The influence of cooling systems parameters used for high power light emitting diodes on their photometric characteristics

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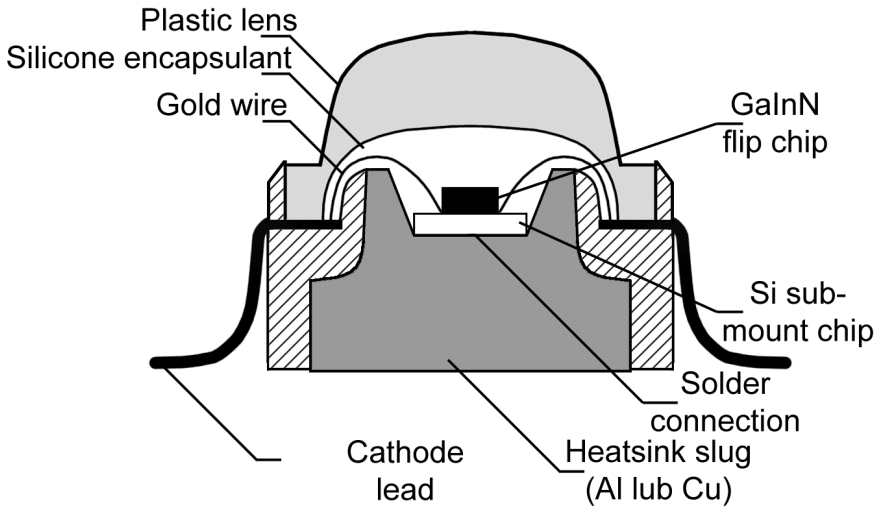
In the paper the most widely used active and passive cooling systems of electronic devices are described, such as radiators, fans, heat pipes, thermoelectric cooling, liquid cooling. Possibility of utilization of the mentioned systems for cooling of high power light-emitting diodes (HP LED) is presented along with the influence of their parameters on junction temperature, luminous flux and lighting efficiency of the diodes. Analysis of the applied systems was found to be easier using heat flow modelled by analogy to an electrical circuit. Evaluation of temperature at all points of the cooling system allowed for of the less effectively operating element. The calculations were conducted in an iterative method taking into account properties of the various kinds of cooling. Usefulness of an individual method of cooling was evaluated taking into account their practical application for luminaries with HP LEDs. For the all analysed cases an experimental verification was done and was presented in the paper.

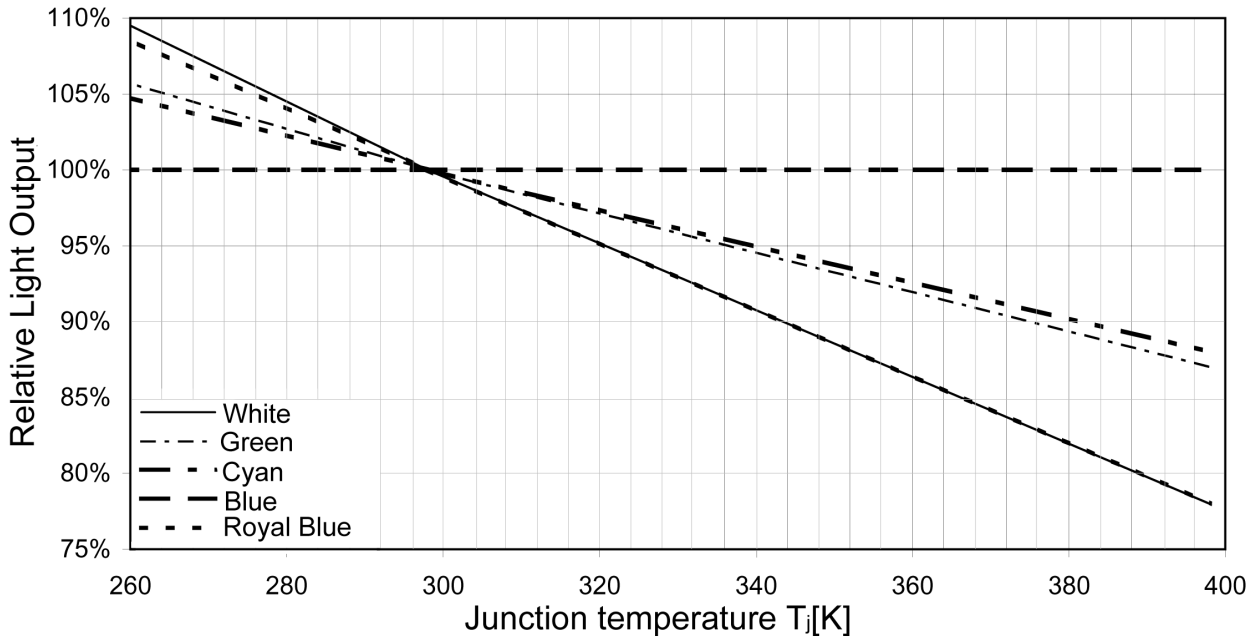
Structure of HP LEDs (High Power Lighting Emitting Diode)

Below is presented the construction of HP LEDs. Internal heatsink slug can be soldered to printed circuit board (for example star shaped) with low thermal resistance.



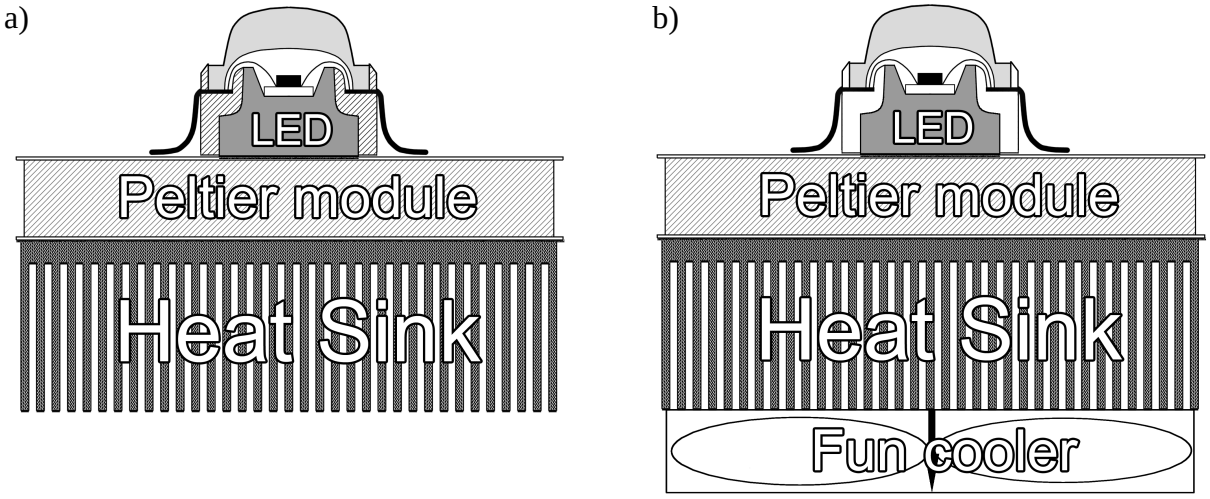
Cross section through high-power package LED. [1]

Below is presented graph showed relation between relative light output and junction temperature (temperature within the LED device) for different LEDs colours. Junction temperature has great influence on luminous efficacy and useful life (defined as 70% lumen maintenance) of diode.

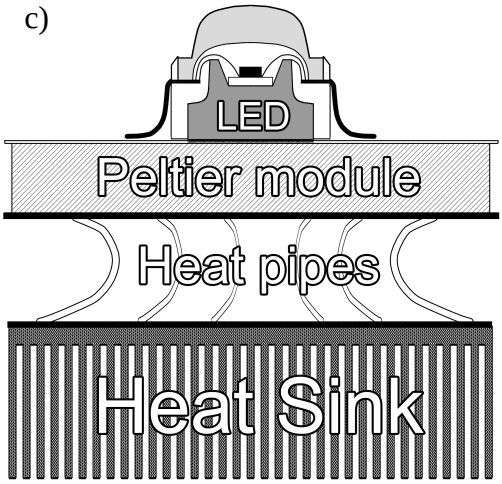


Relative light output vs. junction temperature of LEDs [2]

The graph above showed nominal (100%) light output for base junction temperature – 297 K (25'C). Usually (in standard cooling systems) T_j is typically 60'C or greater. Solution to this problem is using cooling system with thermoelectric couple. Typical and practicable combination standard cooling and Peltier modules is presented below.



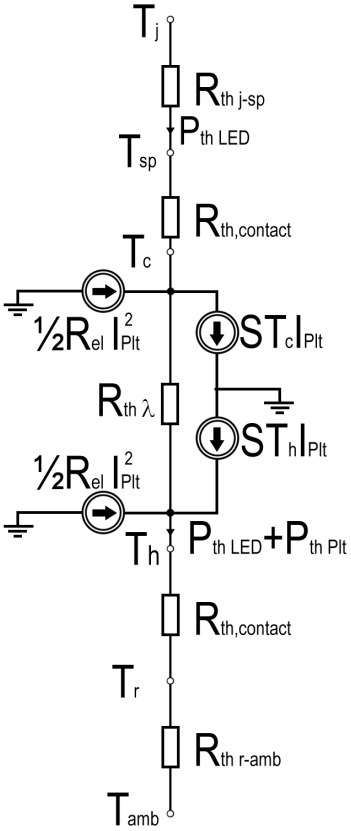
c)



Cooling system:
a) Peltier module and heat sink for natural convection
b) Peltier module and heat sink for forced convection
c) Peltier module – heat pipes with heat sink for natural convection

Electrical model of heat flow in cooling system.

Analysis of the cooling systems was modelled by analogy heat flow to an electrical circuit. Below is presented electrical circuit cooling system with Peltier module [3].



List of symbols:
T_j – junction temperature of LED
$R_{th,j\text{-}sp}$ – heat transfer resistance through a LED junction and solder of LED
$P_{th,\ LED}$ – heat flow of LED – thermal output from LED
$R_{th,contact}$ – thermal resistance between two surfaces
T_C , T_H – cold and hot junction temperature of Peltier module
R_{el}, S, $R_{th\lambda}$, - parameters of Peltier module
I_{Plt} – electric current of Peltier module
$P_{th,Plt}$ – heat flow from hot side of Peltier module
$R_{th\ r\text{-}amb}$ – thermal resistance between hot side of Peltier module and ambient
T_{amb} – temperature of ambient

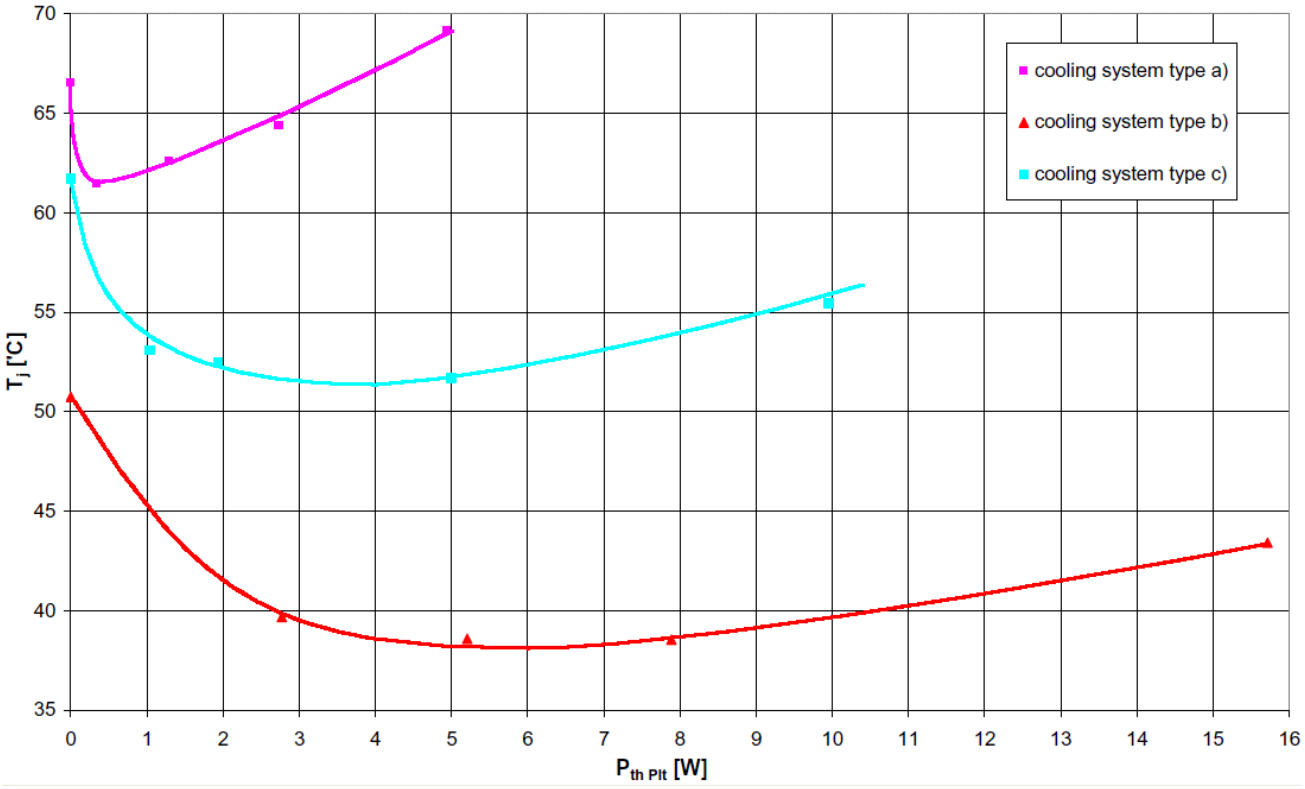
Equations circumscribe junction temperature and temperature difference of Peltier module:

$$T_j = P_{th,LED} \cdot \left(R_{th,j-sp} + R_{th,styk}\right) - \Delta T_{Plt} + \left(P_{th,LED} + P_{th,Plt}\right) \cdot \left(R_{th,rad-oto} + R_{th,styk}\right) + T_{oto}$$

$$\Delta T_{Plt} = T_H - T_C = \left(S \cdot T_C \cdot I_{Plt} - 0.5 \cdot I_{Plt}^2 \cdot R_{el} - P_{th,LED}\right) \cdot R_{th,\lambda}$$

The measurements results for discussed examples are presented below.

No	measurements					calculates		
	$P_{th,LED}$ [W]	$P_{th,Plt}$ [W]	T_{sp} [‘C]	T_r [‘C]	T_{amb} [‘C]	T_j [‘C]	Relative Light Output (White LED)	cooling system
1	2,15	0,00	47,2	39,6	20,0	66,6	90,9%	a)
2		0,34	42,1	42,1		61,5	92,1%	
3		1,28	43,2	49,4		62,6	91,8%	
4		2,73	45,1	56,7		64,4	91,4%	
5		4,94	49,8	67,3		69,2	90,3%	
1		0,00	31,4	24,0		50,7	94,5%	b)
2		2,77	20,3	28,9		39,7	97,1%	
3		5,21	19,2	32,5		38,6	97,3%	
4		7,88	19,2	36,2		38,5	97,3%	
5		15,72	24,1	48,4		43,4	96,2%	
1		0,00	42,4	26,4		61,7	92,0%	c)
2		1,04	33,7	27,9		53,1	94,0%	
3		1,94	33,2	29,6		52,5	94,1%	
4		4,99	32,3	34,4		51,7	94,3%	
5		9,95	36,1	41,7		55,5	93,5%	



Presented the measurements results and graphs show the necessity of Peltier modules selection. Selection of their electrical and geometrical parameters is necessary. It is depending on heat flow the device element and thermal resistance other elements of system.

[1] Schubert E.F.: Lighting Emitting Diodes; Cambridge Univ. Press 2006
[2] Technical Datasheet DS51 – Power Light Source Luxeon K2
[3] Domke K. Skrzypczak P.: Selection of Peltier modules parameters in HP LED’s cooling system,14th Scientific Conference Computer Applications in Electrical Engineering