CoolTube™
LED Cooling Technology

Features

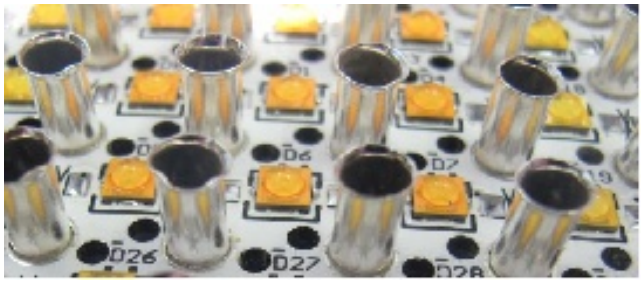
- Eliminates bulky heat sinks
- Eliminates costly aluminium circuit boards
- Utilize with single FR4 circuit board, for both LED cluster and driver circuitry
- Allows scalability of LED cluster without introduction of thermal hotspots
- Facilitates longevity of LEDs through increased cooling efficiency
- Allows for design of compact, low weight luminaires

Traditional LED thermal management techniques

Conventional LED thermal management techniques mount LEDs in clusters on aluminium circuit boards. A heatsink coupled to the back of the board conducts heat away from the LEDs. Fans can be combined with heat sinks to further improve cooling efficiency. Aluminium boards reduce thermal resistance between LEDs and the heatsink, but also between individual LEDs. LEDs in the cluster must be spaced apart to avoid being heated up by their neighbours. “Dotting” and multiple shadow effects occur when LEDs are spaced too far apart. The cooling methods are costly and difficult to scale up for larger LED clusters. Heatsinks, together with separate circuit boards for driver circuitry, result in bulky and heavy luminaire fixtures.

Cooling through protuding tubes

CoolTube™ technology replaces aluminium circuit boards and bulky heat sinks. The LED cluster is mounted on cheaper FR4 printed circuit boards (PCB). Protruding copper[1] tubes are interspersed between the LEDs. The LEDs are thermally-coupled to the surrounding tubes. Heat generated by the LEDs is conducted into the tubes.



Active flow of coolant[2] through the tubes removes heat by convection. Improved thermal isolation of individual LEDs allows closer clustering of LEDs. Different cluster tessellations of LEDs and tubes allow trade-off between cooling efficiency and lumen output. LEDs are fitted with lenses.

[1] or other material with high thermal conductivity

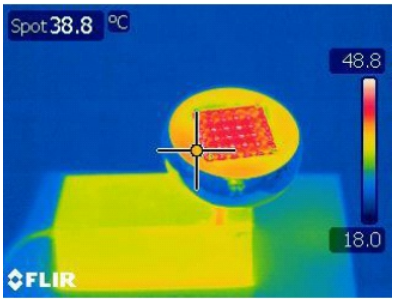
[2] typically air, but possibly also a liquid coolant

Fan driven airflow through tubes

The top of the lenses and tubes form the front surface of the light engine[1]. A fan mounted on the back of the PCB hovers over the tubes protruding through the back of the board. The fan draws or pushes air through the tubes. Bearing-less low-noise fans with long life spans in excess of 70,000 hours can be utilized. The efficiency of the cooling technique allows fans to run below their nominal speed further reducing acoustic sound levels and prolonging life. Other active cooling technologies that do not use a fan, such as Nuventix's SynJet™ technology[2], could potentially also be utilized with CoolTube™ technology.

Scalability of cooling with uniform heat distribution

A distinct advantage of CoolTube™ versus heat sink thermal management is local versus global cooling of the LED cluster. Hotspots in the centre of the cluster are difficult to eliminate with aluminium boards and heatsinks. CoolTube™ technology's local cooling effect on each individual LED results in a more uniform heat distribution across the cluster. This is maintained as the LED cluster is scaled in size[3], as the number of protruding tubes also scale with cluster size to maintain the local cooling effect on each LED.



[1] see range of LED light engines based on CoolTube™ technology at www.marulaled.com/products/engines

[2] See www.nuventix.com/technology/synjet-flash-demos

[3] scaling of the cluster involves increasing the area of and number of LEDs in the cluster

Compact, low weight luminaires

High lumen LED applications, such as the replacement of metal halide luminaires, requires extreme sizes of heatsinks to achieve necessary levels of cooling. This results in bulky, heavy luminaires with low luminous flux per luminaire volume ratios. CoolTube™ technology allows for the design of extremely compact, fit-for-purpose LED lamps, light engines and integrated luminaires. Driver circuitry for the LEDs can be mounted on the same FR4 circuit board as the LED cluster. This eliminates the need for multiple circuit boards, further contributing to luminaire compactness. Luminaires with CoolTube™ inside have some of the lowest luminous flux per volume metrics achieved in the industry. The Marula Puc25[1] provides a good example of what can be achieved.

The puck has a square grid of 25 LEDs. It achieves a luminous flux of 2190 lumens in an enclosure of 282 cm^3. This has a luminous flux to volume ratio of 7.8 lm per cm^3. Remarkably, this is achieved at a LED junction temperature of 67 ºC, giving a calculated L_{70} life span of the LEDs of 267,000 hours[2]. By trading off LED life span, higher luminous flux can be achieved to further increase the luminous flux to volume ratio.

CoolTube™ Inside

To indicate that lamps or light engines utilized in luminaires are cooled by CoolTube™ technology, the CoolTube™ inside logo is appended to the luminaire.

[1] see Marula Puc luminaire at www.marulaled.com/products/luminaires/marulapuc

[2] see Cree Tempo report on the Marula Puc at www.marulaled.com/downloads/marulapuc/cree_tempo_report.pdf