Understanding Lab Claims about Efficacy

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Cutting through the hype and discerning the facts is critical to reading between the lines of laboratory announcements.

Have you ever been confused by conflicting press releases coming from different power LED vendors about new records for efficacy? You are certainly not alone. Depending on the application, efficacy can be an important technical consideration in the selection of LED components for a lighting solution. But how do you compare and interpret lab results, and what do they mean?

First of all, cutting-edge lab results are almost by definition based on new, prototype technology, under optimal conditions. While these kinds of results can be important indicators of future progress in actual products, they should not be a factor in your everyday product selection decisions.

Second of all, the results themselves can be misleading. Efficacy is a function of many different design and operating parameters that can be artificially manipulated for the sake of an impressive-sounding press release.

Efficacy is defined in the industry as lumens per watt (lm/W). Lumen output is a complex function of the total optical power output of the LED across color, and the human eye response. Power in Watts is simply current times voltage. Basic stuff, but important to remember when understanding efficacy claims.

The most commonly manipulated parameter in efficacy claims is current density, computed by dividing the die area (e.g. in square millimeters) by the drive current. By this formula, a 1x1mm die has four times the current density as a 2x2mm die at the same drive current.

Lower current density can dramatically increase efficacy in nitride LEDs. A 4 mm^2 die should *of course* produce more light at a given current than a 1mm^2 die. Similarly, a 1mm^2 die driven at a lower current should *of course* produce better efficacy (but less light) than the same one driven harder, assuming all other conditions are the same. Therefore, before you can understand efficacy, you must know both the die size *and* the drive current under which efficacy was measured in order to interpret the result. If the laboratory does not specify both, then a meaningful conclusion is not possible.

Additionally, different LED designs deliver different relationships between current density and efficacy as drive current changes. The phenomenon that all InGaN LEDs fall in efficiency at high current densities is called "droop". Droop is important in a practical sense because it forces tradeoffs between total lumen output, cost, LED count, and efficiency. But some LED designs fall more quickly than others. So to understand how new lab results may ultimately impact the performance of a real product, the results must be reported at the drive current most likely to be used, if not multiple current levels.

For white LEDs, probably the second most manipulated parameter is color point — not just correlated color temperature (CCT), but the exact (x,y) or (u', v') color coordinates of the LED. Since lumens are a function of human eye sensitivity, and efficacy is a function of lumens, as the color of an LED drifts into spaces where the human eye is more sensitive, the efficacy can improve substantially. Even within "white", drifting off the blackbody radiation curve (the Planckian locus) toward a green tint can add 15% or more to the lumen value and therefore the efficacy of a tested LED. Of course, when you buy packaged LEDs from your vendor this is not an issue; the current, forward voltage, and color bin are specified along with typical or minimum lumens. But this is rarely the case with lab result press releases. Since record efficacy claims coming out of labs tend to be within a 15% margin from the previous record, you don't really know anything unless you know the color point of both lamps.

There are many other factors that interact in complex ways to influence efficacy. For example, because the lumen output of nitride LEDs is affected by junction temperature (T_j) — the temperature at the point inside the die where the light is generated – T_j has a substantial impact on efficacy. Because power (Watts) is the denominator of the efficacy equation, efficacy is affected by forward voltage. You can safely assume that vendors are doing their best to optimize these for the sake of technological leadership in areas that are important to their customers.

In summary, in order to interpret and make apples-to-apples comparisons between lab statements about efficacy, you must know at least the following test conditions:

(1) Die size in square millimeters, or total area if multiple chips

(2) Drive current - preferably multiple results at different, relevant currents

(3) Color point in (x,y) or (u',v')

Anything less is just hype.