GLASE

New Research LED Fixture for Plant Growth

by Dr. Robert Karlicek

GLASE researchers have developed a specialized LED light fixture for tunable irradiance growth efficiency research (TIGER) designed to examine how wavelengths and timing of lighting can impact plant growth rates and nutritional quality. TIGER lights were designed to meet very specific research requirements (listed below) for plant growth in controlled environment growth cabinets:

- Flexibility in wavelength selection
- High photosynthetic photon flux density (PPFD)
- Excellent color mixing for uniform canopy lighting
- Excellent PPFD uniformity at short distances from the fixture
- Modular design, for tailoring to a variety of growth cabinet types
- High speed, pulsed lighting capability for examining new dynamic lighting protocols

For simplicity, we elected to build a 6-wavelength system **(Fig. 1)** using three blue LED (400 nm, 420 nm, and 450 nm), a green LED (525 nm) a red LED (660 nm) and a far red LED (735 nm). We did not use any phosphor converted LEDs so that narrow emission peaks could be used for better definition of wavelength impact on plant physiology.

To achieve the highest possible PPFD for this light, we worked directly with one of the world's leading chip manufacturers to select only the brightest LED semiconductor devices for packaging. As seen from **Fig. 1**, the green (525 nm) PPFD is the lowest, since the efficiency of the best green LEDs remains much lower than blue and red LEDs. (In "LED speak", this is called the green gap problem, a fundamental scientific issue with making green light from LEDs.)

Color uniformity across the canopy (or even a single leaf) was achieved by using a specially designed "6-in-1" LED package (**Fig. 1, inset**) that had been developed for LED stage lighting in the entertainment industry. We worked with the LED packager (Prolight Opto) to replace the stage lighting LEDs with plant lighting LEDs. By putting all of the different wavelength LEDs as close together as possible in a single package, we were able to get excellent color mixing right at the surface of the TIGER light without having to use a diffuser, which would have reduced the PPFD of the module.

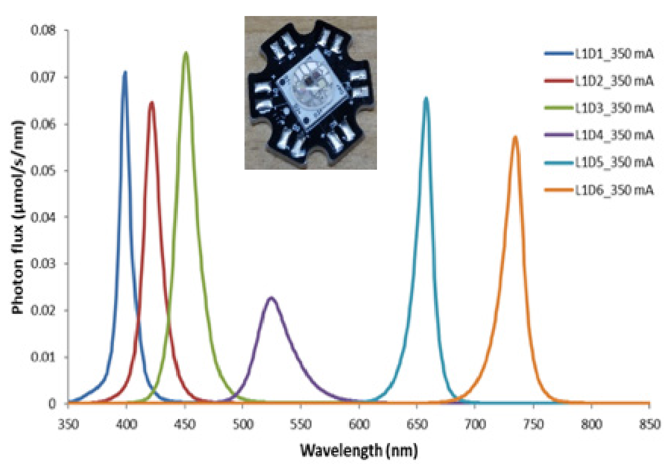

Figure 1: Emission wavelengths of a TIGER light LED package shown in the inset. The close chip packing under a single lens provides excellent color mixing.

Once the basic LED matters were selected, we needed to design the circuit boards, the electrical distribution LED drivers and thermal solution for the TIGER light module. The overall assembly is shown in **Fig. 2**. An individual TIGER module uses 10 LED packages, and has its own AC/DC power converter and analog LED driver system. Modules can be daisy chained together to create bars or other shapes as needed for the particular growth area dimensions used for research. Because our research required the use of many modules to get to high PPFD (especially for green, which is the poorest performer as described above), each module was carefully calibrated for identical performance at any brightness level and for achieving linear dimming characteristics. This calibration data is loaded onto memory in each module to insure uniform, module-to-module performance at any power setting.

Figure 2: Two views of the TIGER light module. TOP – lighting side of the module showing 10 LED packages, each with 6 separate LEDs. The large black box on top is the AC/DC converter. BOTTOM – view of the module top showing cooling fans, as each module can dissipate up to 60 W at full brightness.

There are two ways to dim LEDs - analog dimming using linear current control, and pulsed dimming where the LED is pulsed on for a given period of time, and then turned off, and this process is repeated at a set frequency. The former method is more like sunlight but harder to control, the latter pulsed method is widely used in LED lighting for general (people) illumination. One should also remember that LEDs run on constant DC current, not voltage. The role of the LED driver is control the flow of electrical current to the LEDs in the module independent of the voltage needed to get that current to flow. Because each module has six independent wavelengths, each module needs six separately calibrated drivers.

The final requirement for high speed pulsed operation is to study new ways to impact plant growth outcomes. The idea of using LEDs for generating light pulses to reduce plant lighting energy use has been around for almost 20 years, and there have been mixed results on plant growth quality or energy savings. More recent, more sophisticated pulsed lighting schemes have shown promise in accelerating plant growth rates, with significant improvement in biomass efficacy (higher kilogram of plant mass per kilojoule of energy used). This work is very preliminary, but with the special high speed switching capabilities of the LED current driver used in TIGER lights, we hope to examine this opportunity for reduced lighting energy use much more carefully.

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The Greenhouse Lighting and Systems Engineering (GLASE) consortium is funded by NYSERDA and its Industrial Members.

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