Electricity Consumers: LED Lighting

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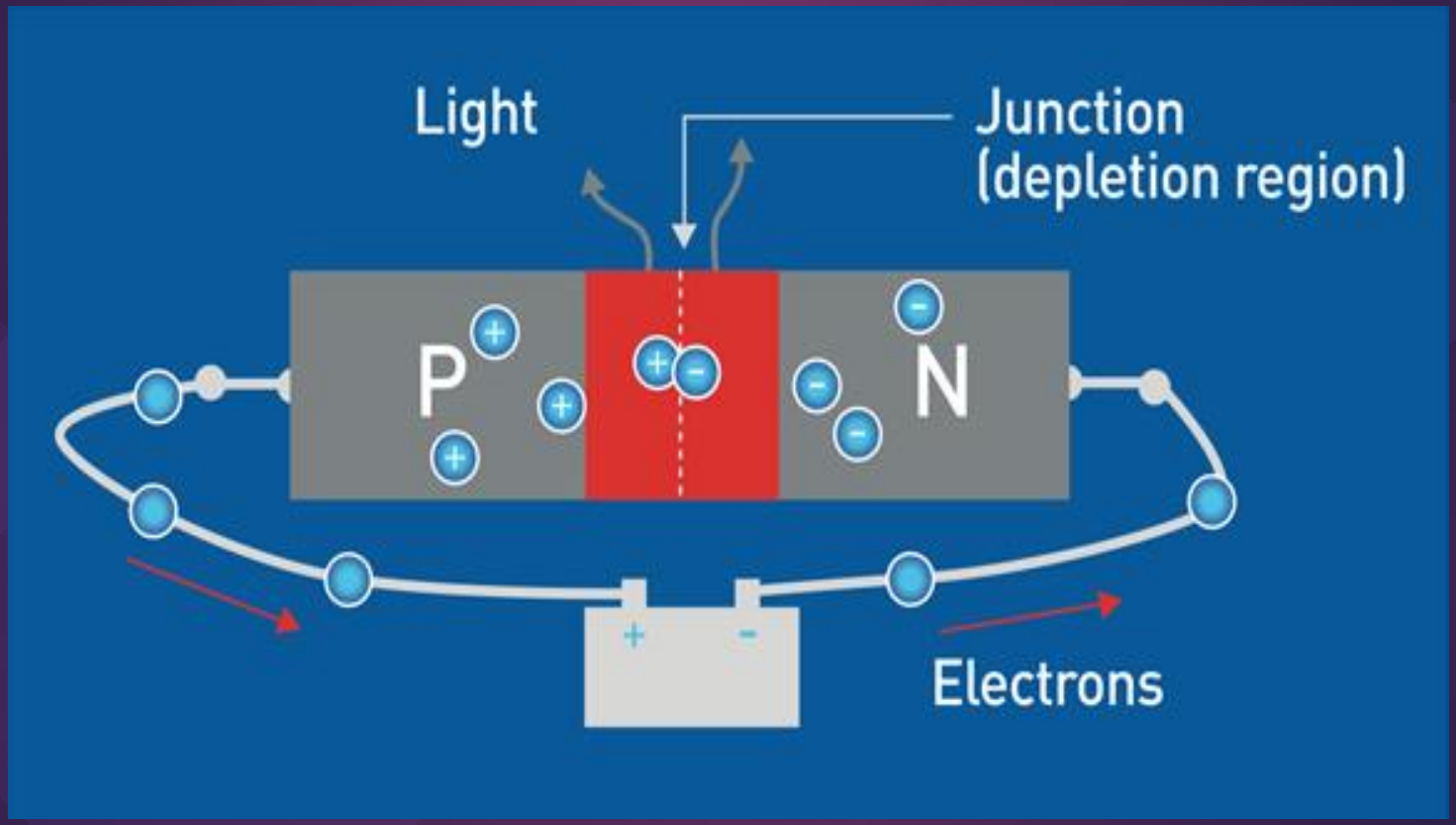
Background: What is an LED?



Advantages of LED Lighting

- Ultra-long lifetime
- No toxic mercury content
- No UV or IR radiation
- Small size
- Digitally controllable
- Fast-changing light intensity

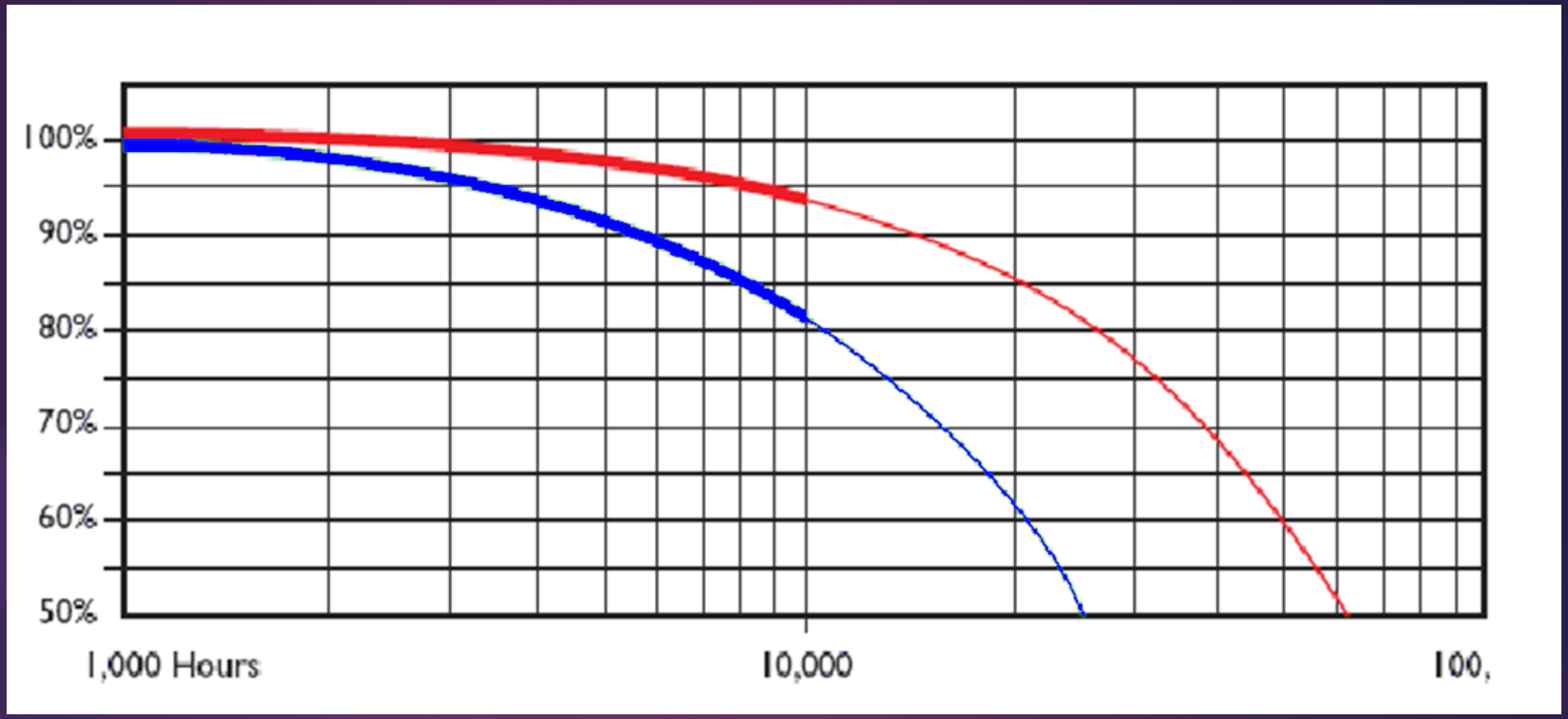
LED Applications for a Home

- Replace incandescent and fluorescent light bulbs in homes
- Light sensors – responding to changing light levels
- TV - more dynamic images
- Outdoor lighting – for gardening

Problem

LED lighting tends to have a high junction temperature, or operating temperature.

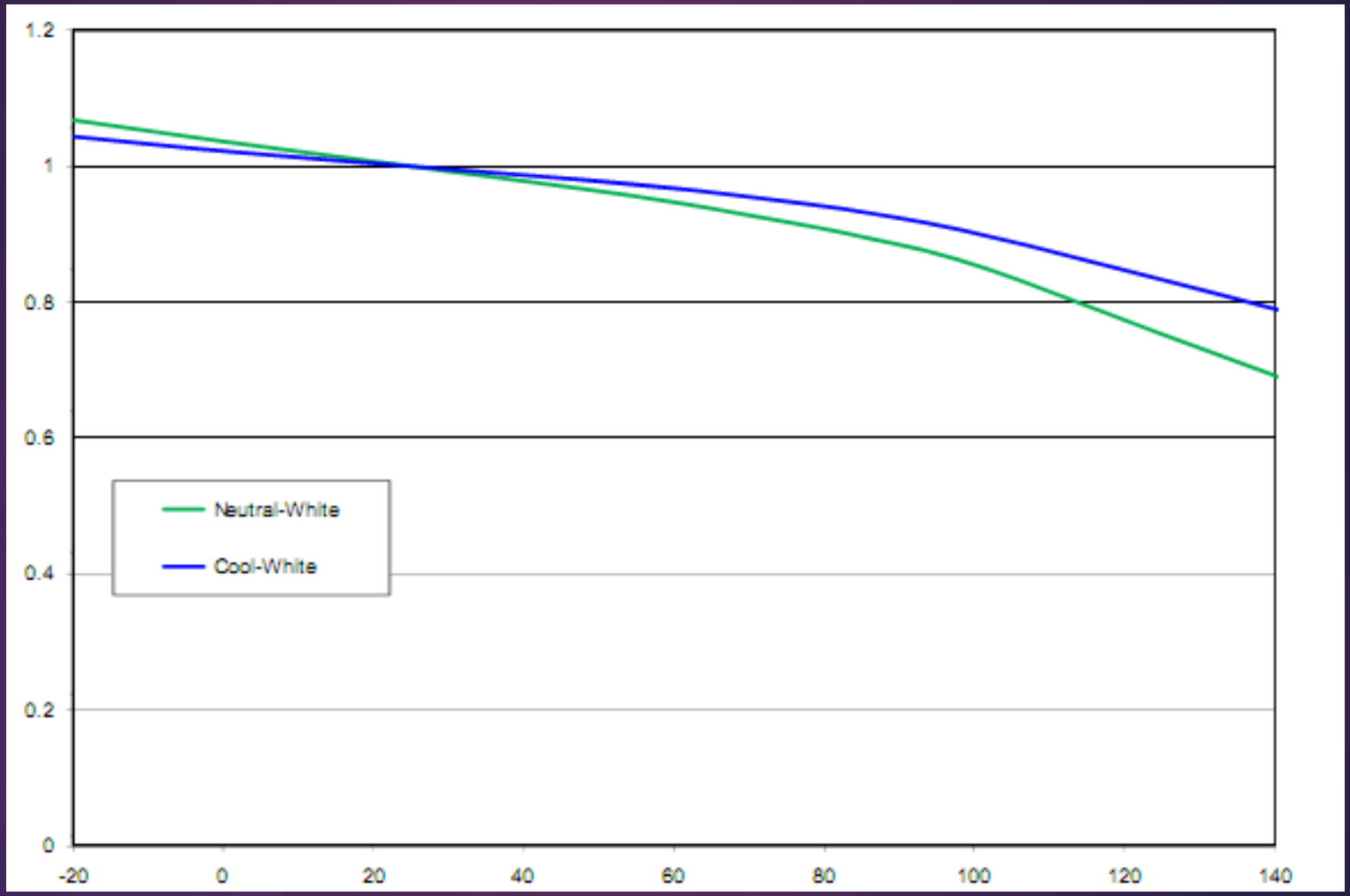
Relationship Between Junction Temperature and Lifetime



Junction Temperature 74 C

Junction Temperature 64 C

Light Flux vs. Junction Temperature



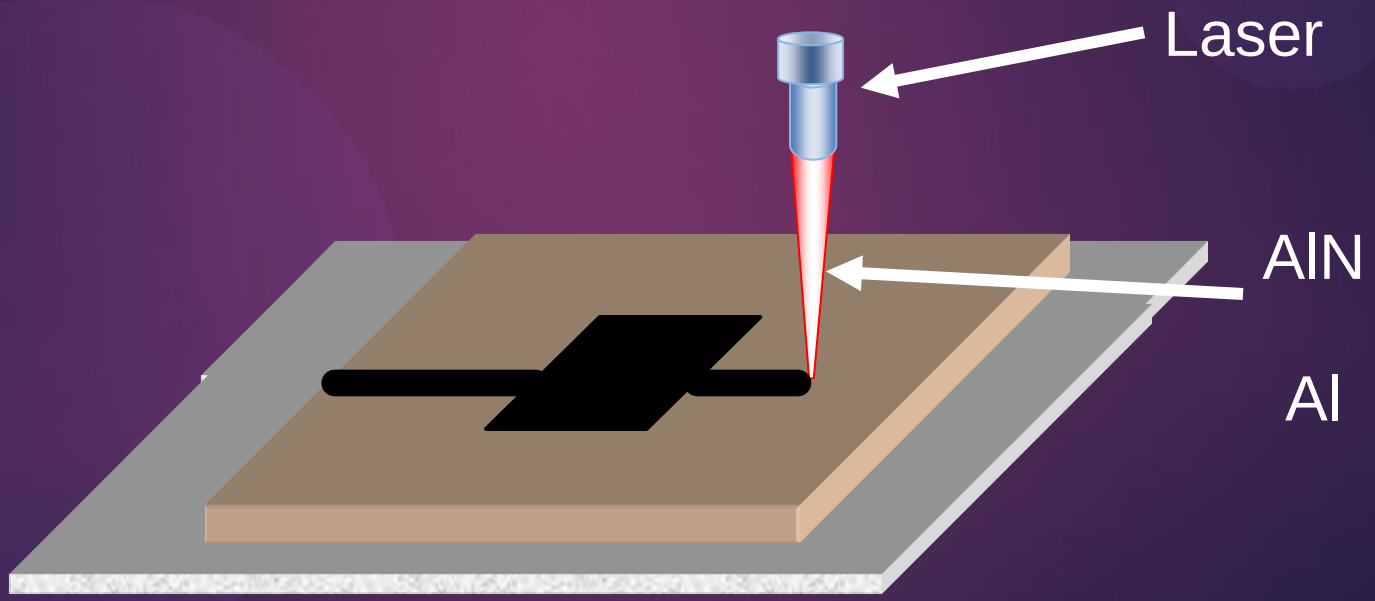
Goal / Purpose

- To increase LED efficiency by reducing LED junction temperature through the use of:

  - aluminum nitride (AIN) substrate
  - Phase-Change Material (PCM)
  - aluminum heat sink

Why AlN?

- High heat conductivity (up to 200 $\frac{W}{K \cdot m}$)
- High heat transfer area



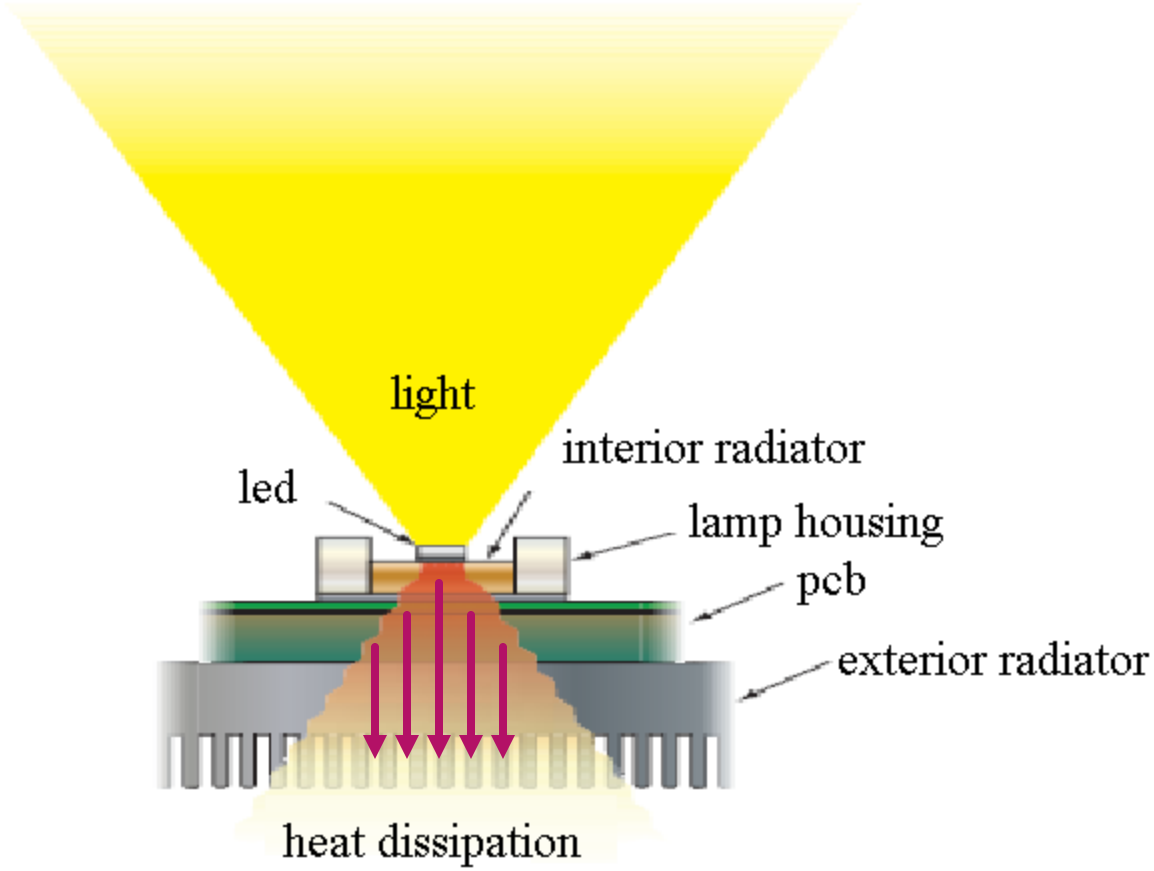
Why Phase Changing Material?

- PCMs use the heat given off by semiconductors to melt a solid to a liquid.
- The melting point temperature is maintained as heat is added and the phase change occurs.

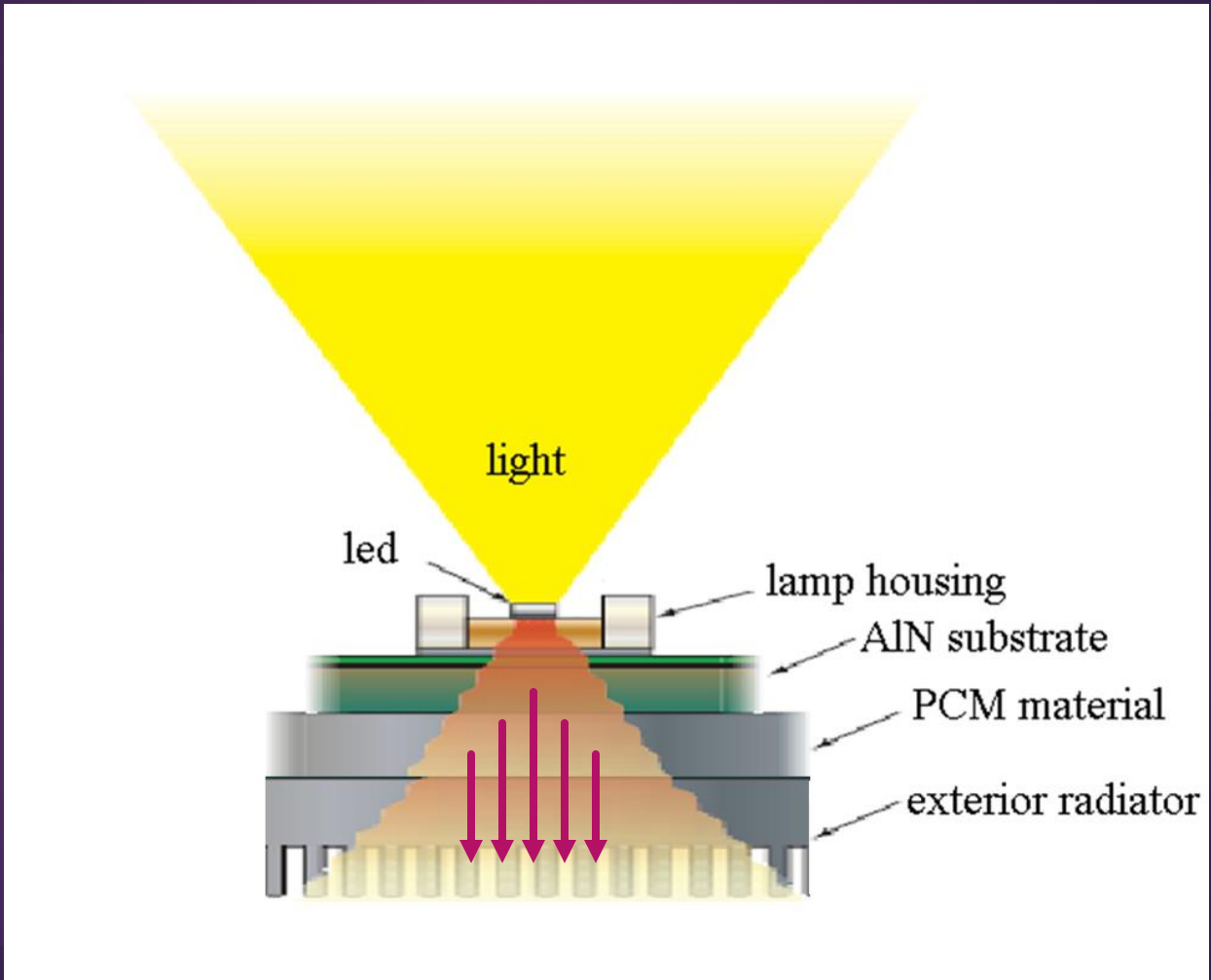
Why a Heat Sink?

- A heat sink is a passive heat exchanger that cools a device by dissipating heat into surrounding air.
- By releasing heat, a heat sink can accelerate the freezing process when liquid PCM turns back into solid PCM.

Standard LED Cooling



Our Design: PCM-cooled LED Using AlN Substrate and Heat Sink



Efficiency Related to Cost

- Paraffine PCMs, AlN, and Al come at low cost
- Although these lights are more expensive, the high upfront cost is compensated by improvement of LED lifetime.
- All three components might not be necessary to lower-power LEDs.

Conclusion

The use of AlN substrate, PCM cooling, and a heat sink in a single system can:

1) decrease the junction temperature of the LED
2) improve the lifetime of the LED
3) improve LED efficiency (by up to 20 %)
4) be economically feasible

References

- http://ledsmagazine.com/features/2/5/8
- 2010 Philips solid-state lighting solutions, Inc.
- Evaluating Light Output Technical brief (Philips)
- U.S. Department of Energy

Acknowledgements

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PCM LED Cooling

- **Parameters of the Led:**
- Led power consumption is 80 W
- Input voltage is 220 V
- Junction temperature is 65^0C
- Dimension is 370*285*195 mm
- **Typical parameters of the PCM material:**
- Melting point is 30^0C
- Specific latent heat is 200 kJ/kg
- Thermal conductivity is 0.3 W/m^{0}C
- Density is 850 kg/m^3
- Specific heat capacity is 2200 J/kg^{0}C
- The estimations were provided for NIBBE Led Model: NB-FDL02-80 of SHENZEN NIBBE TECHNOLOGY CO., LTD

Calculations

- The mass of the PCM equal:
- m = ρ*V, where ρ is PCM density, V is PCM volume.
- m = (.37*.285*.195)*850 = 17.5 kg
- The input power P = 80*08 = 64 W (80% of the led power transforms to the heat).
- The melting time of the PCM is:
- t = 17.5*250000/64 = 19 hours
- It means that in above mentioned case during 19 hours the temperature in the pcm material30^{0}C. The junction temperature can be easy estimated if we know the heat resistance junction to case:
- Tj =Tc + P*R, where R is heat resistance in ^{0}C/W, Tc is case temperature. For example if R = 0.1 ^{0}C/W the junction temperature will be 36^{0}C.
- 5 kg of PCM is needed for the LED to operate for 4.5 h