In plant factories, LED lighting fixtures significantly contribute to energy consumption around 40 to 50%

[@kheirabadiCoolingServerElectronics2016] [@dengLiquidMetalCooling2010]

; With LED being also an electronic device, direct application of air-cooling heatsinks can address the heating issue associated with LEDs; however, the heat dissipated from LEDs still permeates into indoor air, affecting temperature and humidity control, rendering it an incomplete solution to the problem at hand.

Y. Lai et al proved with experiments that active liquid cooling is an effective solution for high brightness LEDs in automotive headlights, outperforming air cooling and passive liquid cooling methods.

Water cooling technology is widely adopted and boasts higher efficiency in computer server applications, with COPs reaching up to 20 【7】; it is particularly suitable for scenarios with dense heat loads. Nonetheless, when implemented in plant factories, water cooling requires overcoming challenges such as transferring heat across multiple layers of growing racks (which necessitates pump-powered propulsion) and ensuring effective outdoor heat expulsion (which demands additional energy input from pumps) 【8】.

Although utilizing nutrient solutions for cooling purposes in plant factories presents some feasibility, it confronts numerous challenges: if no independent piping system is added and heat transfer relies solely on conductive contact between LED lights and growth racks, it may negatively affect the growth conditions for plants. Conversely, installing additional pipe routes to dissipate heat outdoors before entering the growth racks effectively resembles constructing an independent water cooling system, which would prevent rapid rises in nutrient solution temperatures should the water cooling system fail 【9】.

In summary, using nutrient solutions for cooling introduces more complexity and is not the most efficient or energy-saving thermal conduction option 【10】. Furthermore, while immersion cooling exhibits excellent heat dissipation properties, its effectiveness cannot be harnessed under heating conditions because the cooling liquids typically used are detrimental to plants 【11】.

Based on the above discussion, this paper proposes a novel cooling solution aiming to:

* Design and implement an efficient heat conduction mechanism for LED aluminum substrates, rapidly removing the generated heat.
* Transfer this heat to a sustainable heat storage pool designed for directional discharge to the outdoor environment.

The ultimate objectives envisioned are:

* Achieving zero-energy cooling of LED chips during cooling operations;
* Recouping and reusing waste heat generated by LEDs without compromising their light output performance under heating conditions.