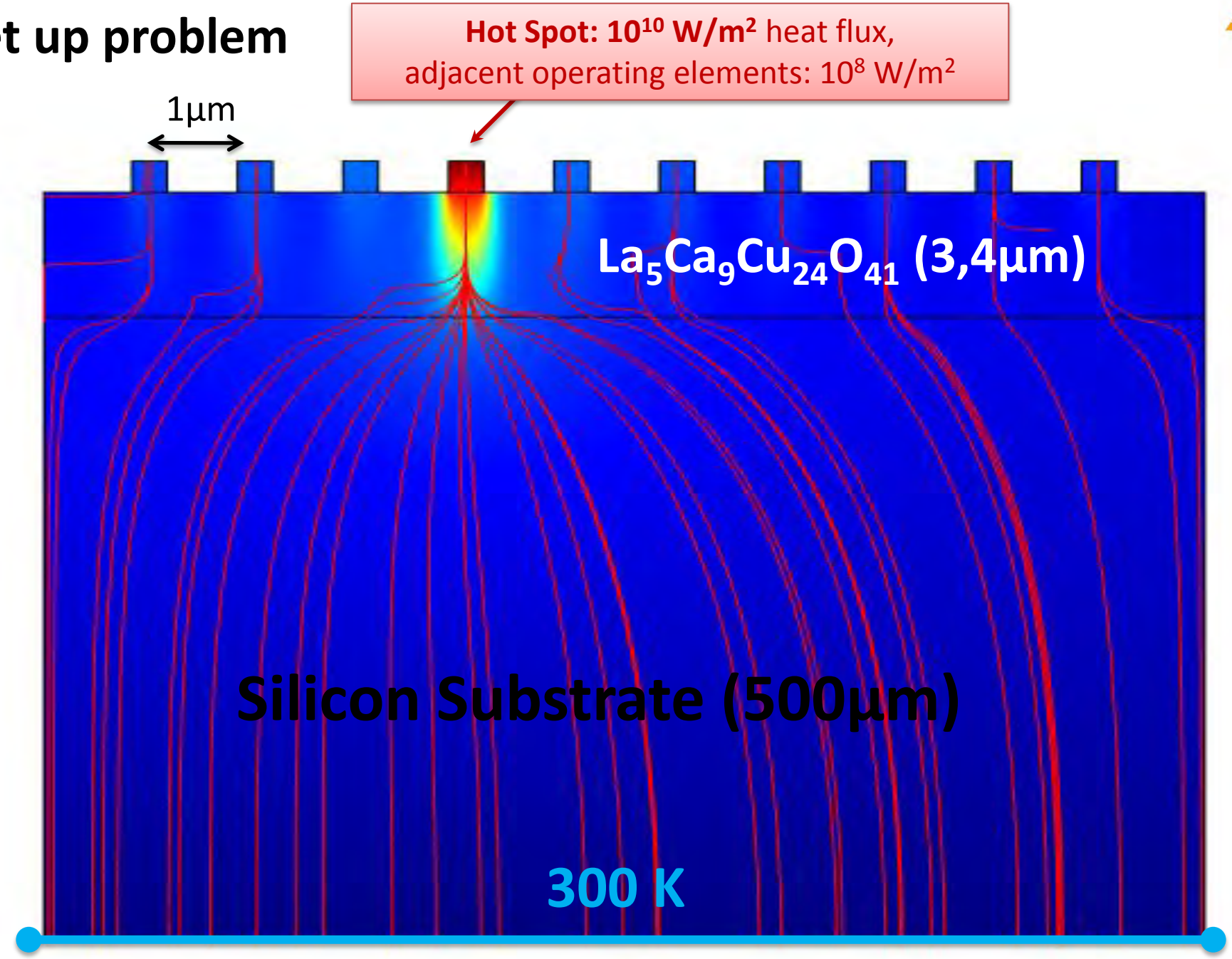


Set up problem

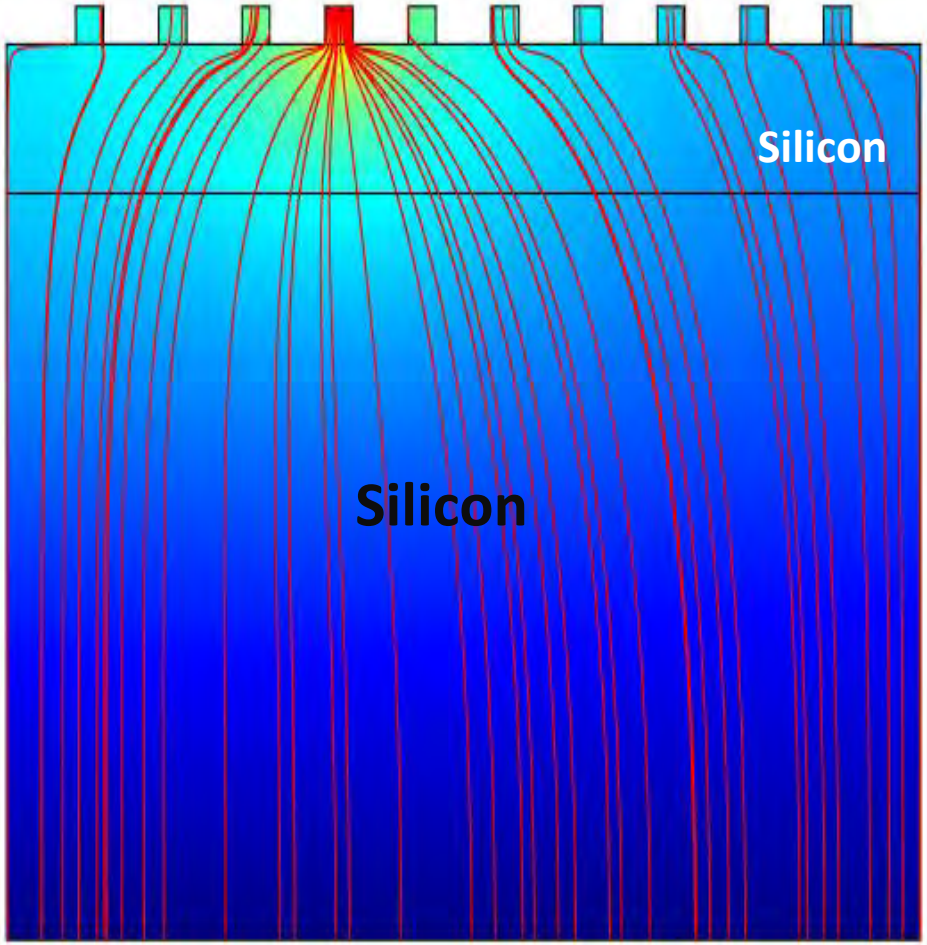


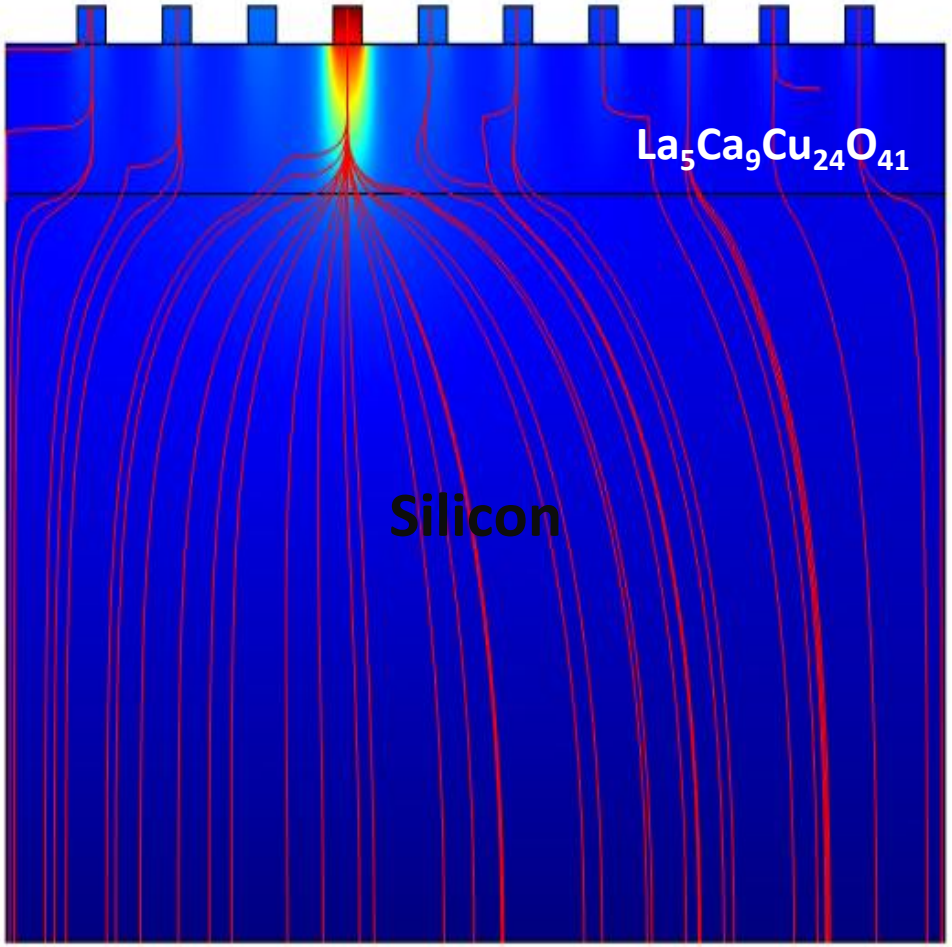


Set up problem

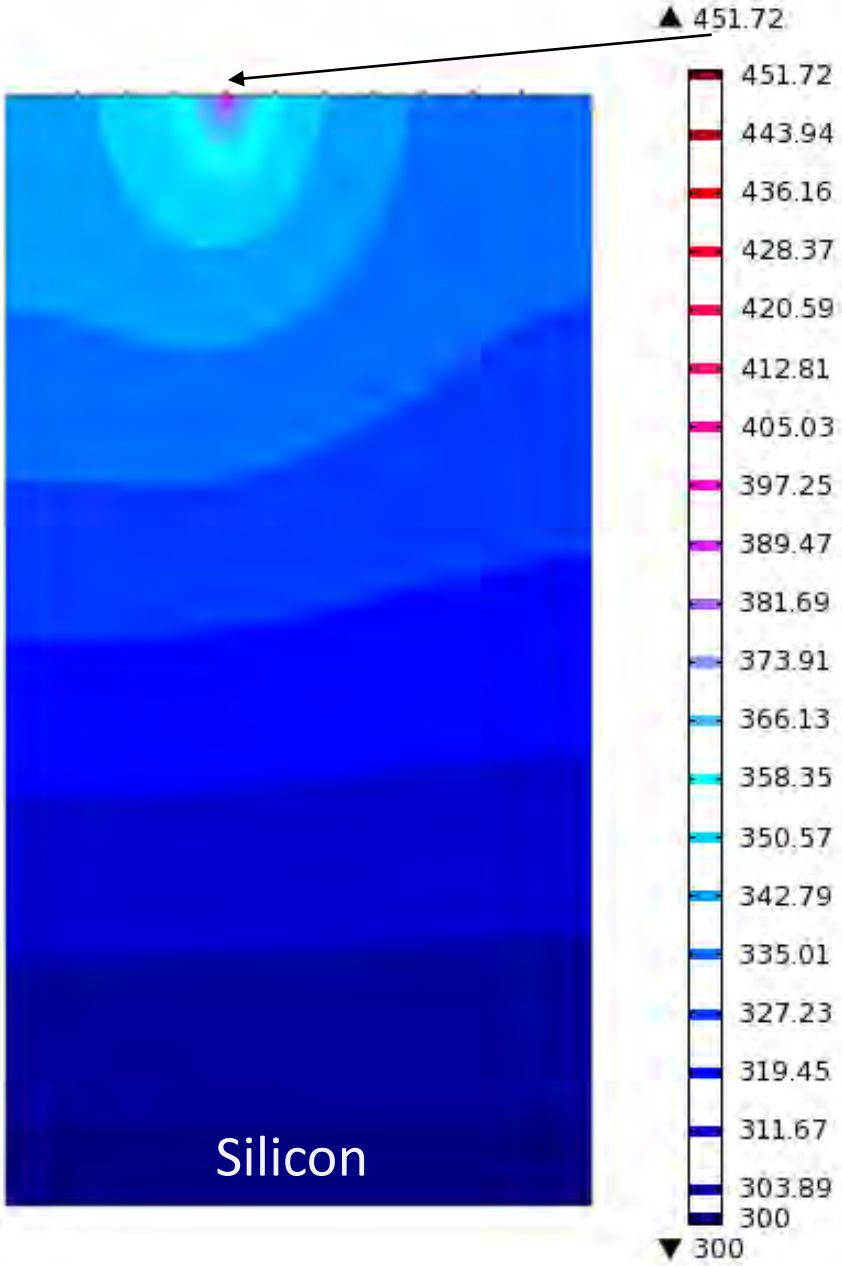


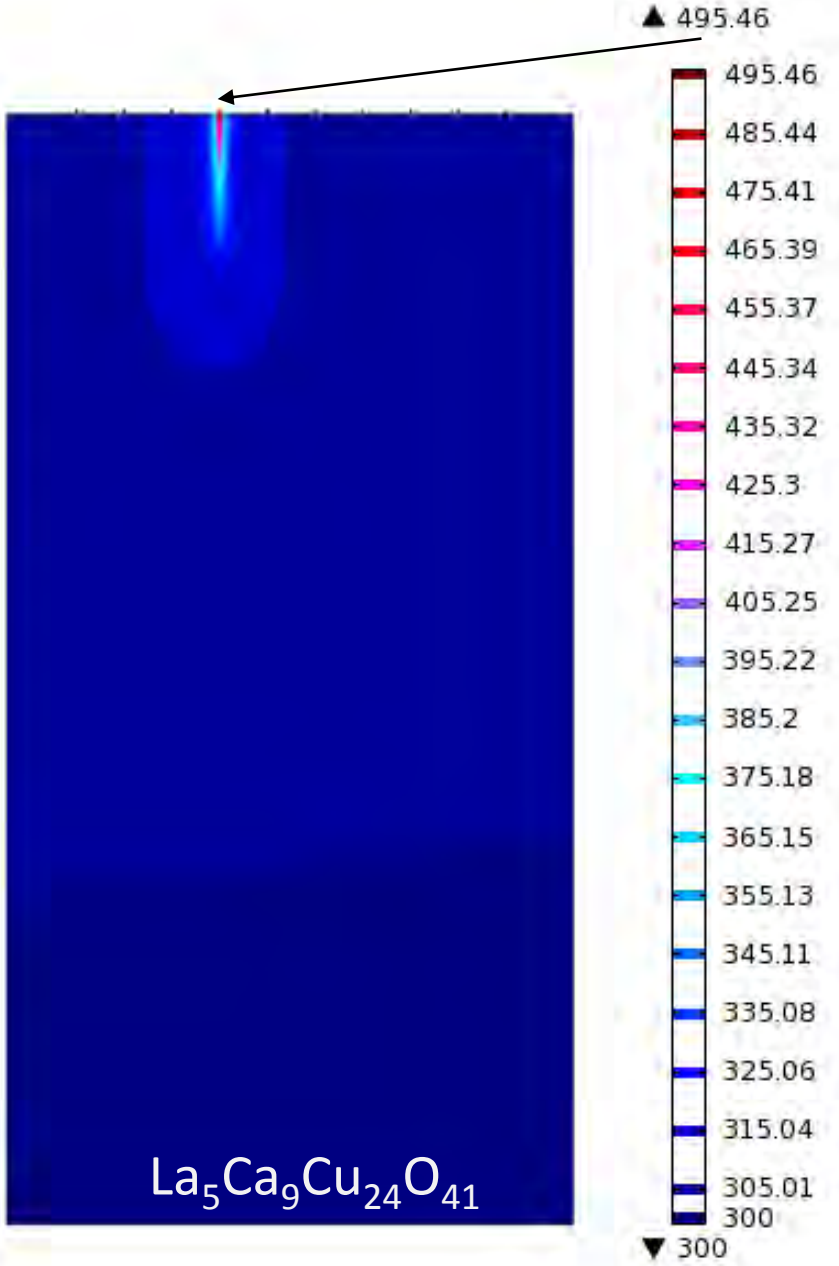
Set up problem



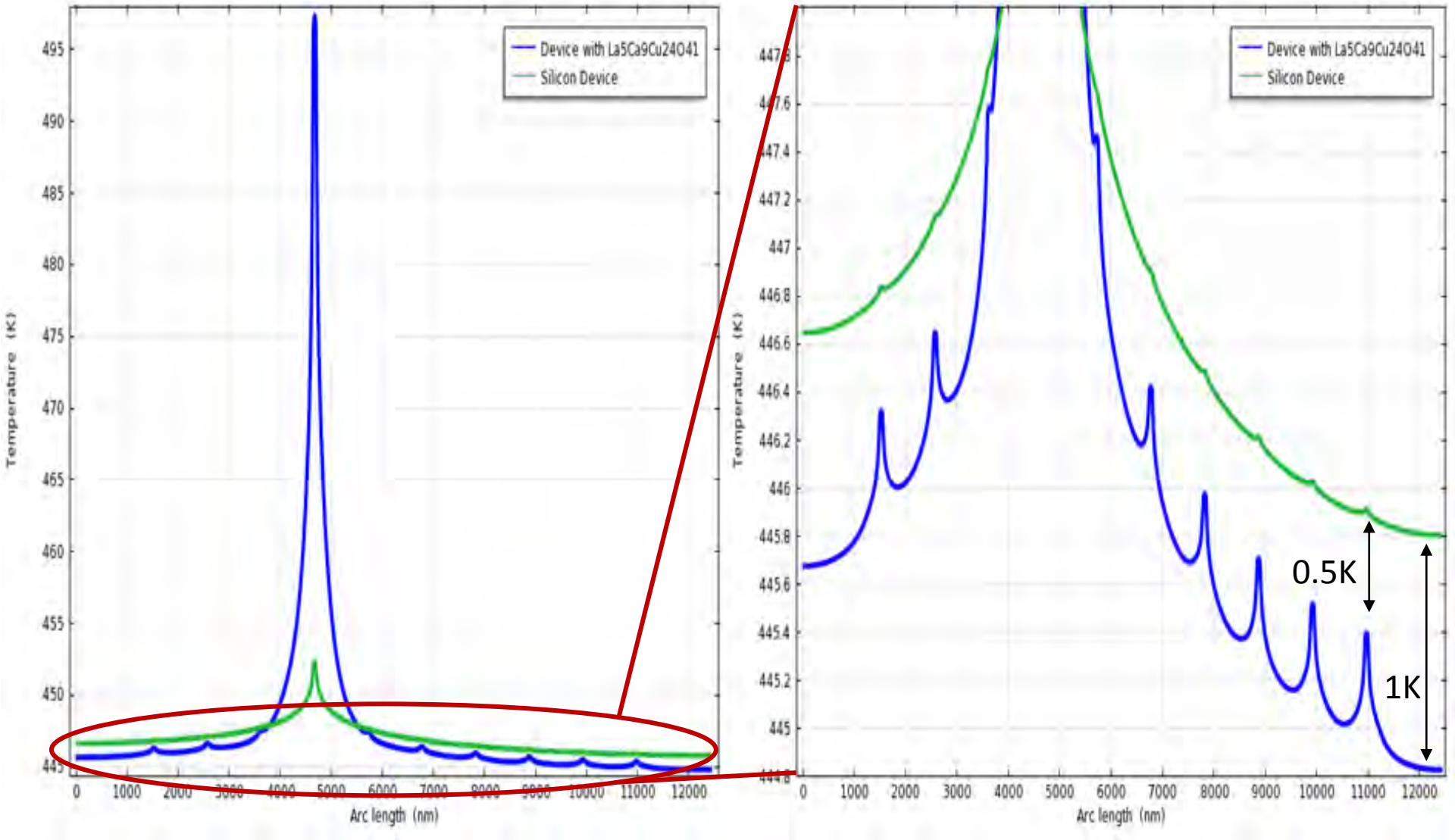


Isotherms


▲ 451.72
451.72
443.94
436.16
428.37
420.59
412.81
405.03
397.25
389.47
381.69
373.91
366.13
358.35
350.57
342.79
335.01
327.23
319.45
311.67
303.89
300
▼ 300
Silicon


▲ 495.46
495.46
485.44
475.41
465.39
455.37
445.34
435.32
425.3
415.27
405.25
395.22
385.2
375.18
365.15
355.13
345.11
335.08
325.06
315.04
305.01
300
▼ 300
$La_5Ca_9Cu_{24}O_{41}$

Temperature Profiles



Conclusions

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• Introducing $La_5Ca_9Cu_{24}O_{41}$ layers → "protecting" the adjacent operating elements due to the 1D heat conduction

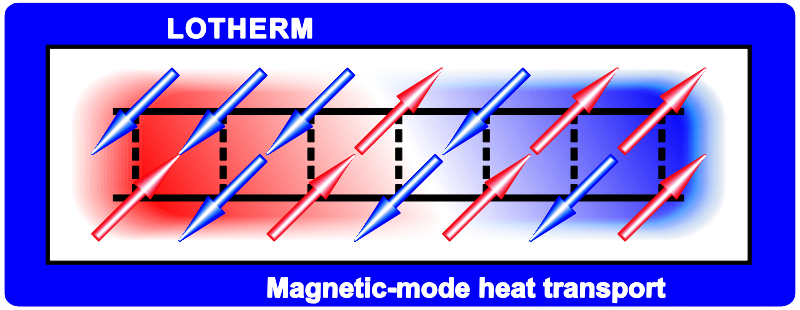
• Although we are introducing thermal resistance in the device we reduce the T of the adjacent operating elements by almost 1 degree

• Each degree reduction of temperature in the electronic devices can increase their lifetime!

• Simulate layers of the order of nanometers
• How much we can approach reality by using COMSOL Multiphysics

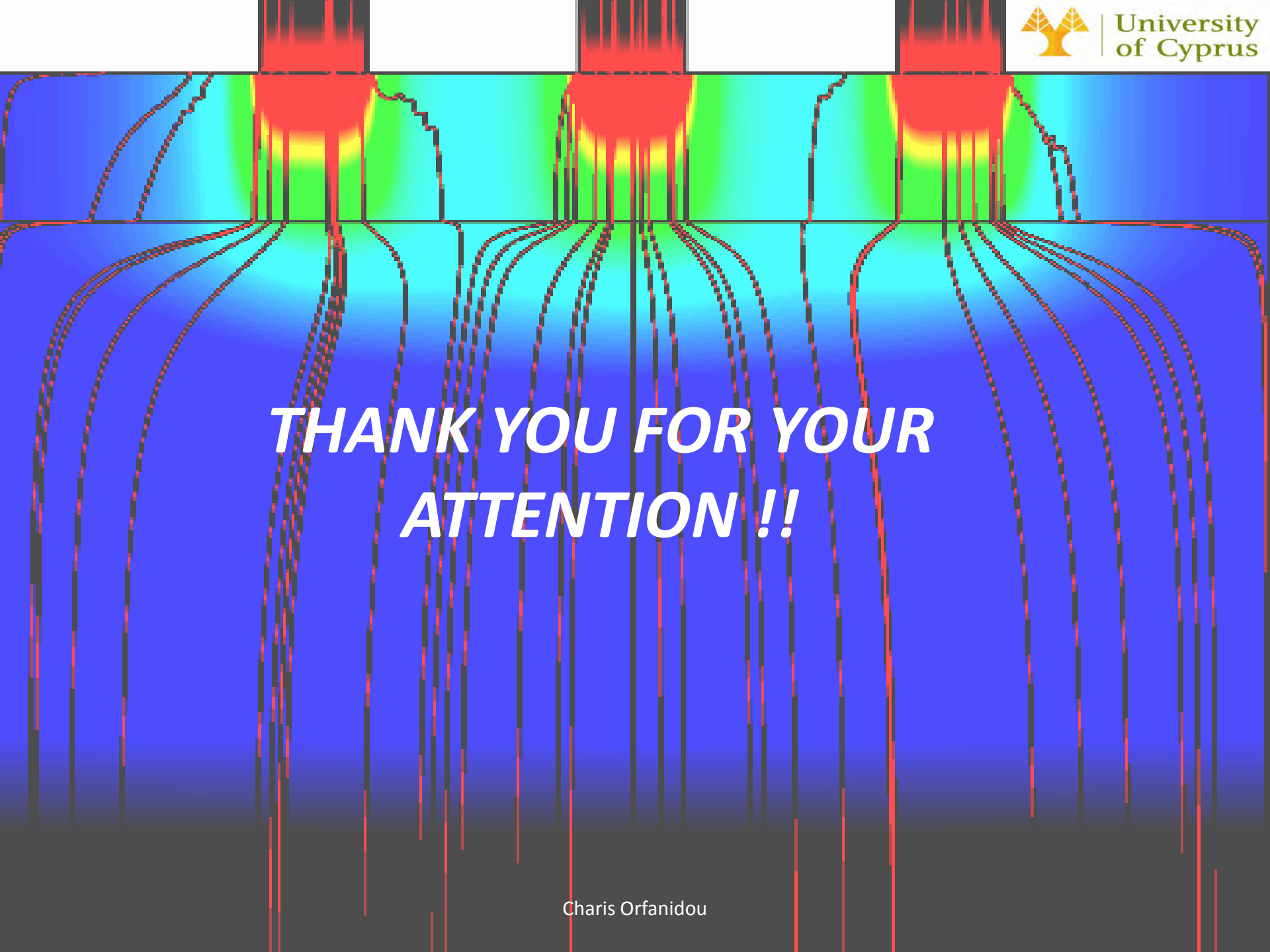
Acknowledgements

This work was supported by the European Commission through the ITN Marie Curie LOTHERM



Prof. Ioannis Giapintzakis

Materials Science Group, Mechanical and Manufacturing Engineering Department, UCY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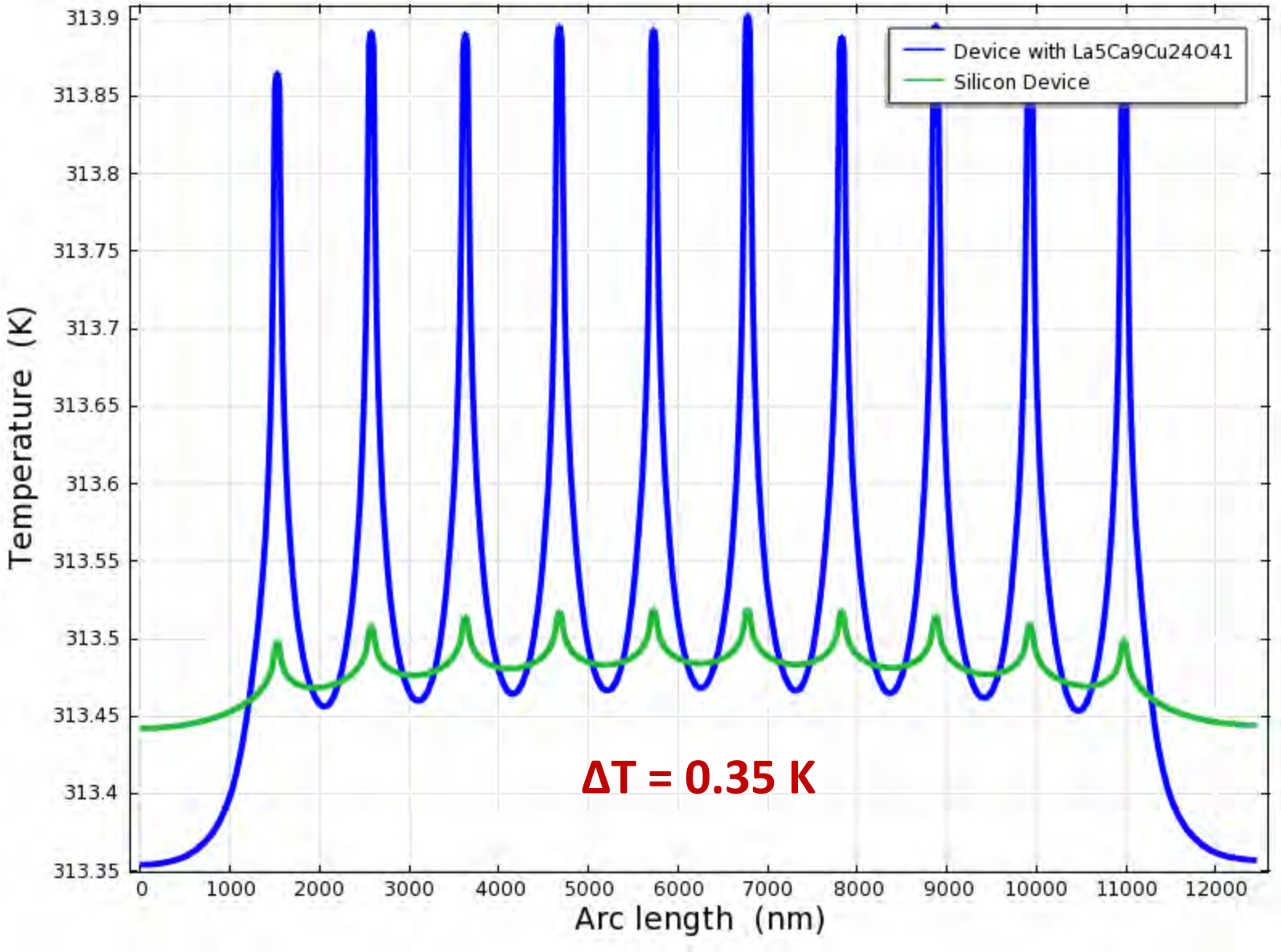
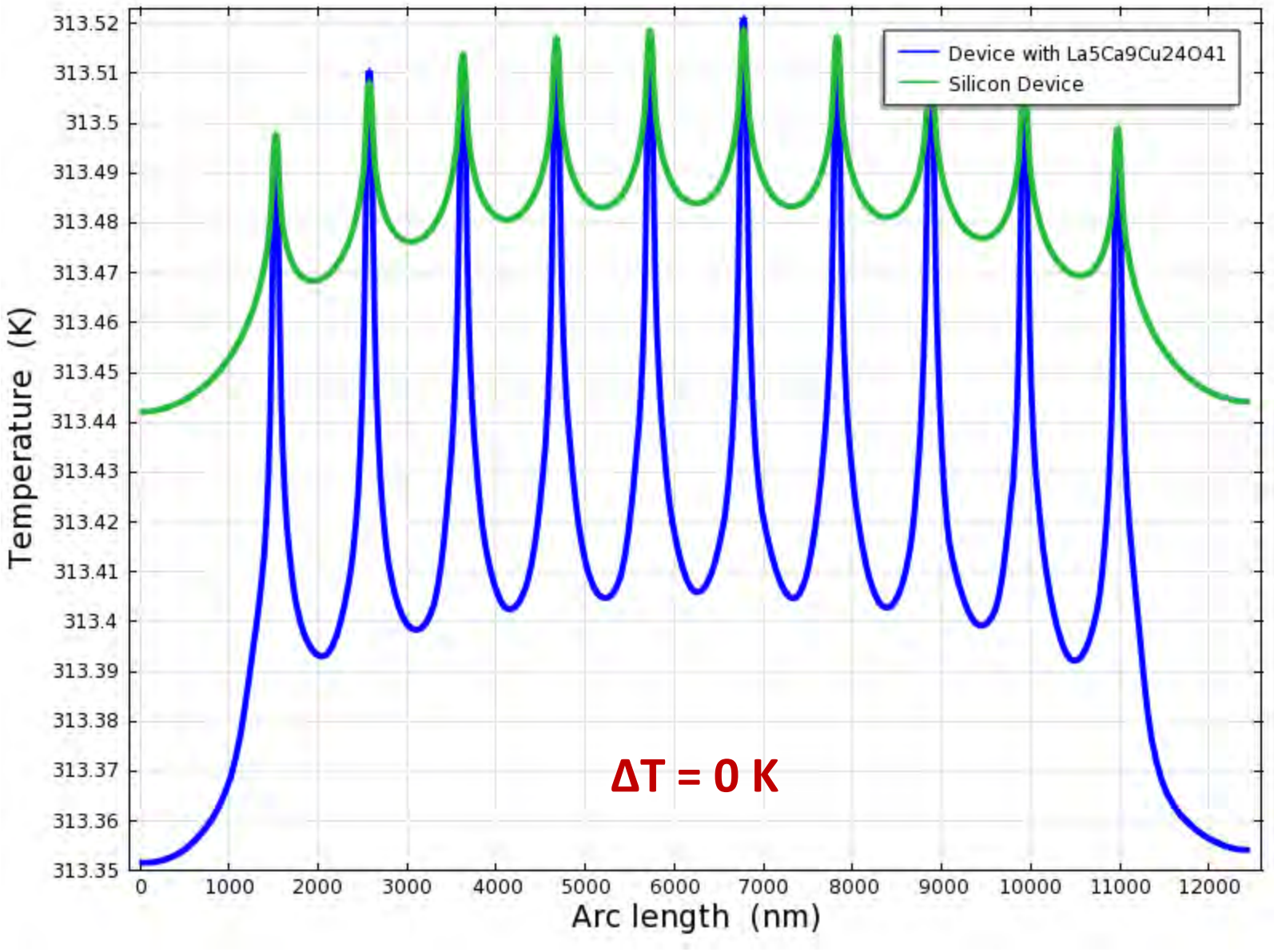
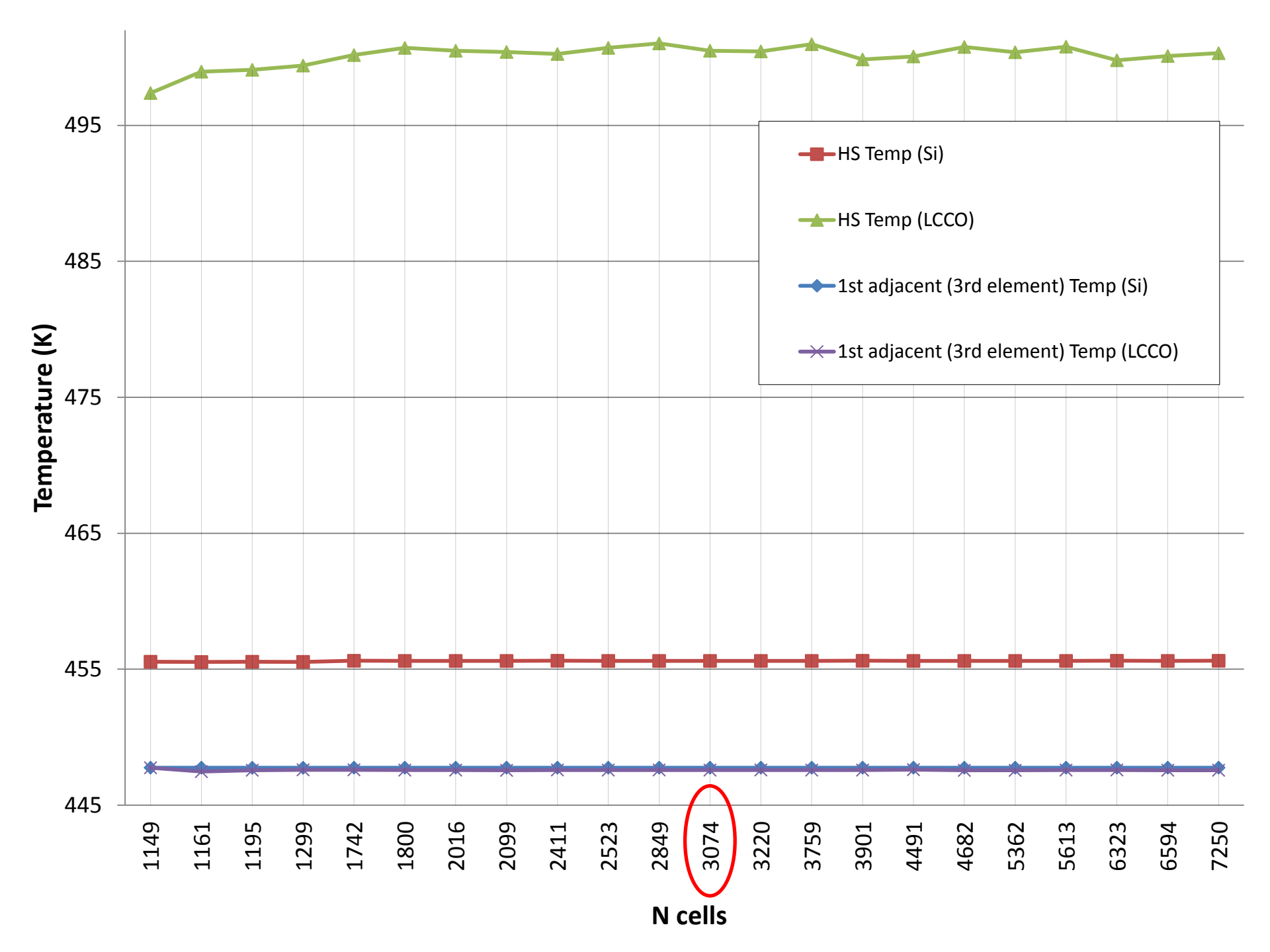
THANK YOU FOR YOUR ATTENTION !!
Charis Orfanidou

Operating Temperature, κ_{LCCO} = {1, 100, 1} W/m*K



Operating Temperature, κ_{LCCO} = {1, 550, 1} W/m*K




Temperature (K)
495
485
475
465
455
445
HS Temp (Si)
HS Temp (LCCO)
1st adjacent (3rd element) Temp (Si)
1st adjacent (3rd element) Temp (LCCO)
1149
1161
1195
1299
1742
1800
2016
2099
2411
2523
2849
3074
3220
3759
3901
4491
4682
5362
5613
6323
6594
7250
N cells