Horticulture Lighting Fixture Thermal Performance

by Bob Karlicek, Rick Neal

The performance and reliability of LED lighting systems requires good thermal management to keep the LEDs cool. Generally speaking, the cooler the LED device inside the fixture housing, the more efficient and reliable the fixture becomes. Fortunately, thermal management for LED lighting systems has advanced significantly over the past decade, mostly at the LED package level where the input electrical power is converted to light. Past the LED package, thermal management is pretty straight forward, with the goal being to move heat from the LED to the air around the fixture, where either passive, convective air flow, or active or forced air flow (using fans) moves the heat into the surrounding environment. GLASE has developed a process for evaluating the overall thermal performance capabilities of horticulture lighting fixtures and has applied this procedure to evaluate several representative, commercially available horticulture lighting fixtures over the past several years. This process can be rather complicated and a full understanding of a fixture's thermal performance typically requires a destructive teardown of the fixture to examine materials used, evaluate thermal bottlenecks (typically at the interface between different materials), and estimate the thermal impedance (resistance to heat flow) from the LED to the air around the fixture.

Over the past several years, GLASE has evaluated several horticulture lighting fixtures, finding a range of thermal management approaches that have evolved as the LED lighting industry has matured. For the most part, current commercial fixtures are thermally similar, having relied on broadly available thermal solutions developed for the LED lighting industry as a whole. As shown on in Figure 1, LED packages are always mounted on a metal clad printed circuit board (MCPCB). The LED chips are inside the small rectangular packages (in this case, two different types of phosphor converted white LEDs) that are soldered to a circuit board laminated onto a sheet of aluminum. The photograph in Figure 1 is of the board end where wires to the LED driver are attached. Note that screws are used to attach the MCPCB to a heat sink, shown in Figure 2 for a different horticulture lighting fixture. For both of these assemblies, the screw positioning and torque must be carefully factored into the design and assembly processes of the fixture to ensure good thermal contact with the underlying heat sink.

Figure 1.

Figure 2.

Almost all of the luminaires that were examined consisted of an extruded aluminum fixture designed to house the driver, and included certain features for holding optical enclosures. Note that good fixture thermal design also includes a thin, thermal interface material (TIM) in-between the bottom of the MCPCB and the top of the heat sink. At the thermal interface between the MCPCB and the extrusion, TIM selection and careful assembly is required to insure low thermal impedance as the LED heat works its way toward the environment. This interface needs to be thin, free of air gaps and uniformly compressed to insure good thermal performance.

The next thermal barrier to complete the thermal management profile involves how well air can move around the heat sink to ensure good exchange of fixture thermal energy with the ambient. An example of a well-designed thermal structure is shown in Figure 3, where a specially designed fin structure is

Figure 3.

attached to the aluminum extrusion for improved heat exchange with the air. Another critical feature of this fin thermal design element is that, in addition to shedding heat, it needs to be easily cleaned, allow for good air flow, and not risk getting blocked by dirt and debris in the CEA environment.

Of course, a good thermal evaluation requires assessing the fixture's temperatures from the LEDs to the exterior heat exchange surface. This is most easily done using an IR thermal imaging camera. A thermal image of the ribbed heat sink from Figure 3 is shown during operation in Figure 4. By knowing the LED operating temperature (using techniques beyond the scope of this article) and how the thermal energy is distributed throughout the fixture, it is possible to make an informed decision about the overall thermal performance capability of the horticulture lighting fixture.

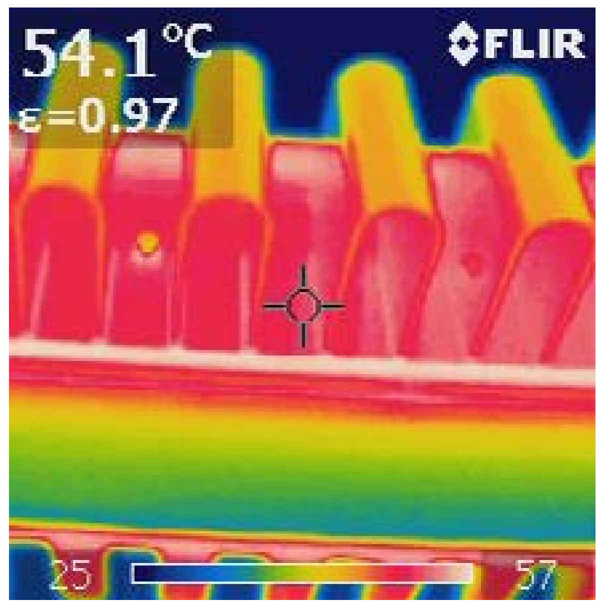

Figure 4.

In closing, the thermal design of a horticulture lighting fixture will play a strong role in the overall operating efficiency and lifetime of the fixture. Exceptionally good thermal designs can be more expensive, and good assembly procedures are required to insure the fabrication of good, thermally conductive interfaces all the way from the LED chip to the ambient operating environment.

Research continues to explore a wide variety of new approaches to thermal management for power electronics, including high performance, high efficiency lighting fixtures. Current thermal strategies have the advantage of reduced costs due to their use by the much larger LED lighting industry. In the future, new materials and assembly techniques will improve thermal management of horticulture lighting systems even further, likely including the development of cost-effective water-cooling approaches that could significantly improve the efficiency and lifetime of high-power lighting fixtures even further. Advanced water-cooling designs are being increasingly explored for high performance computing systems and power electronics systems, and as these applications grow, cost reductions will continue to make their way to an affordable range of better thermal performance strategies for CEA lighting systems.

Stay tuned!

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