Conjugate Heat transfer analysis on Microchannel Heat Sinks for High Power LEDs

Dheepan Chakravarthii. M. K. [*], Shanmugan. S[*] and Mutharasu. D[*]

[*] – Lab 335, Nano Opto-electronics Research (NOR) Lab, School of Physics, Universiti Sains Malaysia, Penang, Malaysia

Introduction

Light emitting Diode (LED) has been proved to be the best resource for commercial as well as industrial lighting applications. However, thermal management in high power LEDs is a major challenge in which the thermal resistance (R_{th}) and rise in junction temperature (T_J) are notable parameters. Heat dissipation in the LED has been partly achieved with the evolution of efficient heat sinks. This paper deals with the design of heat sink with innovative advective extended surfaces which contributes for the multi-dimensional heat dissipation. Also simulation of heat distribution over the proposed heat sink design proved the influence of the design and material removal over heat distribution. It is suggested that the new design will help to reduce the junction temperature considerably thus enhancing the performance of LEDs.

Conservation Equations

Conservation of Mass: $\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \mathbf{V}) = 0$

Conservation of Energy: $\frac{\partial T}{\partial t} + \mathbf{V} \cdot \nabla T = \kappa \nabla^2 T + H/\rho c_P$

Conservation of Momentum: $\frac{\partial \mathbf{V}}{\partial t} + (\mathbf{V} \cdot \underset{\big\downarrow}{\nabla})\mathbf{V} = \frac{1}{\rho} \nabla \cdot \boldsymbol{\sigma} + \mathbf{g}$

(Advection term)

Geometrical Modelling

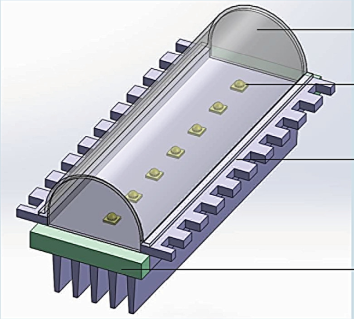

Fig 1. Baylight Module (Assembly)

Figure shows the 40W baylight Module. The junction temperature of the LEDs measured from the experiment is **138°C** and the maximum temperature of the heat sink is **78°C**. This adversely decreases the lifespan of the system. The modified heat sink in the figure have radial and advective fins which assist multi-dimensional heat transfer. The exploded view of the assembly is shown in the fig.2.

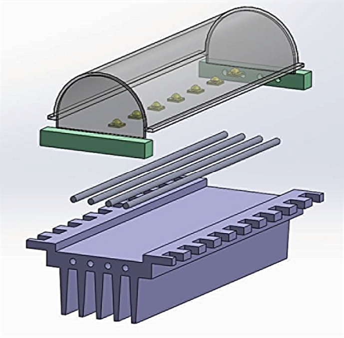

Fig 2. Baylight Module (Exploded View)

Computational Method

Conjugate heat transfer mechanics (conduction by solid and convection through air) are considered with this model and computed using COMSOL Multiphysics 5.1.

Parameters	Module in COMSOL Multiphysics 5.1
Heat Transfer in Solids and Fluids	Heat transfer Module
Fluid flow velocity and Reynolds Number	Fluid Flow Module (Laminar flow)

Variable	Value	Units
Overall Heat transfer Rate	5	W
Ambient Temperature	30	°C
Pressure	1	atm

Results

The geometry of the Heat sink considered consists of 10 advective fins and the radial fins attached to the heat sinks is fixed to 5 for each simulation. For every increase in the number of radial fins, the Reynolds number is decreased accordingly in order to maintain the pumping rate of the fluid (air).

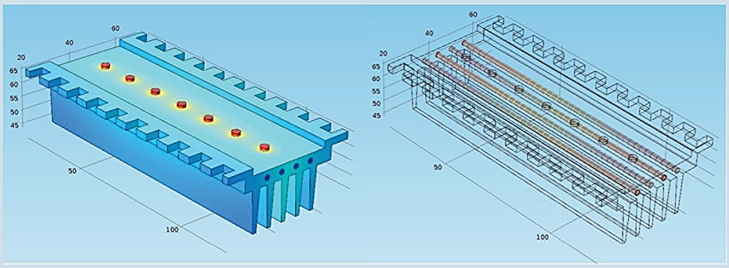

Fig 3. Temperature Distribution and Isothermal contour in Heat sink

Table : Summary of Junction Temperature and Heat Sink Temperature

Number of Axial Fins	Number of Radial Fins	Total Surface Area of heat transfer (mm^2)	Fin Heat Transfer Rate ($W/m^2.K$)	Junction Temperature (°C)	Maximum Heat Sink Temperature (°C)
10	5	23094	2.9	98.9	77.1
12	5	24191	3.6	97.1	75.22
14	5	26014	4.7	96.5	74.91
16	5	26938	5.04	95.8	70.63
18	5	28640	5.9	94.4	69.52
20	5	29814	6.33	93.2	68.05

Conclusion

The change in maximum temperature of the heat sinks is from **78°C to 68.05 °C ($\Delta T \approx 10$°C)**. The detailed analysis shows the importance of the proposed design with advective heat transfer surfaces. The pressure contours gives an absolute idea by which the nominal number of fins can be optimized for the reduced surface temperature as well as the reduced pumping power.

References

Liu, D., H. Yang, and P. Yang, Experimental and numerical approach on junction temperature of high-power LED, Microelectronics Reliability, 2014. 54(5): p. 926-931.

Poppe, A., et al. Multi-domain simulation and measurement of power LED-s and power LED assemblies in Semiconductor, Thermal Measurement and Management Symposium, 2006 IEEE Twenty-Second Annual IEEE. 2006. IEEE.

Simplifying Complexity

Excerpt from the Proceedings of the 2015 COMSOL Conference in Kuala Lumpur