LEDs MAGAZINE

Active cooling can boost lumen output in LED lighting

Active cooling technology can offer thermal capabilities that are superior to passive heat sinks and can raise lumen output and extend LED life in solid-state lighting, says **RYAN AHEARN**.

This will be a big year for LEDs in general lighting applications, with expectations of 59% growth compared with 2010. Retrofitting fixtures or replacing existing incandescent and fluorescent lighting solutions with solid-state lighting (SSL) is gaining steam – and quickly. Users value LED lights for their energy efficiency, long life and low maintenance. LEDs are saving businesses and cities millions of dollars a year in energy and maintenance costs and providing consumers with a more-energy-efficient, high-quality light for their homes.

However, further advancements are still required to make LEDs the lighting technology of choice for retail, residential and outdoor lighting applications. Cost and lumen output are currently the main limitations to the widespread adoption of LED lighting.

The cost of manufacturing LEDs is expected to decrease substantially by 2015. The US Department of Energy forecasts that the manufacturing cost of an LED luminaire or fixture will fall by about 40 to 45 percent over the next five years. These cost savings will be further enhanced by government subsidies and rebates.

Lumen output is another key factor in the adoption of LED lighting. Although LED technology continues to advance, high-lumen-output LED applications cannot be achieved with passive cooling alone. LED lights cooled by a passive heat sink, rather than with an active cooling solution like a synthetic jet, are inherently larger, which makes retrofitting difficult. A smaller heat sink may result in a lamp or luminaire that is less reliable due to heat damage to the LEDs, or a source that produces insufficient light for market success.

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Thermal issues in LED lighting

Thermal dissipation is a key factor that limits the lumen output of an LED light. LED bulbs are available that are as much as 80 percent more energy efficient than traditional incandescent lighting, but the LED components and the driver electronics still create a considerable amount of heat. If this heat is not dissipated properly, the LED's quality of light and life expectancy decrease dramatically.

Heat sinks solve thermal management problems for low-lumen LED lamps. Lighting manufacturers have had little difficulty developing viable 40W-equivalent LED retrofits for A-lamps, and many also have solutions in place for 60W-equivalent lamps. It is when you get into the high lumen counts that thermal management becomes a challenge. A heat sink alone will not cool a 75W- or 100W-equivalent lamp.

The demand for these high brightness bulbs is evident – 75W and 100W lamps make up a significant piece of the lighting market. Businesses are eager to take advantage of the energy and maintenance savings inherent with LED lighting. The Energy Independence Security Act of 2007 will be requiring higher efficiency bulbs starting in 2012. These new requirements have consumers looking for an incandescent replacement that has a good quality of light and a long life in addition to a high lumen output.

In order to reach the desired lumen values in a fixed form factor, active cooling may be required to dissipate the heat produced by the LED components. Some active cooling solutions, such as fans, don't have the same life expectancy as the LED itself. In order to create a viable active cooling solution for high-brightness LEDs, the method of thermal management must be inherently low in energy consumption, flexible enough to fit into a small form factor and have an expected life equal to or greater than that of the light sources.

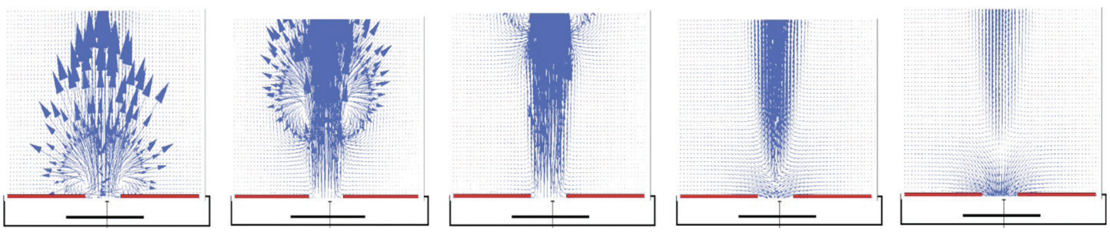

FIG. 1. Velocity vectors of the synthetic jet flow as air is expelled.

Synthetic jet cooling

Synthetic-jet technology provides an active cooling solution for LED lighting, and has been adopted by many major global lighting companies. The compact cooling modules address all of the constraints currently hindering the development of LED lighting: effective heat dissipation, small form factor and reliability.

Synthetic jets are an alternative to the traditional fan and are much better suited to the increasingly challenging demands of LED thermal management. The jets are formed by periodic suction and ejection of air out of an opening that is caused by the motion of a diaphragm, as displayed in Fig. 1. The first three panels in Fig. 1 show the ejection phase, during which a vortex accompanied by a jet is created and convected downstream from the jet exit. Once the vortex flow has traveled well downstream, ambient air from the vicinity of the opening is entrained, as displayed in the last two panels of Fig. 1.

The rapid-fire pulses of turbulent air, typically 30 to 200 pulses per second, break up the thermal boundary layer and increase the amount of heat transferred away from the heat source (most often the LED heat sink), allowing more heat to be removed with less air. These rapid-fire pulses of air can be directed precisely where cooling is needed, such as the fins of a heat sink, further lending to the synthetic jet's thermal efficiency.

Synthetic-jet technology offers several benefits. First, the technology makes it possible to remove more heat with less air and does not require additional air to be drawn in as with conventional jets. Heat sinks can be up to two-thirds smaller and lighter, therefore reducing the size of the light engine and making retrofitting more viable, while still maintaining the lumen output necessary for the light to be effective. Synthetic jets are 50% more thermally efficient in removing heat from the source compared to laminar flow normally associated with active cooling.

The synthetic jet form factor lends itself to the design of any LED lighting fixture: retrofit, outdoor lighting, retail, industrial lighting, etc. Synthetic jets have the unique ability to bend airflow in ways that are nearly impossible with traditional air movers, allowing unique designs.

Finally, the form factor of the synthetic jet also lends itself to durability, which is essential in ensuring the long life of the LED light. The modules contain frictionless moving parts which make them reliable, long lasting, resistant to dust and particle contamination and virtually silent.

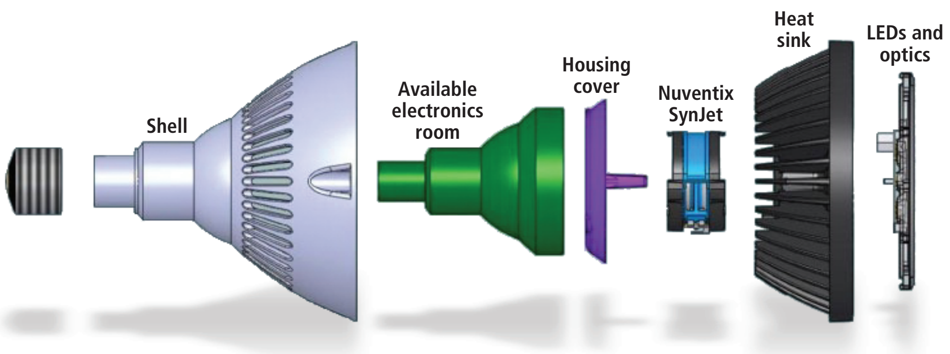

FIG. 2. PAR38 reference-design model with Nuventix SynJet engine.

Making retrofit lamps brighter

Let's consider an example of an LED retrofit lamp that utilizes synthetic-jet technology. Ledon Lamp GmbH, based in Austria, focuses on making high-efficiency LED lamps. Ledon created prototypes of 75W- and 100W-equivalent, incandescent-replacement LED lamps in a near-A-lamp form factor. Although not a true A-lamp envelope, the company does expect the bulb to fit into the majority of applications. With the help of synthetic-jet thermal management, Ledon was able to demonstrate the appropriate values of lumen output, which have never been achieved before, with the help of synthetic jet thermal management.

To achieve the 75W and 100W equivalency, Ledon included the synthetic jet in the top side of the bulb. Located above the synthetic jet is a heat spreader that conducts heat from the LEDs to the heat sink. The heat sink forms nozzles for the synthetic jet to push air through and distribute the airflow to the heat sink fins. The nozzles above the synthetic jet are radially distributed at the edge of the heat sink, between the fins, to allow the synthetic jets to achieve good heat exchange with ambient air.

FIG. 3. Synthetic jet engine with oscillating diaphragm.

In order to cool the driver electronics, one chamber of the synthetic jet is connected to the housing of the driver. Vents on the bottom of this housing are opened to allow the exchange of air, thereby effectively cooling the driver electronics and enabling 75W and 100W LED incandescent replacements. All of this flexibility in design would not have been possible without the synthetic jet's flexibility to direct air in multiple directions for cooling the drive electronics and LEDs.

PAR38 reference design

Nuventix has also created a thermal-management reference design for a PAR38 retrofit lamp (Fig. 2). The reference design, when used in conjunction with the Nuventix SynJet (Fig. 3), provides lighting designers with a system for building an LED array with an output of more than 2500 lm that fits into the PAR38 form factor. In contrast, today's typical LED-based PAR38 replacements deliver about 1500 lm.

The design features a Texas Instruments (TI) custom electronic driver control device, which enables a smaller form factor by integrating discrete components into a single IC.

The SynJet enables up to 40W of cooling in the PAR38 reference design while consuming less than 500 mW of power. Additionally, the SynJet and TI's IC provide lamp designers more design-option flexibility, enabling more lumens in a smaller form factor and thereby using fewer LEDs.