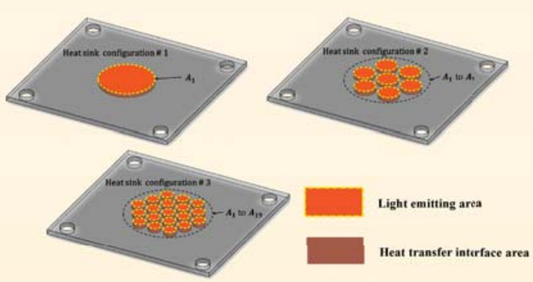
Using a remote phosphor layer heat sink to reduce phosphor temperature

Increased demand for higher light output from smaller white LED light engines has resulted in high radiant energy and heat densities on the LED chip's phosphor layer. Past studies have looked at various methods to reduce the phosphor layer's operating temperature to help keep the light engine cool and preserve light output and life. In this study, the LRC investigated the use of a phosphor layer heat sink for dissipating the heat generated by the phosphor layer through systematic analyses of heat sink geometry and material properties.

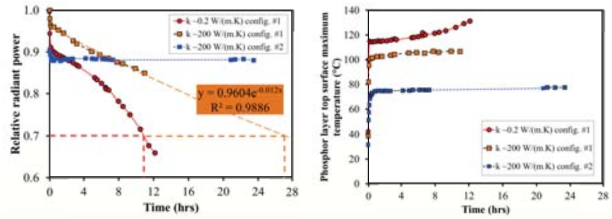
Experiment

Three different geometrical configurations of phosphor layer heat sinks were constructed to assess the ability of a phosphor layer conductive structure to dissipate heat. The heat sink configurations consisted of different numbers of cylindrical holes machined into aluminum plates. When maintaining the same total emitting area for all configurations, increasing the number of holes also increased the heat transfer interface surface area. An epoxy and phosphor mixture was deposited into the cylindrical cavities at an equal thickness for each sample and then cured. An LED light engine was used to irradiate the phosphor layer heat sink configurations. The surface temperature of the phosphor layer heat sink was measured with an infrared imaging camera. The radiant power from the phosphor layer was measured with a spectroradiometer.

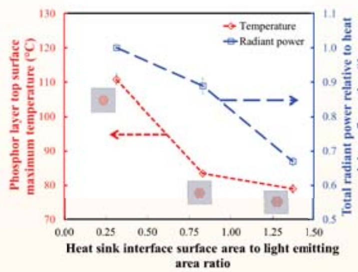


$$\text{Heat sink \# 1}, A_1 = \text{Heat sink \# 2}, \sum_{n=1}^{7} A_n = \text{Heat sink \# 3}, \sum_{n=1}^{19} A_n$$

Heat transfer interface of heat sink configurations #1, #2 and #3.



Relative light output (left) and phosphor layer heat sink maximum temperature (right) as a function of time for each of the three configurations.



Phosphor layer heat sink maximum temperature and relative light output variation as a function of heat sink surface area to emitting area ratio for heat sink configuration #1.

Results

Overall, the study showed the potential of a dedicated phosphor layer heat sink in reducing the operating temperature of the phosphor layer. The experimental results showed a decrease in phosphor layer operating temperature with an increase in heat sink interface surface area, but also a total radiant power decrease. Ray-tracing simulations identified the low surface reflectance of the heat sink interface area as the cause of this decrease in radiant power. The study also showed improved performance of the phosphor layer heat sink with respect to lumen maintenance, doubling the time to reach the end of useful life (L70) by maintaining a lower phosphor layer operating temperature over the long term.

Reference

Perera, I.U., and N. Narendran. 2018. Analysis of a remote phosphor layer heat sink to reduce phosphor operating temperature. *International Journal of Heat and Mass Transfer* 117: 211-222.

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