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White LED lumen testing

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08-07-2005, 10:28 AM

jtr1962
Flashaholic*

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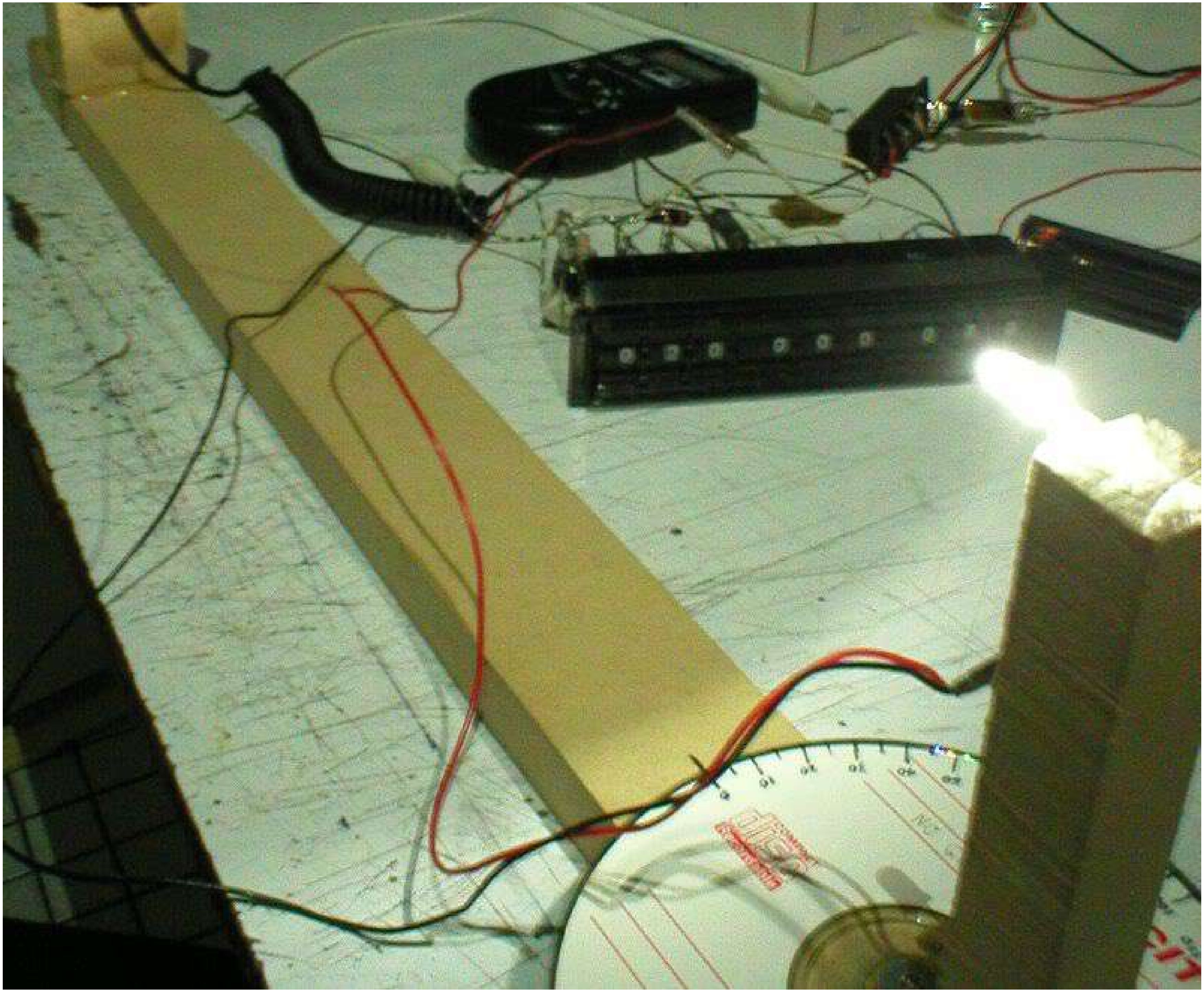
White LED lumen testing

Having acquired quite a few different types of white LEDs over the last two years I've long wanted to see how they stacked up against each other. To that end, and since summer is traditionally my season for indoor projects, I ran a slew of tests. Besides the usual intensity and Vf measurements, I also built a device to enable me to estimate lumen output:



I made a cradle to hold my light meter out of silicon rubber for consistency of measurements. An old CD serves as the dial to rotate the LED. Starting at 0°, I first position the LED so that the light meter reading is as high as I can get it in order to obtain a hot spot reading. This is important because the relative value of all the other measurements to the highest reading is what will ultimately determine the accuracy. I record the reading, and then rotate the dial in 5° increments all the way to 180°, recording all the light meter readings. A few times during the test I block off the LED in order to obtain a background reading which needs to be subtracted from all the readings. The value is usually 0.1 to 0.2 lux, and while it may not sound like much, at the 17.5" distance between the LED and light meter it can affect the final result by as much as half a lumen.

After I obtain my results on the test jig running the LED at 20 mA I then take lux readings of the LED at one meter at different currents using the constant current source with the thumbwheel switches to change the current. I also record the LED's Vf. I then plug all the data into an Excel spreadsheet made for that particular LED and come up with the final results. Here is a .zip file containing all my spreadsheets so far for anyone who wants to see how I do my calculations.

This post contains my results for low-power LEDs. For those interested in power LEDs, I collected all of my power LED test results in this post.

Although I have tested many LEDs in this thread, I am not in a position to recommend specific LEDs for use in flashlights or other devices to people. I feel the need to mention this because I have received quite a few PMs asking me which LED would be good for such and such project. I feel it would be best to start a new thread asking for LED recommendations rather than asking me. I just don't have the time or desire or ability to help people determine which LED to use in any given project.

Before showing graphs of the results here is a list and short description of the LEDs I tested so far in order of date of purchase (all are from eBay with the exception of the Hebei LED and the old Nichia):

Nichia(?) 5600 mcd 20° 5mm white (purchased 2001 from Hosfelt Electronics)
A bought a pair of these for $3 each back in 2001 when white LEDs were something of a novelty. In fact, until I started buying on eBay I only had a handful of white and blue LEDs as they were just too pricey to buy in quantity. Anyway, based on the tapered shape and the warm color this LED is probably a Nichia. It actually greatly outperformed the 5600 mcd spec, and did surprising well for a 4-year old white LED, coming in at 28 lm/W efficiency at 20 mA. The tapered shape seems to avoid the ring of light at 60° off-axis as is the case with straight narrow viewing angle 5mm LEDs. As a result, the hot spot is brighter for a given lumen output, and very little light comes out the back.

SpectrumLEDs (noshankyhank at time of purchase) 6,000 mcd, 30° 5mm white (purchased May 2003)
The first white LED I purchased on eBay. Very blue tint.

ChiWing 5,000 mcd 3mm white (purchased July 2003)
Bluish color, wide angle beam.

ChiWing 8,000 mcd 20° 5mm white (purchased July 2003)
Slightly bluish-green, outperformed specs, fairly long-lived based on the one used in my PC as a power indicator. Very low Vf in the 3.00 volt area.

BestHongKong 10,000 mcd 20° 5mm white (purchased February 2004)
Slightly purple, outperformed specs, degrades almost instantly at drive currents above 60 mA.

SpectrumLEDs 8,000 mcd 20° 5 mm white (purchased November 2004)
Decent color but very dim for a late 2004 LED, seemed to degrade rapidly even at 20 mA.

warden_jp2002 26,000 mcd 20° white (purchased February 2005)
Slightly bluish tint, the highest output LED tested by me to date due to a slight wider beam for a 20° LED, no longer available on eBay.

Hebei L5B47VW5C 60° 5mm white (purchased March 2005)
Nice color, wide angle beam, purchased for testing for use in my taxi lighting project. Ultimately rejected for that purpose due to costs and output but still a quality LED, and probably very-long lived.

LCK 12,000 mcd 20° 5 mm white (purchased July 2005)
White with just a hint of blue, greatly outperformed specs, maybe these are LCK's 26,000 mcd LEDs which were put into a 12,000 mcd bag by accident.

BestHongKong 25,000 mcd 20° 5mm UWLC series white (purchased July 2005)
The UWLC series is designed for better color rendering and purer white. These LEDs excel on both counts, especially when rendering reds, and are neither too blue nor too yellow, coming in at a color temp of around 5000K. A slightly wider beam than most 20° LEDs, these come in near the low end of their 14,000 to 25,000 mcd range spec, average in the 16,000 to 17,000 mcd range. The wider beam gives them more output than would be expected for an LED with their intensity.

Light of Victory 35,000 mcd 20° 5mm white (purchased July 2005)
The second best color of any LED I've tested so far. Intensity is a close match to the warden_jp2002 26,000 mcd whites but slightly less in lumen output. These seem a match for the Nichia CS in terms of both lumens and intensity. Low Vf compared to most other white LEDs.

LCK 12,000 mcd 20° 5mm warm white (purchased July 2005)
The first warm white LED I've purchased. Color temp looks like 3200K to 3300K. As with the LCK 12,000 mcd white, it outperformed specs.

Jeled 40,000 mcd 20° 5mm white (purchased December 2005)
Very similar color to the Light of Victory 35,000 mcd, and identical lead frame design. Intensity is nearly 31,000 mcd at 20 mA, a new record for 5mm, 20° white LEDs. Vf is middle of the pack at 3.3V at 20 mA. I also managed to reach over 70,000 mcd at 80 mA, well above my previous records. These intensity records seem to be mostly because the beam is a bit more tightly focused rather than from increased output. Efficiency at 20 mA is a solid 70 lm/W, still less than the warden_jp2002 from early 2005.

BestHongKong 40,000 mcd 20° 5mm white (purchased January 2006)
Note that these are NOT the UWLC series pure white but are optimized for intensity instead. Part number is BEB1000003-100. They are slightly bluish white rather than pure white, maybe about 8000K, but with a very even beam. They are also not anywhere near 40,000 mcd at 20 mA due to a much wider than usual beam. A few of the ones with tighter beams were in the 25,000 mcd area but most were about 20,000 mcd. Vf is a bit on the high side at 3.4V to 3.45V at 20 mA. Thanks to the wide beam, output and efficiency are close to the best I've measured so far. In fact, at 5 mA these set a new efficiency record of nearly 97 lm/W. Although I didn't test at lower currents, they may well break 100 lm/W at 2 or 3 mA. Given the results of this test and the Jeled 40,000 mcd, there hasn't been that much improvement in overall white LED efficiency since early last year, although LEDs of top efficiency are now more widely available (remember that the record setting warden_jp2002 26,000 mcd LEDs last year were a very limited run, and it took until late in the year before comparable LEDs were widely available).

Jeled 50,000 mcd 20° 5mm white (purchased January 2006)
Identical to their 40,000 mcd LED in design, except the color is slightly whiter. I tested three samples and averaged the results. In short, I

broke all my previous records by a good margin. Intensity averages around 41,000 mcd at 20 mA and 55,000 mcd at 30 mA. I also reached average intensities over 90,000 mcd at 80 mA. One of the three with a somewhat tighter beam managed over 100,000 mcd at 80 mA. Vf is tending to the high side at 3.4V at 20 mA. Efficiency at 20 mA averaged 82 lm/W, well above previous records. At 5 mA all three samples were well above 100 lm/W, with an average of 110 lm/W. Just for kicks I tested at lower currents to see if efficiency improved further. It did, averaging nearly 125 lm/W at 1 mA, which is well into HID and HPS territory. Assuming a luminous efficacy of 330 lm/W, typical for white LEDs, energy to light conversion efficiency at 1 mA is around 40%. I also noticed an interesting phenomenom. After I test intensity versus current, I measure the intensity and Vf again at 20 mA just to see if the LED's characteristics changed from the excursion to 80 mA. Usually I find little if any change, and it's usually just a slight decrease in intensity from being abused. In this case, I not only found that intensity was *higher* after the test, but also that Vf was lower! This is very much what happens with a Luxeon. Because of this I redid the entire intensity versus current tests for all three LEDs after the initial "burn-in", for lack of a better word. Overall the changes bumped the average efficiency from about 75 lm/W at 20 mA to the 82 lm/W figure mentioned earlier. The changes also occurred in an LED that was run at 20 mA overnight.

Peak Snow 29 5mm white (acquired February 2006)
CPF member **Pinter** was kind enough to send me 5 samples of the Peak Snow 29 LEDs for testing. These LEDs have a wider than usual beam and a very even color. Color temperature on one sample looked like about 5500K with the rest falling around 6500K. Efficiency on these was impressive, averaging nearly 80 lm/W at 20 mA for the 5 samples. Even more interesting was that the samples ranged from 70 lm/W all the way up to a bit over 90 lm/W at the nominal 20 mA. Average intensity was 21,260 mcd and average output was 5.11 lumens, both figures about equal to the Nichia CS. This verifies the claim Peak makes which states that the Snow 29 LEDs match the Nichia.

Nichia CS bin B1U 15° 5mm white (acquired February 2006)
Along with the Peak Snow 29 LEDs Pinter also sent me 4 samples of the Nichia CS LEDs. At the nominal 20 mA operating current these came in at close to 75 lm/W, 4.83 lumens output, and 24,100 mcd intensity. The consistency between samples was very impressive as well-the worst measured 70.6 lm/W while the best was 76.0 lm/w, a variation of less than 8%. Where the Nichias really shined (pun intended) was at higher currents. The majority of LEDs I've tested increased little in output beyond about 70 or 80 mA, and so I usually stopped the testing at 80 mA. The 80 mA output was typically about 2.2 to 2.5 times the 20 mA output. On the other hand, the Nichias gave about 2.75 times their 20 mA output at 80 mA, and the curve showed no signs of flattening out. Therefore, I tested up to 100 mA, which is as high as my test jig goes (and the absolute maximum limit for 5mm LEDs). At 100 mA the Nichias were giving nearly 3.1 times the 20 mA output, or on average nearly 15 lumens! To put this into perspective remember that this isn't much less than Luxeons were giving a few years ago, and at 350 mA. Furthermore, the Nichias showed no signs of stress following their brief excursion to 100 mA. Their output at 20 mA once they cooled down was exactly the same as before. If you really need to overdrive a 5mm LED, then the Nichia is the best candidate.

MPJA 15,000 mcd 10mm white (acquired July 2006)
This is one of four different types of LEDs sent to me by CPF member **milkyspit** for testing. I wasn't expecting much based on the 15,000 mcd rating since this is way under the ratings for similar very narrow beam 10mm LEDs from other manufacturers. The five samples all exceeded their ratings by a large margin, coming in at 41.4, 47.8, 60.0, 62.9, and 81.9 cd at 20 mA. I tested the lumens on the best and worst ones, and averaged the results. Of course the intensity far exceeds anything I've tested to date, but this was expected given the tight focus. The efficiency averages a respectable 60.9 lm/W at 20 mA. Color is somewhat blue, with a color temperature of roughly 9000K. The beam is as smooth as can be expected from an LED with as tight a focus as these, but the bond wires and die are clearly visible. Measured beam angle is only about 8.5° but alot of light falls outside the main beam.

unknown 26,000 mcd 5mm white (acquired July 2006)
This is the second of four different types of LEDs sent to me by CPF member milkyspit for testing. After testing I'm reasonably sure that this *isn't* one of the warden_jp2002 26K LEDs which milkyspit thought it might be. Rather, the tapered shape causes me to think this is a Nichia.

Based on the color and intensity, I'd say it's a Nichia CS 1BU rank T, and this is what I labeled the results as. The three samples came in at 15.5, 16.8, and 17.9 cd at 20 mA. I tested the middle one for lumens. Efficiency is 61.6 lm/W at 20 mA. Unlike the othe Nichia CS LEDs I tested, these don't do as well at higher currents. The output is more or less maxed out at 80 mA. These may in fact *not* be Nichias, but if so I have no idea what they are.

LS Diodes THC3 4-die 5mm white (acquired July 2006)
This is the third of four different types of LEDs sent to me by CPF member milkyspit for testing. This is the first quad-die LED I've ever tested so the results are quite interesting. The beam is very smooth and white, coming in at about 6000K. Half-intensity beam angle is fairly wide at 27.4° so the intensity is nothing to write home about, reaching only 8,300 mcd at 20 mA. Efficiency at 20 mA is 72.8 lm/W which is very respectable. Note though that since each die is only receiving 5 mA this number isn't as good as it appears at first glance. Where this LED shines is at higher currents. Once you exceed 40 mA it surpasses every 5mm white LED tested to date in efficiency. Even at 100 mA efficiency is still a very decent 50.1 lm/W. As expected, forward voltage is very low compared to other 5mm whites since each die is only getting 1/4 of the current.

SMJLED 4-die 5mm white (acquired July 2006)
This is the fourth of four different types of LEDs sent to me by CPF member milkyspit for testing. As with the LS Diodes THC3, the beam is very smooth and white. Color temperature is about 6500K to 7000K. Beam angle is fairly wide (31.6°) so the intensity is low, reaching only 7,100 mcd at 20 mA. Efficiency at 20 mA is 87.8 lm/W which is a new record. Once again, note that since each die is only receiving 5 mA this number isn't as good as it appears at first glance. Again, this LED shines at higher currents. Once past 20 mA it surpasses every 5mm white LED tested to date in efficiency. At 100 mA efficiency is 57.2 lm/W. As expected, forward voltage is very low compared to other 5mm whites since each die is only getting 1/4 of the current. Lumen output far exceeds any 5mm LED tested to date, reaching 17.67 lumens at 100 mA. While these numbers are great, remember that at 100 mA each die is only getting 25 mA. Just for comparison purposes four Jeled 50,000 mcd whites each running at 25 mA would output 26.5 lumens at an efficiency of 76.7 lm/W. Basically, this means that the dies used in the SMJLED (and the LS Diodes THC3) are decent, but not the best available.

Nichia NSPW310BS-E 60° 3mm white (purchased August 2006)
I purchased 200 of these on eBay to be used for lighting projects requiring very small LEDs. The beam is bluer in the middle, and most of the LEDs seem to have a color temperature in the 6500K to 7500K range. A few are significantly more blue or yellow than this however. Since these are wide angle LEDs intensity wasn't very high, coming in at around 2,600 mcd at 20 mA. Half-intensity beam angle measured 51°. As with the other Nichias I've tested, these do well at higher currents, giving nearly 3 times their 20 mA output when driven at 100 mA. They might do even better soldered to a PC board with heavy traces. Efficiency was low for a white LED these days, coming in at 36.2 lm/W at 20 mA but peaking in the 50 lm/W area when driven at 2 to 5 mA. Nevertheless, 36 lm/W is still 4 to 10 times higher than the efficiencies of the grain of wheat incandescents which LEDs like this might be used to replace. The NSPW310CS, which is the newer, brighter version of this LED, would do about 65 lm/W based on the relative typical intensities given by Nichia.

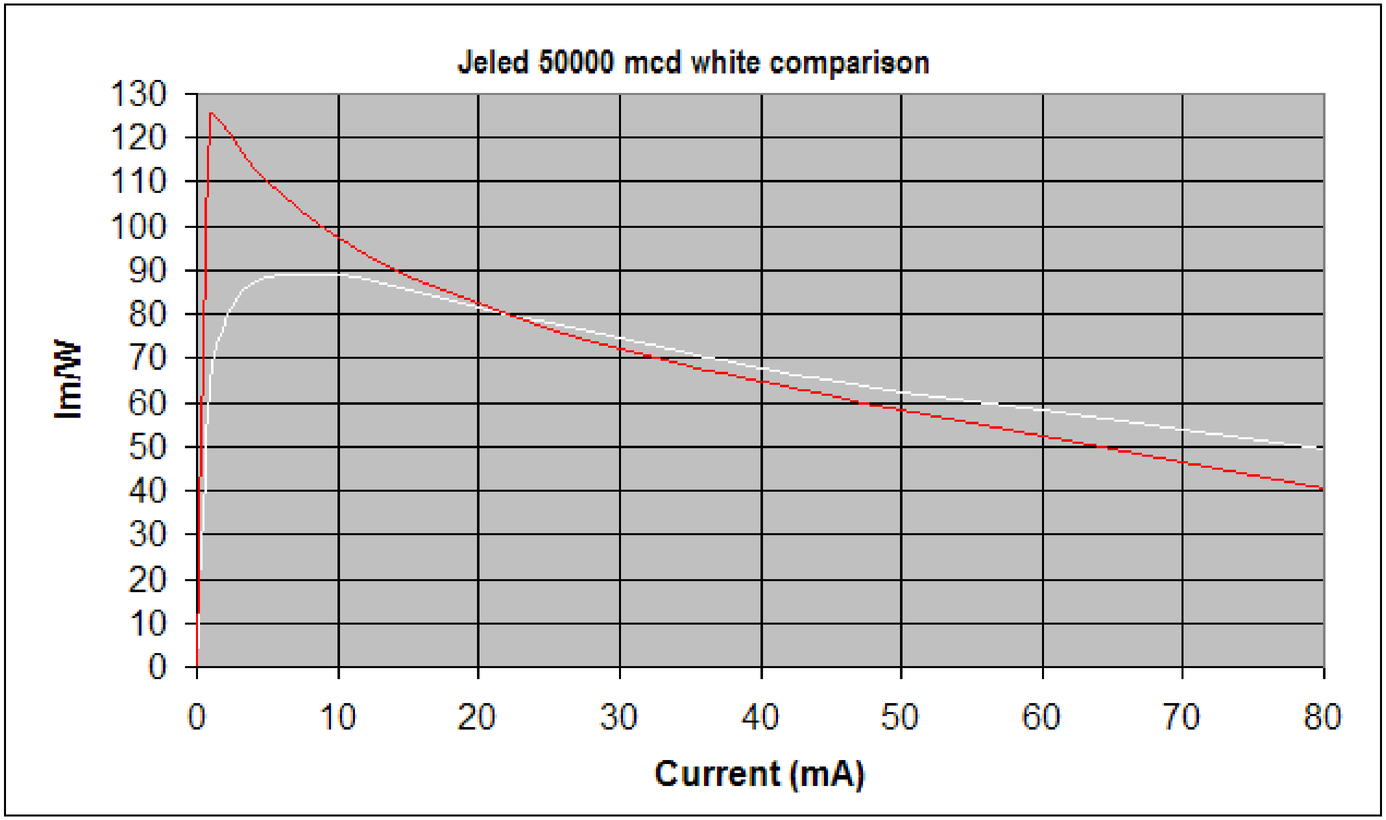
Jeled PLCC-2 2000 mcd white (purchased August 2006)
I purchased 100 of these PLCC2 surface mount LEDs on eBay to be used for small scale area lighting projects. I also purchased 50 each of the 4 available colored PLCC-2 LEDs (blue, green, red, orange). The beam is very even and color temperature seems to be in the 7000K to 7500K range. Since these are very wide angle LEDs intensity wasn't very high, coming in at around 950 mcd at 20 mA. Half-intensity beam angle measured 112°. Efficiency was unspectacular for a white LED these days, coming in at 43.4 lm/W at 20 mA but breaking 60 lm/W area when driven at 1 to 5 mA. I'll admit to being underwhelmed by these since they are speced at 2000 mcd typical. Had they done so with the same light distribution pattern they would have had efficiencies around 90 lm/W. Nevertheless, the mid 40s isn't horrible, and since I would mainly use these on something non-battery powered like a train layout efficiency isn't terribly important. These would make great miniature imitation metal halide parking lot lights, for example. Had they lived up to spec they would have been almost as efficient as the real ones!

The orange ones would do a fair job simulating sodium vapor streetlights. As to why these aren't in the same league as the Jeled 50Ks, my guess is they're not using their best dice, and also the PLCC-2 package basically blocks any light past 90° which might be reflected off the sides or front of the encapsulant. This can be as much as an additional half a lumen, and that would have brought the efficiency up to the low 50s.

BestHongKong 20° 5mm warm white (purchased June 2006)
These are my second purchase of warm white LEDs. They have a hotspot with a color temp in the 3300K to 3500K range and a corona of somewhat lower color temp resembling the light from a sodium vapor street lamp. Overall I d say the average color temperature is around 3000K. The intensity is around 14,500 mcd at 20 mA, Vf is a low 3.12V, beam angle is 11.9°, and overall efficiency is an unspectacular for these days 37 lm/W. Remember though that warm white LEDs tend to have somewhat lower efficiencies than their cool white cousins. Overall the output of this LED is much closer to the incandescent it seeks to replace than the greenish hued LCK warm whites I tested last year.

LCK 40,000 mcd 15° 5mm white (acquired January 2007)
This is one of four different types of LEDs sent to me by CPF member **TMorita** for testing. The three samples came in at 30.2, 30.9, and 31.3 cd at 20 mA. The average output at 20 mA was 4.91 lumens, average Vf was 3.26V, and average efficiency was a very respectable 75.2 lm/W. There wasn't much variation between samples in any of the parameters. The beam was somewhat blue, perhaps 8000K, but very smooth. Measured beam angle was 15.1°. These seemed to have less efficiency loss at higher currents than most other eBay LEDs I've tested so far. Even at 80 mA they managed 46.6 lm/W.

Jeled 50,000 mcd 25° 5mm white test #2 (acquired January 2007)
This is the second of four different types of LEDs sent to me by CPF member TMorita for testing. The three samples came in at 32.6, 36.2, and 30.1 cd at 20 mA. The average output at 20 mA was 5.01 lumens, average Vf was a very low 3.07V, and average efficiency was a very respectable 81.5 lm/W. There was a little more variation between samples than with the LCK 40Ks in terms of beam angle and intensity but overall output and Vf were close for all the samples. The beam was a little blue but somewhat blothy. Average color temperature looked around 6500K to 7000K. Measured beam angle was 13.5°. As with the LCK 40Ks, these seemed to have less efficiency loss at higher currents than most other eBay LEDs I've tested so far. At 80 mA they managed an even better 49.4 lm/W. It seems plausible that these and the LCK 40Ks may be using the same chip since the test results are similar. Since this is my second test of the Jeled 50Ks there appear to be some notable differences from my first test a year ago. Efficiency is about the same but Vf is much lower so total output is about half a lumen less. Efficiency at higher currents is much improved, as is total output. The original Jeled 50Ks only managed about 2.3 times their 20 mA output at 80 mA, or roughly 13 lumens. The newest batch manages about 2.8 times and 14 lumens while having about 21% greater efficiency. The only downside is that the efficiency of the newer Jeled 50Ks peaks at around 5 to 10 mA in the 90 lm/W area while the older ones averaged as high as 125 lm/W at 1 mA and close to 100 lm/W at 10 mA. You can see the differences below with a side-by-side comparison on the same chart (new in white, old in red). If I had to guess what the change was, I'd say a larger physical size, less efficient chip was used. This would account for the lower Vf and lower peak efficiency. However, by virtue of lower current density efficiency is actually better from about 20 mA and up. This is actually a very sensible decision since if anything 5mm white LEDs tend to be overdriven, not underdriven. Perhaps the larger chip was also used to help lumen maintenance. Lumen maintenance is probably getting more important for inexpensive Chinese LEDs since many are being used in Christmas lights where short lifetime would be very apparent. On another note, based on this test and the LCK 40Ks I'm somewhat disappointed that in a year 5mm LED efficiency has been stagnant. I was expecting 100+ lm/W at 20 mA by summer 2006.



LCK 35,000 mcd 2-die 30° 5mm white (acquired January 2007)
This is the third of four different types of LEDs sent to me by CPF member TMorita for testing. The three samples came in at 8.8, 8.0, and 9.0 cd at 20 mA. The average output at 20 mA was 3.50 lumens, average Vf was a very low 3.02V, and average efficiency was a decent 58.0 lm/W. There wasn't much variation between samples in any of the parameters. The beam was a pure white similar to the BestHongKong UWLC series with a color temperature of around 5000K, and very smooth. Measured beam angle was 21.3°. Even though these are two-chip LEDs they didn't do as well at higher currents as the LCK 40K and the second batch of Jeled 50Ks in terms of output. However, because they are dual die they will probably last longer at higher currents. Note that even at their rated 40 mA these don't come anywhere near their ratings of 35,000 mcd and 30° beam angle. However, this isn't unusual for eBay LEDs. The only way to know what you're getting is to buy it and test it. For what these cost they are still a decent value even if they don't live up to their billing.

Jeled 15,000 mcd 140° superflux white (acquired January 2007)
This is the fourth of four different types of LEDs sent to me by CPF member TMorita for testing. I only tested one of the three samples since the other two appeared very similar in output. The result was 2.9 cd and 3.46 lumens at 20 mA. Beam angle was 60.6°. Vf was 3.26V and overall efficiency was 53.1 lm/W. Color was very blue, perhaps as high as 9000K, and the beam was very smooth. Of course, these figures are nowhere near the claimed output of 15,000 mcd and a 140° beam angle. However, consider that an LED with those specs would have a total output of around 70 lumens so I wasn't expecting this part to meet specs. If it did, it would have had an efficiency in the 1000 lm/W area which would be physically impossible! Overall this is a decent LED which should give long life owing to the superior heat dissipation of the superflux or pirahna package.

New LS Diodes THC3 4-die 5mm white (acquired February 2007)

CPF member **milkyspit** sent me a new THC3 and a Quickar 5m100w for comparison testing. The beam is very smooth and white, coming in at about 6500K. Half-intensity beam angle is fairly wide at 29.4° so the intensity is only 6,400 mcd at 20 mA. Efficiency at 20 mA is 65.5 lm/W, a little lower than the original THC3 which was 72.8 lm/W. As with other 4-die LEDs this one does well at higher currents. Even at 100 mA efficiency is still a very decent 47.6 lm/W. As expected, forward voltage is very low compared to other 5mm whites since each die is only getting 1/4 of the current.

Quickar 5m100w 4-die 5mm white (acquired February 2007)
This LED is similar to, but less expensive than, the LS Diodes THC3. In a head-to-head comparison with the new THC3 it did very well. The beam is very smooth and white, quite similar to the THC3, and with a similar color temperature of roughly 6500K. Half-intensity beam angle is fairly wide at 33.9° so the intensity is a mere 5,600 mcd at 20 mA. Efficiency at 20 mA is 63.2 lm/W, a little lower than the new THC3. At 100 mA efficiency is a very decent 46.4 lm/W, just a hair under what the new THC3 does. Once again, forward voltage is very low compared to other 5mm whites since each die is only getting 1/4 of the current.

SuperbrightLEDs 7,500 mcd 90° superflux (acquired February 2007)
CPF member **TMorita** sent me this LED along with a bunch of others for testing. The result was 2,600 mcd and 3.83 lumens at 20 mA. Beam angle was 72.0°. Vf was a very low 3.04V and overall efficiency was a decent 63.0 lm/W. Color was pure white, about 6500K, and the beam was very smooth. This is a decent LED which should give long life owing to the superior heat dissipation of the superflux or pirahna package.

LVEHK 10,000 mcd 20° 3mm white (acquired February 2007)
TMorita sent me 3 samples of this LED for testing. The results were 3.0, 3.0, and 3.6 cd at 20 mA, way less than spec. Average beam angle was 29.7°, somewhat wider than claimed, which explains the lower intensity. Color was somewhat blue, around 8000K. Average efficiency of the three samples was only 25.9 lm/W, average output was 1.67 lumens, and average Vf was 3.22V. Although efficiency of these isn't that great, it is much better than the 2 to 4 lm/W of the tiny incandescents which they might be used to replace.

SpectrumLEDs 2,000 to 4,000 mcd 180° 4.8mm white (acquired February 2007)
TMorita sent me 3 samples of this LED for testing. These are the 4.8mm "top hat" package which is designed for area lighting applications. The results were 1.75, 1.84, and 1.81 cd at 20 mA, around the low end of the spec. Average beam angle was 105.6°. Color temperature was 6500K, which is pure white to most people. Even though the intensity was low because of the wide beam angle average efficiency of the three samples was an excellent 79.2 lm/W. Average output was 5.10 lumens, and average Vf was 3.22V. Consistency between samples was impressive-outputs were 5.06, 5.15, and 5.10 lumens. Overall these are great LEDs for any application required flood lighting, or perhaps to focus with a reflector.

SuperbrightLEDs 18,000 mcd 15° 5mm white (acquired February 2007)
TMorita sent me 3 samples of this LED for testing. The results were 24.6, 23.3, and 24.2 cd at 20 mA, higher than spec. Average beam angle was 15.3°. Color temperature was a slightly but not offensively blue 7000K. The beam was smooth. Average efficiency of the three samples was a decent 66.0 lm/W. Average output was 3.99 lumens, and average Vf was a very low 3.02V. Consistency between samples was impressive-outputs were 4.12, 3.76, and 4.09 lumens. Overall these LEDs are solid performers.

SuperbrightLEDs 18,000 mcd 30° 5mm white (acquired February 2007)
TMorita sent me 3 samples of this LED for testing. The results were 13.1, 13.2, and 12.3 cd at 20 mA, way less than spec. Average beam angle was 20.2°, also less than spec. Color temperature was a match to the 15° version of this LED, coming in at 7000K. The beam was smooth. Average efficiency of the three samples was a solid but not overly impressive for these days 50.7 lm/W. Average output was 3.19 lumens, and average Vf was 3.14V. Consistency between samples was even more impressive than the 15° version-outputs were 3.10, 3.24, and 3.22 lumens. Overall these LEDs are decent even though they didn't meet their specs.

BestHongKong 35,000 mcd 20° 5mm white (acquired February 2007)

TMorita sent me 3 samples of this LED for testing. The results were 29.0, 29.1, and 29.5 cd at 20 mA, slightly less than spec. Average beam angle was 14.7°. Color temperature averaged around 7000K but the beam was a little blotchy, with a blue center and yellowish corona. Average efficiency of the three samples was a decent 65.8 lm/W. Average output was 4.53 lumens, and average Vf was a somewhat high 3.44V which hurt the efficiency numbers. Consistency between samples was quite impressive-outputs were 4.53, 4.64, and 4.41 lumens. The high Vf and poor scaling of output with current (output at 80 mA was only 2.06 times the output at 20 mA) indicates that these LEDs likely use small but efficient dice.

LVEHK 55,000 mcd 20° 5mm white (acquired February 2007)
TMorita sent me 3 samples of this LED for testing. The results were 28.6, 28.4, and 29.7 cd at 20 mA. Note however that the 55,000 mcd spec is at 25 mA. Average intensity of the three samples at 25 mA was 34.6 cd, still somewhat below spec. Average beam angle was 14.0°. Color temperature averaged around 7000K but the beam was a little blotchy, with a blue center and yellowish corona. Average efficiency of the three samples was a decent 64.1 lm/W. Average output was 4.15 lumens, and average Vf was 3.23V. Consistency between samples was decent-outputs were 4.30, 4.20, and 3.94 lumens. Output scales very well with current (output at 80 mA is 2.53 times the output at 20 mA), and efficiency numbers increase by only about 25% at lower currents compared to at 20 mA, indicating that these LEDs use large dice. While these LEDs are decent, and comparable in performance to the BestHongKong 35,000 mcd, I was disappointed that they didn't even come close to their brightness and beam angle specs.

LVEHK 65,000 mcd 40° 8mm white (acquired February 2007)
TMorita sent me 3 samples of this LED for testing. The beam pattern was somewhat unusual with a slightly darker spot in the center, and the brightest part of the beam around the dark spot. The results (dead center of the beam) were 6.8, 5.2, and 7.5 cd at 20 mA, way less than spec. About 5° off-axis these numbers were around 15% higher. Average beam angle was 31.1°. Color temperature was quite blue, about 9000K. Average efficiency of the three samples was a not too impressive 43.2 lm/W. Average output was 3.06 lumens, and average Vf was a very high 3.55V which definitely hurt the efficiency numbers. Consistency between samples was good-outputs were 3.16, 2.91, and 3.13 lumens. Despite the high Vf indicating a small die output scales very well with current (output at 80 mA was 2.65 times the output at 20 mA), perhaps because the larger lead frame of the 8mm package conducts away heat better.

LVEHK 140,000 mcd 12° 10mm white (acquired February 2007)
TMorita sent me 3 samples of this LED for testing. The results were 63.5, 59.8, and 59.8 cd at 20 mA, well below spec. Average beam angle was 7.5°. Color temperature averaged around 7000K to 7500K but the beam was reasonably smooth, at least as smooth as can be expected from LEDs as tightly focused as these. Average efficiency of the three samples was a decent 67.6 lm/W. Average output was 4.44 lumens, and average Vf was 3.29V. Consistency between samples was decent-outputs were 4.59, 4.39, and 4.35 lumens. Output scales very well with current (output at 80 mA is 2.57 times the output at 20 mA), and efficiency numbers increase by only about 25% at lower currents compared to at 20 mA, indicating that these LEDs use large dice. These are decently performing LEDs overall.

BestHongKong 135,000 mcd 12° 10mm white (acquired February 2007)
TMorita sent me 3 samples of this LED for testing. The results were 166.2, 129.0, and 144.9 cd at 20 mA, all over or very close to spec. Average beam angle was an extremely narrow 6.5°, almost all hotspot with virtually no sidespill. Color temperature averaged a blotchy, slightly yellow 5000K but the blotchy beam quality is to be expected from LEDs as tightly focused as these. Average efficiency of the three samples was an excellent 79.6 lm/W. Average output was 5.14 lumens, and average Vf was 3.23V. Consistency between samples wasn't that great-outputs were 5.54, 4.67, and 5.18 lumens. Output scales very poorly with current (output at 80 mA was only 2.16 times the output at 20 mA), indicating that these LEDs likely use very small but very efficient dice. The much higher efficiency numbers at low currents (in the 115 lm/W area at 1 to 2 mA) further support this conclusion. A single one of these LEDs can make a very impressive flashlight with plenty of throw.

Nichia NFSW036L, bin T, tint C1 white (acquired February 2007)
CPF member TMorita sent me this LED along with a bunch of others for testing. The result was 3,340 mcd and 4.02 lumens at 20 mA. Beam

angle was 51.3°. Vf was an extremely low 2.72V and overall efficiency was a decent 73.9 lm/W. Color was similar to a cool-white fluorescent, about 4500K, and the beam was very smooth. The LED's output scaled very well with current, giving 3.57 times the output at 100 mA as it did at 20 mA. Efficiency at 100 mA was a decent 49.7 lm/W. However, all this is to be expected since this LED is designed to operate at 150 mA with a heat sink. This is also why the Vf was very low. Although my tester couldn't go above 100 mA by looking at the relative outputs in the spec sheet for this LED I estimated output at 150 mA to be around 20 lumens. This is right on spec.

SuperbrightLEDs RL5-W45-360 360° 5mm white (acquired February 2007)
CPF member TMorita sent me this LED along with a bunch of others for testing. The very wide but very low output presented special measurement difficulties. Even at 17.5" distance of my testing jig the intensity hitting my light meter was only in the 2 lux area, and the scattered background light accounted for about one-third of this. Measuring the intensity at 1 meter proved impossible at 20 mA so I did it at 100 mA and used the intensity ratio measured at 17.5" to calculate my results. The result was a mere 280 mcd. Calculated output was 4.18 lumens at 20 mA, close enough to the 4500 mlm (4.5 lm) spec. 50% beam angle was nonexistent since the LED more or less emitted in a complete 360° circle. Vf was 3.16V and overall efficiency was a decent 66.2 lm/W. Color was slightly blue, about 7000K. These are very unusual LEDs in that it appears they have their phosphor deposited on the outer surface of the package. They appear yellow unlit but once lit they are white. Any application where an LED seeks to mimic a light bulb in terms of intensity distribution would be a good one for these.

SuperbrightLEDs RL8-W110-360 360° 8mm white (acquired February 2007)
CPF member TMorita sent me this LED along with a bunch of others for testing. This is an 8mm version of the 360° LED described above. Again, the very wide but very low output presented special measurement difficulties as described for the RL5-W45-360. The intensity at 20 mA was only 280 mcd. Calculated output was 4.48 lumens at 20 mA. At 60 mA, which is what these LEDs are speced at, output is 10.54 lumens, slightly above the 9000 mlm (9.0 lm) spec. 50% beam angle was nonexistent since the LED more or less emitted in a complete 360° circle. At 20 mA Vf was a very low 2.85V and overall efficiency was an excellent 78.6.2 lm/W. Corresponding numbers at 60 mA were 3.12V and 56.3 lm/W. Color was cool-white fluorescent white, about 4500K. These are very unusual LEDs in that it appears they have their phosphor deposited on the outer surface of the package. They appear yellow unlit but once lit they are white. Any application where an LED seeks to mimic a light bulb in terms of intensity distribution would be a good one for these.

ISP 22,000 mcd 25° 5mm white (acquired March 2007)
Three of these were sent to me by CPF member **TMorita** for testing, and are special order using one large single die for operation at 100 mA. They are not the stock 2-die ones rated at 40 mA. The three samples came in at 6.4, 6.6, and 7.1 cd at 20 mA. The average output at 20 mA was 3.37 lumens, average Vf was a very low 2.94V, and average efficiency was a decent 57.3 lm/W. There wasn't much variation between samples in any of the parameters, especially the forward voltage. The beam was slightly blue, with a color temperature of around 7000K, and very smooth. Measured beam angle was 25.7°, which slightly exceeds the advertised 25°. At higher currents these did very well, giving slightly over 13 lumens at 100 mA. At their rated 100 mA these manage 25,900 mcd, exceeding their 22,000 mcd rating. Overall these are decent LEDs, and probably quite long lasting at higher currents due to their large-die construction.

LCK 55,000 mcd 15° 5mm white (acquired March 2007)
TMorita sent me 3 samples of this LED for testing. The results were 27.4, 27.4, and 27.9 cd at 20 mA. Average beam angle was only 10.6°, so the less than rated intensity wasn't due to a wider beam angle as is sometimes the case. Color temperature averaged around 7000K but the beam was a little blotchy, with a blue center and yellowish corona. Average efficiency of the three samples was a decent 59.8 lm/W. Average output was 3.79 lumens, and average Vf was 3.17V. Consistency between samples was quite good-outputs were 3.80, 3.73, and 3.84 lumens. Output scales very well with current (output at 80 mA is 2.65 times the output at 20 mA), and efficiency numbers increase by only about 25% at lower currents compared to at 20 mA, indicating that these LEDs use large dice. These LEDs are decent but I was disappointed that they didn't even come close to their brightness and beam angle specs.

Jeled 55,000 mcd 15° 5mm white (acquired March 2007)

CPF member **Minjin** sent me two of these for testing. The two samples came in at 35.2 and 32.4 cd at 20 mA. The average output at 20 mA was 5.11 lumens, average Vf was a very low 3.05V, and average efficiency was a very respectable 83.9 lm/W. This means that the Jeled 55Ks squeak by for a new efficiency record for 5mm single die LEDs at 20 mA. The beam was a little blue but somewhat blothy. Average color temperature looked around 6500K. Measured beam angle was 14.1°. These have less efficiency loss at higher currents than most other eBay LEDs I've tested so far. At 80 mA they managed 50.9 lm/W. Even at 100 mA they are a decent 42.1 lm/W (and over 15 lumens!). Peak efficiency numbers increase by only about 20% at lower currents compared to at 20 mA, indicating that these LEDs use large dice. While I'm glad to have finally measured a new efficiency record, I remain disappointed that in over a year 5mm LED efficiency has more or less been stagnant. Since 5mm LED efficiency usually precedes the next jump in power LED efficiency by up to a year, and there are planned increases in power LED efficiency for 2008, I remain hopeful that we'll have 5mm LEDs of 100+ lm/W at 20 mA within the next few months.

Hebei 520MW7C 20° 5mm white (acquired June 2007)
CPF member **LEDude** sent me 10 samples of this LED for testing. I picked three of the ten at random to test. The results were 15.6, 14.1, and 15.9 cd at 20 mA. Average beam angle was 19.3°, very close to spec. Color temperature averaged around 7000K-7500K and the beam was a very smooth. Average efficiency of the three samples was a decent 65.1 lm/W. Average output was 3.98 lumens, and average Vf was a low 3.06V. Consistency between samples was quite good-outputs were 4.04, 4.01, and 3.88 lumens. Output scales fairly well with current (output at 80 mA is 2.42 times the output at 20 mA). It's been over two years since I last tested Hebei LEDs. These LEDs are quite an improvement in efficiency over their previous offerings.

Hebei 530MW7C 30° 5mm white (acquired June 2007)
CPF member LEDude sent me 10 samples of this LED for testing. I picked three of the ten at random to test. The results were 12.0, 12.3, and 11.4 cd at 20 mA. Average beam angle was 22.1°, somewhat under spec. Color temperature averaged around 7000K with a very smooth beam. Average efficiency of the three samples was a decent 58.9 lm/W. Average output was 3.55 lumens, and average Vf was a very low 3.01V. Consistency between samples was quite good-outputs were 3.57, 3.49, and 3.60 lumens. Output scales fairly well with current (output at 80 mA is 2.41 times the output at 20 mA). Overall, performance is very similar to the 520MW7C but that's to be expected since they likely use the same die, but moved further towards the front of the epoxy package for a wider beam angle.

Hebei 550MW7C 50° 5mm white (acquired June 2007)
CPF member LEDude sent me 10 samples of this LED for testing. I picked three of the ten at random to test. The results were 5.1, 4.5, and 4.9 cd at 20 mA. Average beam angle was 47.9°,very close to spec. Color temperature averaged around 6500K with a very smooth beam. Average efficiency of the three samples was a decent 66.5 lm/W. Average output was 4.14 lumens, and average Vf was a low 3.12V. Consistency between samples was quite good-outputs were 4.36, 4.07, and 4.00 lumens. Output scales fairly well with current (output at 80 mA is 2.51 times the output at 20 mA). Performance is very similar to the 520MW7C and 5307C as expected. All three of these LEDs are quite decent performers given the low cost, and quite well made.

Jeled 210000 mcd 10mm warm white (acquired December 2007)
CPF member **knabsol** sent me 3 samples of this LED for testing. The results were 5.1, 5.5, and 5.6 cd at 20 mA. Average beam angle was 26.7°, less than the specified 40°. Color temperature was very low, perhaps 2500K, and with a very smooth beam. In all honesty these looked more like sodium vapor lamps than anything else. Average efficiency of the three samples was only 38.1 lm/W. Average output was 2.20 lumens, and average Vf was a low 2.88V (expected due to the 5-die construction). Consistency between samples was not so good-outputs were 1.81, 2.27, and 2.53 lumens. Output scales very well with current as expected (output at 100 mA is 3.47 times the output at 20 mA). Even at 100 mA the intensity of these averages only 18.7 cd, well below the spec of 210 cd. Not sure what to make of these really. The large case size seems to make the beam smoother rather than focus it.

Jeled 255000 mcd 10mm white (acquired December 2007)
CPF member knabsol sent me 3 samples of this LED for testing. The results were 8.9, 9.9, and 11.3 cd at 20 mA. Average beam angle was 24.2°, less than the specified 30°. Color temperature was around 7500K, and the beam was very smooth. Average efficiency of the three

samples was a decent 60.6 lm/W. Average output was 3.48 lumens, and average Vf was a low 2.87V (expected due to the 5-die construction). Consistency between samples was OK-outputs were 3.30, 3.31, and 3.84 lumens. Output scales very well with current as expected (output at 100 mA is 3.70 times the output at 20 mA). At 100 mA the intensity of these averages only 37.2 cd, well below the spec of 255 cd. As with their warm white cousins, the large case size seems to make the beam smoother rather than focus it. In both cases performance seemed disappointing given the 5-die construction.

Oatley Electronics 80000 mcd 10mm white (acquired December 2007)
CPF member **lctorana** sent me 3 samples of this LED for testing. The results were 5.7, 6.1, and 7.1 cd at 20 mA. Average beam angle was 38.8°. Color temperature was around 7500K, and the beam was very smooth. Average efficiency of the three samples was a very decent 72.4 lm/W. Average output was 4.26 lumens, and average Vf was a low 2.94V. (expected due to the multi-die construction). Consistency between samples was excellent-outputs were 4.06, 4.31, and 4.41 lumens. Output scales very well with current as expected (output at 100 mA is 3.60 times the output at 20 mA). At 100 mA the intensity of these averages only 22.7 cd, well below the spec of 80 cd. These are supposed to be able to output 25 lumens at 150 mA. My test jig only went to 100 mA, and the average output at that current was 15.34 lumens. At 150 mA output would probably be around 20 or 21 lumens, not much below the 25 lumen spec. Overall, these are pretty decent LEDs. It seems in all cases that the large 10 mm case size seems to make the beam smoother rather than focus it. For maximum focusing it appears that the 8mm case is best based on my tests so far.

Deal Extreme 20mm white (acquired March 2008)
CPF member **nein166** loaned me one of these for testing. This thing is huge! The die area and leads are much larger than on normal indicator type LEDs. Results at 20 mA are 6.6 cd, 4.23 lumens, and 70.7 lm/W. Beam angle is 39.1°, and Vf is a very low 2.99V. Output scales well with current, and at 100 mA is nearly 3 times that of 20 mA. Beam is extremely smooth and around 7000K. These make great area lights. I would imagine that they would have a very long lifetime even at 100 mA due to the superior thermal path.

BestHongKong 25000 mcd 5mm 5-die white (acquired March 2008)
CPF member **TMorita** sent me 3 samples of this LED for testing. These are BestHongKong's 5-die whites which have 5 dies and a larger lead frame to allow operation at 100 mA. The results were 6.0, 6.5, and 6.9 cd at 20 mA. I assume the 25,000 mcd rating is at 100 mA, so the corresponding results at 100 mA are 24.3, 25.8, and 28.1. The average is 26.1 cd, slightly above spec. Average beam angle was 34.7°, less than the specified 50°. Color temperature was around 7000K, and the beam was very smooth. Average efficiency of the three samples was a decent 72.8 lm/W at 20 mA and 52.9 lm/W at 100 mA. I was expecting somewhat better than that due to the 5-die construction. Apparently they're not using the most efficient dies for these. Average output was 4.07 lumens at 20 mA, and average Vf was a low 2.87V (expected due to the 5-die construction). Corresponding figures at 100 mA were 16.41 lumens and 3.10V. The 16.41 lumens comes reasonably close to the specified 20 lumens at 100 mA. Consistency between samples was excellent-outputs were 3.91, 4.14, and 4.16 lumens at 20 mA. Output scales very well with current as expected (output at 100 mA is 4.03 times the output at 20 mA). Overall these appear to be a decent, well-constructed LED capable of sustained operation at higher currents.

LED Tech 14000 mcd 5mm 100 mA white (acquired March 2008)
CPF member TMorita sent me 3 samples of this LED for testing. These are LED Tech's 100 mA whites which have a larger lead frame to allow operation at 100 mA, and probably also multiple dies. The results were 2.8, 2.8, and 3.2 cd at 20 mA. I assume the 14,000 mcd rating is at 100 mA, so the corresponding results at 100 mA are 11.0, 11.2, and 12.3. The average is 11.5 cd, somewhat below spec. Average beam angle was 77.1°, nearly equal to the specified 80°. Color temperature was around 7000K, and the beam was very smooth. Average efficiency of the three samples was a very decent 86.8 lm/W at 20 mA and an excellent 63.8 lm/W at 100 mA. These are better numbers than the very similar BestHongKong LEDs because they're apparently using better dies. Average output was 5.12 lumens at 20 mA, and average Vf was a low 2.95V (expected due to the multi-die construction). Corresponding figures at 100 mA were 20.06 lumens and 3.15V. Consistency between samples was OK-outputs were 4.71, 5.05, and 5.60 lumens at 20 mA. Output scales very well with current as expected (output at 100 mA is 3.92 times

the output at 20 mA). Overall these appear to be a decent, well-constructed LED capable of sustained operation at higher currents.

Nichia NSPS500GS-K1 5mm white (acquired March 2008)
CPF member TMorita sent me 3 samples of this LED for testing. These are Nichia's latest and greatest 5mm whites. The results were 36.0, 39.2, and 39.8 cd at 20 mA. I think these are speced for 44,000 mcd, so the average of 38.3 cd is only slightly out of spec. Average beam angle was 13.4°, a little less than the specified 15°. Color temperature was around 7000K, and the beam was very smooth. Average efficiency of the three samples was a excellent 96.7 lm/W at 20 mA, so these take the new efficiency crown. Even at 100 mA efficiency manages to remain at nearly 50 lm/W. Average output was 6.15 lumens at 20 mA, and average Vf was 3.18V. Corresponding figures at 100 mA were 21.43 lumens and 4.34V. Given the rather steep increase in Vf with current, these don't appear to be multi-die as some here have speculated. Consistency between samples was OK-outputs were 5.75, 6.19, and 6.52 lumens at 20 mA. Output scales very well with current despite the apparent single-die construction (output at 100 mA is 3.48 times the output at 20 mA). This isn't much worse than the two types of multidie LEDs just tested. It looks like Nichia has another winner here, and we have a new efficiency champ.

Cree C503B-WAN-CCACB231 5mm white (acquired January 2009) ***NEW!***
CPF member **Holepuncher** sent me 3 samples of this LED for testing. These are Cree's brightest commercially available 5mm whites. The results were 26.9, 26.2, and 25.4 cd at 20 mA. These are speced for 23,500 to 32,900 mcd according to the datasheet, so the average of 26.17 cd is well within spec, although on the low side. Average beam angle was 15.1°, dead on the specified value of 15°. Color temperature was around 6500K, and the beam was extremely smooth. Average efficiency of the three samples was an excellent 79.2 lm/W at 20 mA. At 100 mA efficiency drops to 31.5 lm/W. Average output was 4.93 lumens at 20 mA, and average Vf was a low 3.11V. Corresponding figures at 100 mA were 12.36 lumens and 3.92V. Consistency between samples was great-outputs were 4.67, 5.16, and 4.97 lumens at 20 mA. Output doesn't scale as well with current as some other recent 5mm LEDs I've seen, but it's not horrible, either. Overall these appear to be great LEDs, and could be even better if they used Cree's best dice. Just doing some rough assumptions regarding phosphor conversion efficiency of 80% and package efficiency of 80%, I've calculated that these are using blue dice with an output of about 24 mW @ 20 mA. Cree's best dice produce 33 to 35 mW. This would produce a white LED of 110 to 115 lm/W, perhaps even as high as 125 lm/W in a wide-angle package.

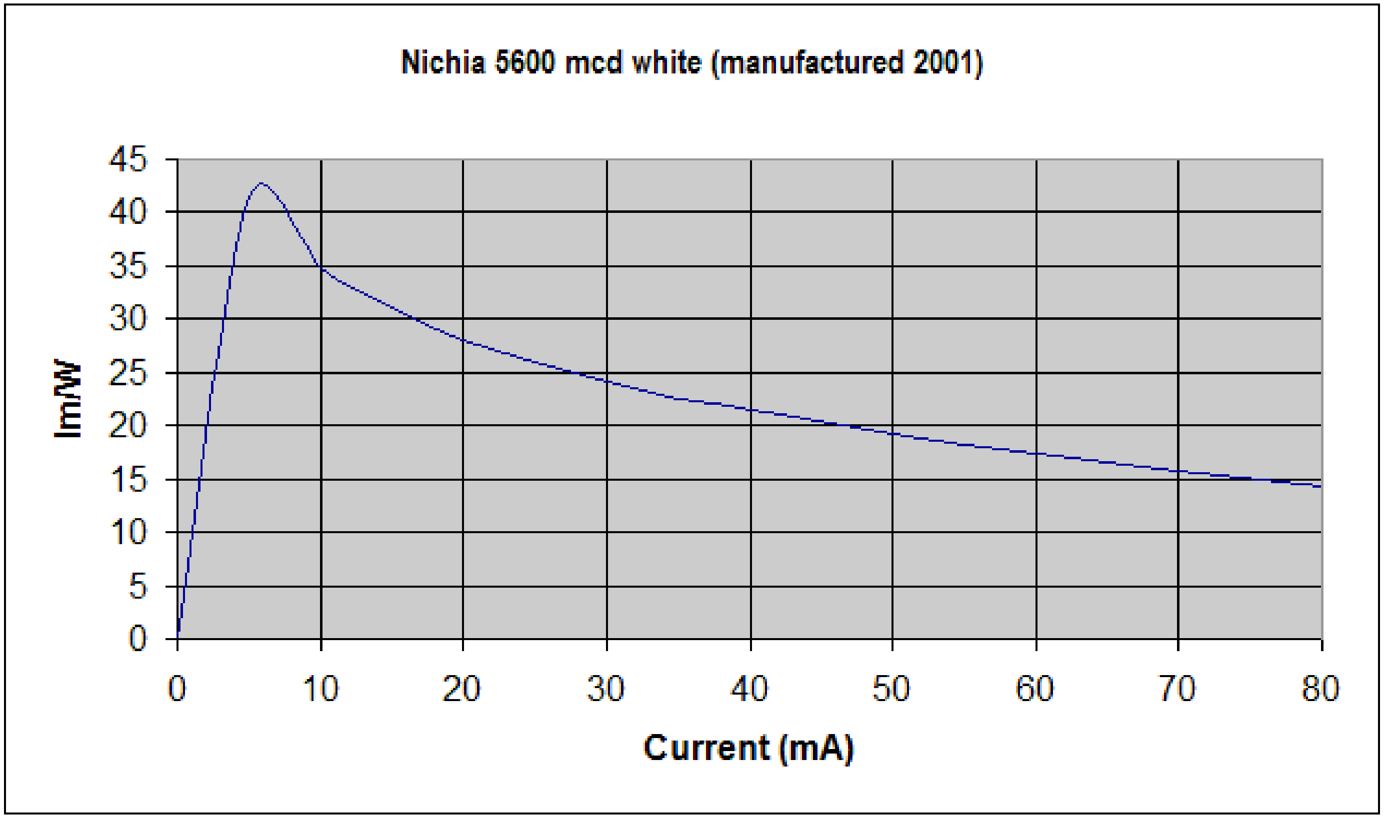
cece718 6000 mcd flat top 3mm white (acquired January 2009)
I purchased 100 of these for use in model railroading lighting applications. These are the flat top 3mm LEDs sold on eBay by seller cece718. Color temperature is around 7000K, and the beam is very smooth. I knew these couldn't come anywhere close to their 6000 mcd spec given their wide angle. I measured 800 mcd at 20 mA. Output was 3.49 lumens and efficiency was an OK for nowadays 54.1 lm/W. Beam angle was a very wide 129°. Output doesn't increase much with current, and levels off at 5.91 lumens at 60 mA. This isn't surprising given the poorer thermal properties of the 3mm package, and in service I doubt I would run these LEDs over 10 mA. Overall, these LEDs aren't bad given their price. In fact, I was pleasantly surprised they performed as well as they did. It was only a few years ago that only the best LEDs managed 50 or 60 lm/W. Nowadays most commodity LEDs seem to reach that mark.

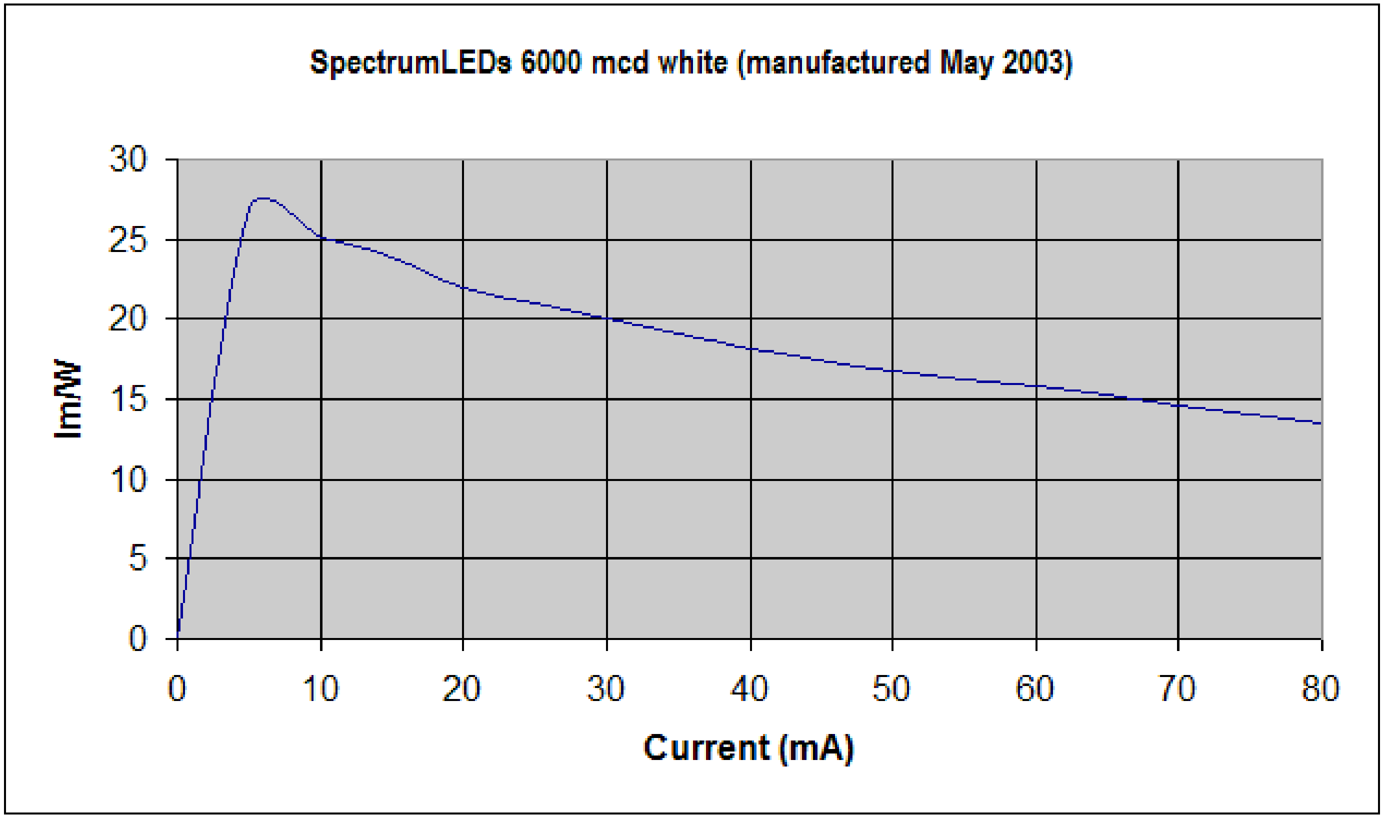
Osram LW E6SG PLCC4 white (acquired May 2009) ***NEW!***
I purchased 200 of these for use in model railroading lighting and LED night light applications. These are surface mount PLCC-4 style LEDs. Color temperature is around 5500K, somewhat warmer than usual for small LEDs and the beam is very smooth. Intensity was 1010 mcd at 20 mA. Output was 3.15 lumens and efficiency was an OK for nowadays 48.8 lm/W. Beam angle was a very wide 119°. Output scales well with current, and was 8.07 lumens at 100 mA. The claim to fame of these LEDs is a special silicon encapsulant which gives a lifetime of 50,000 hours at 25 mA and 25°C. I put them in 9 LED night lights so far in order to attempt to validate this claim. The LEDs which were previously in

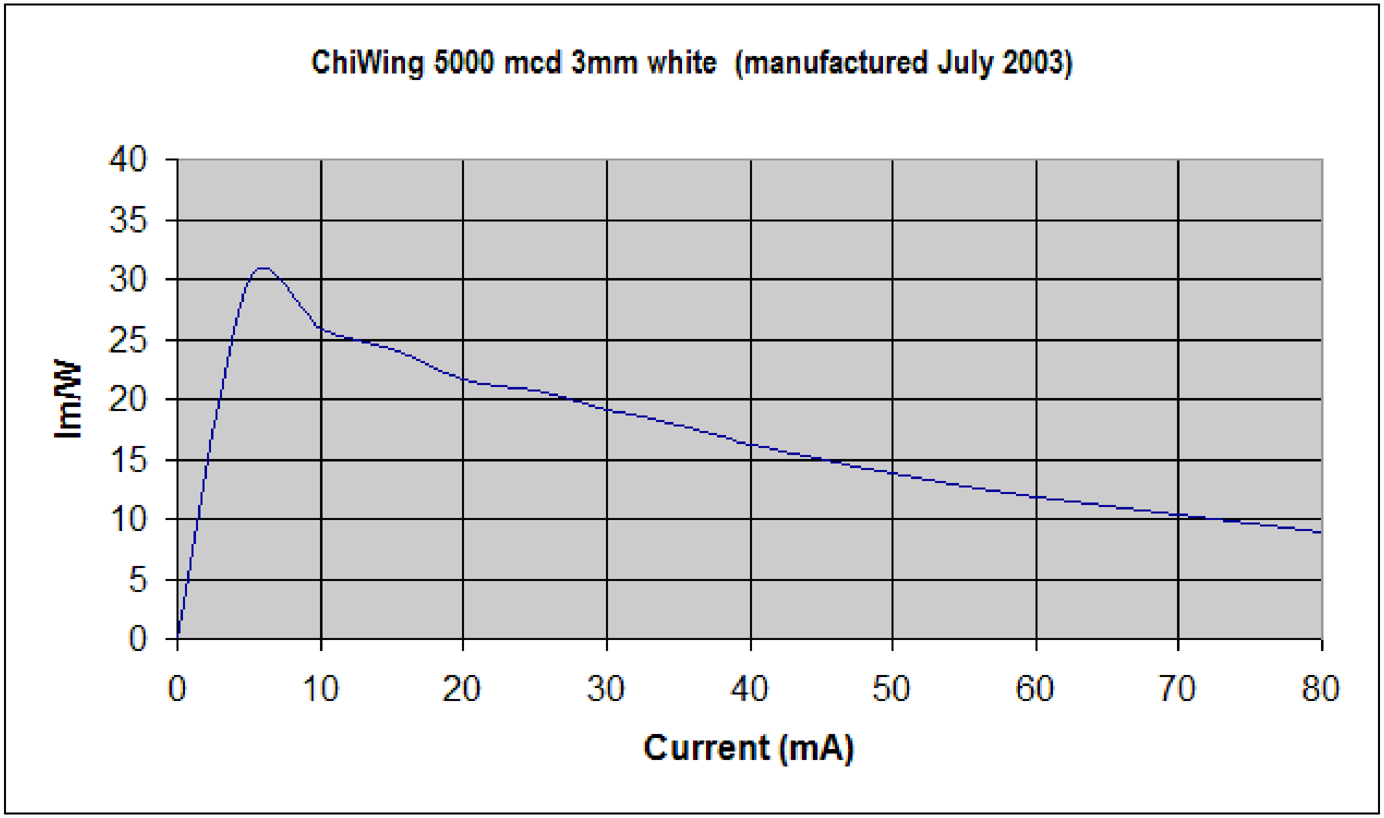
these night lights faded to practically nothing after 3 years of continuous use.

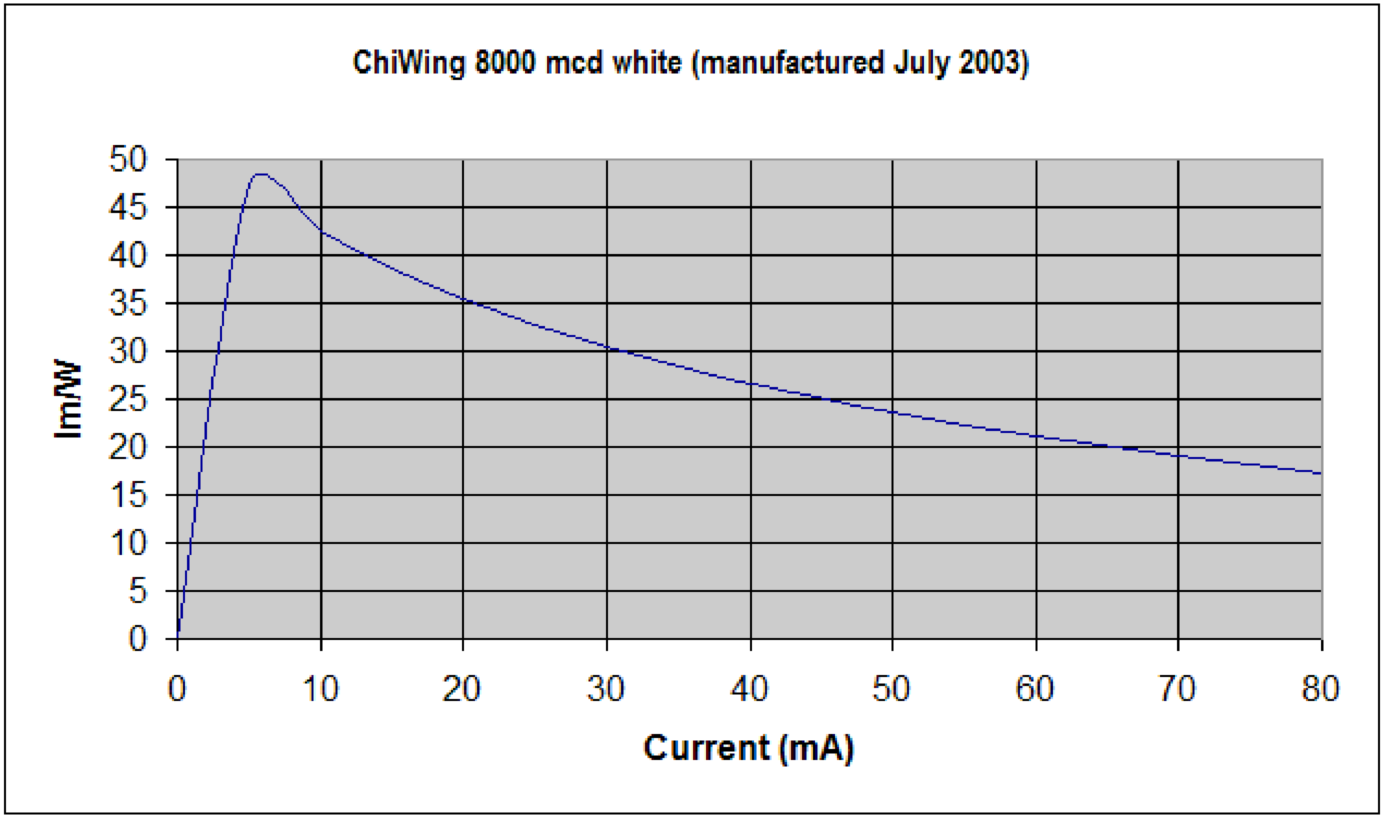
I'll be adding to this list as I acquire more white LEDs...

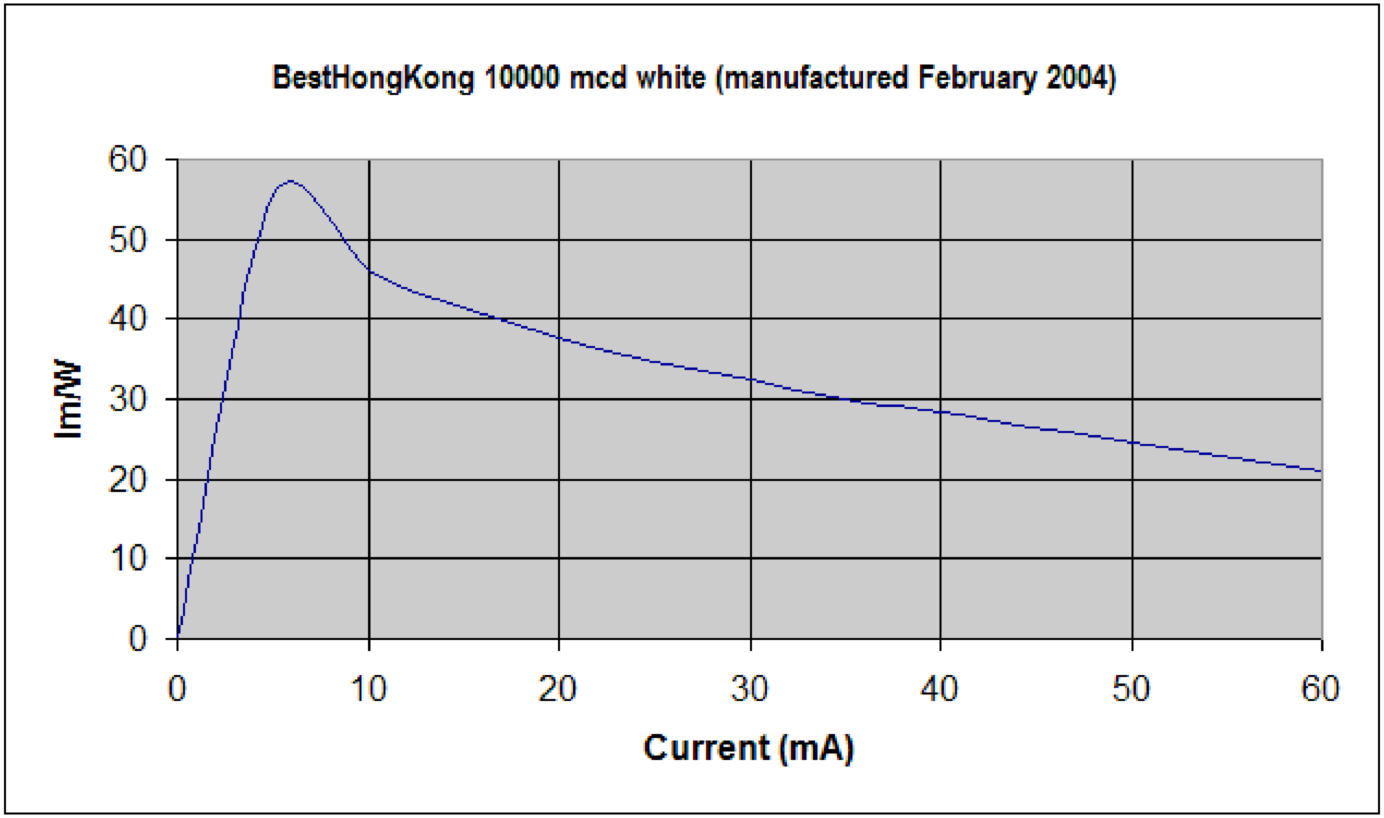
Here are the graphs for efficiency versus current:

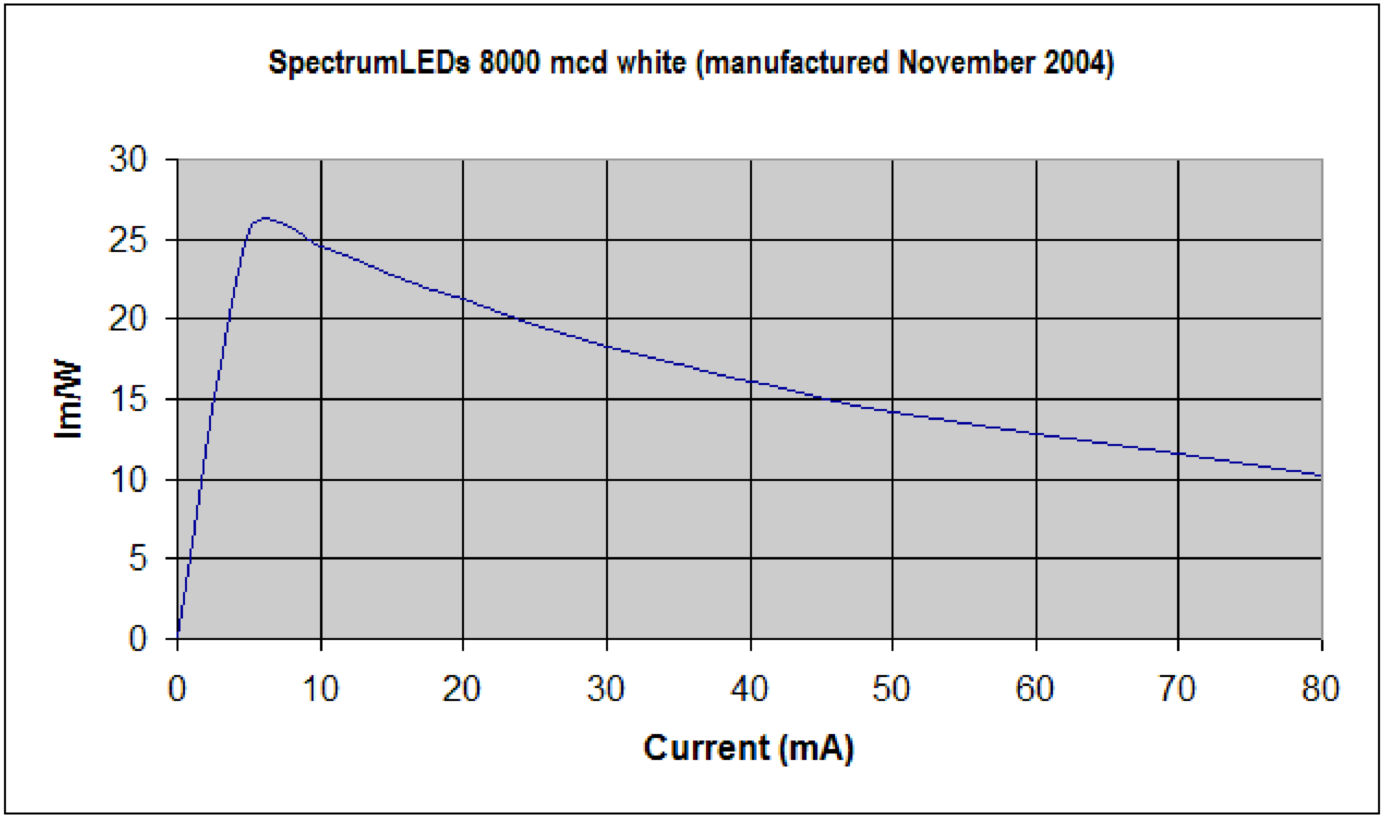


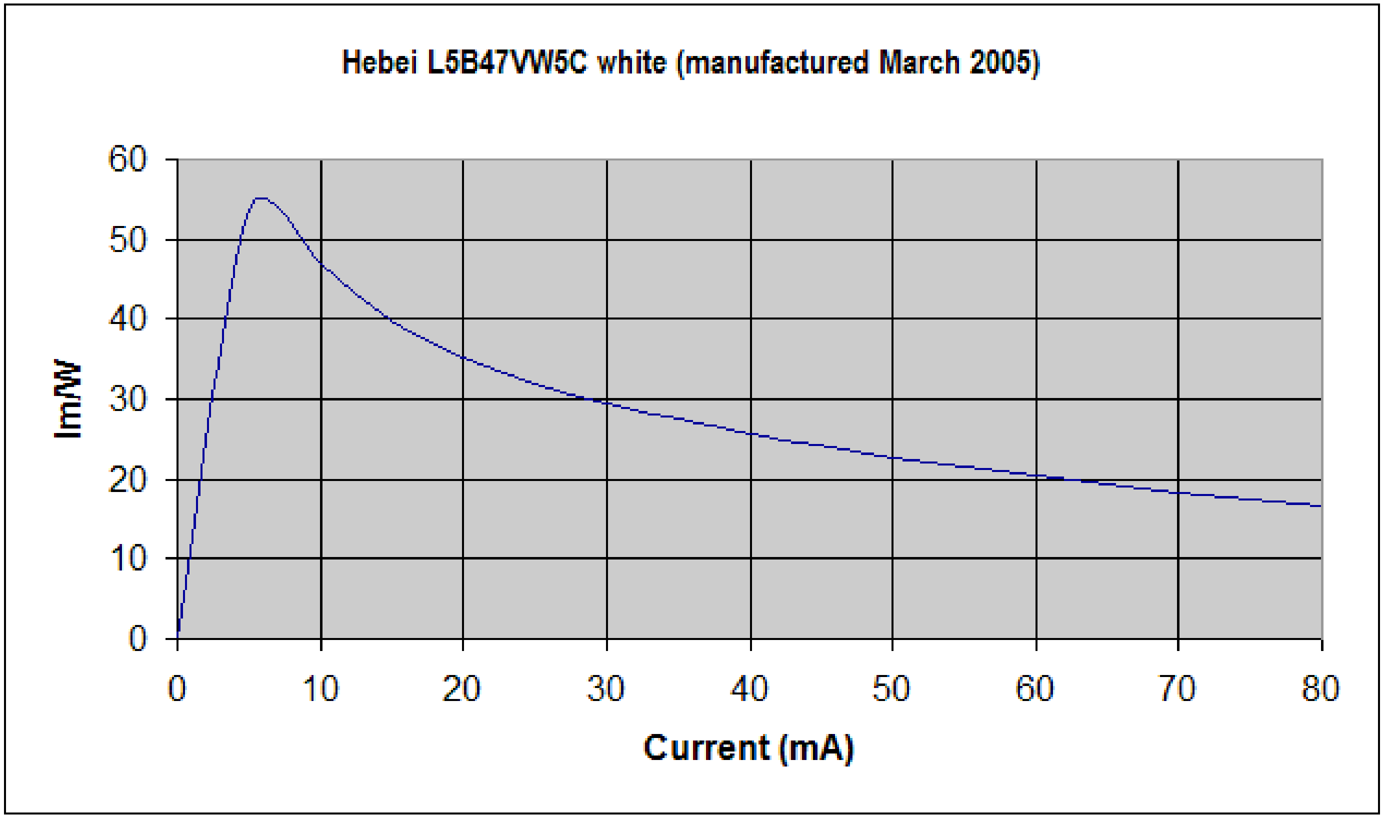

SpectrumLEDs 6000 mcd white (manufactured May 2003)
lm/W
30
25
20
15
10
5
0
0
10
20
30
40
50
60
70
80
Current (mA)

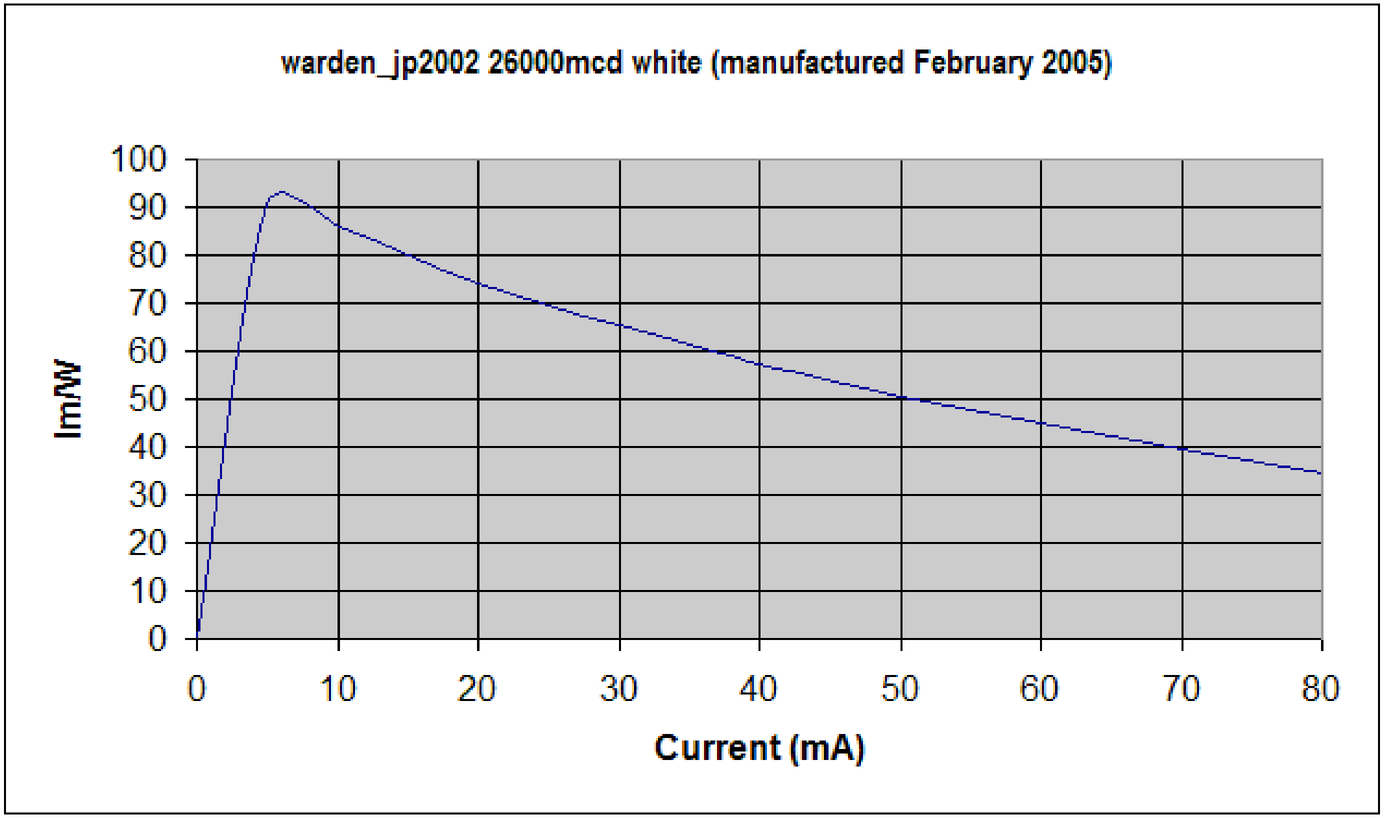

ChiWing 5000 mcd 3mm white (manufactured July 2003)
lm/W
40
35
30
25
20
15
10
5
0
0
10
20
30
40
50
60
70
80
Current (mA)

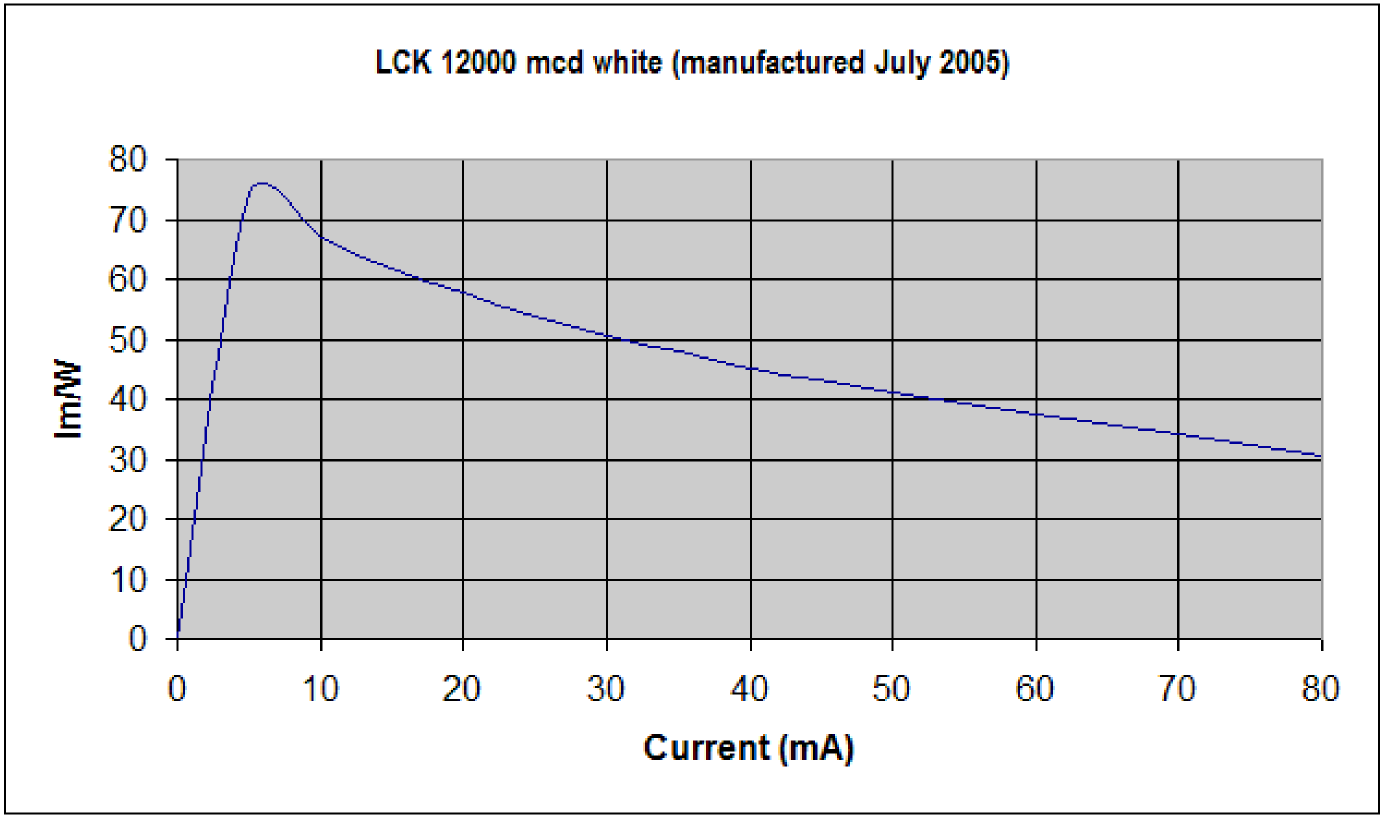

ChiWing 8000 mcd white (manufactured July 2003)
lm/W
50
45
40
35
30
25
20
15
10
5
0
0
10
20
30
40
50
60
70
80
Current (mA)

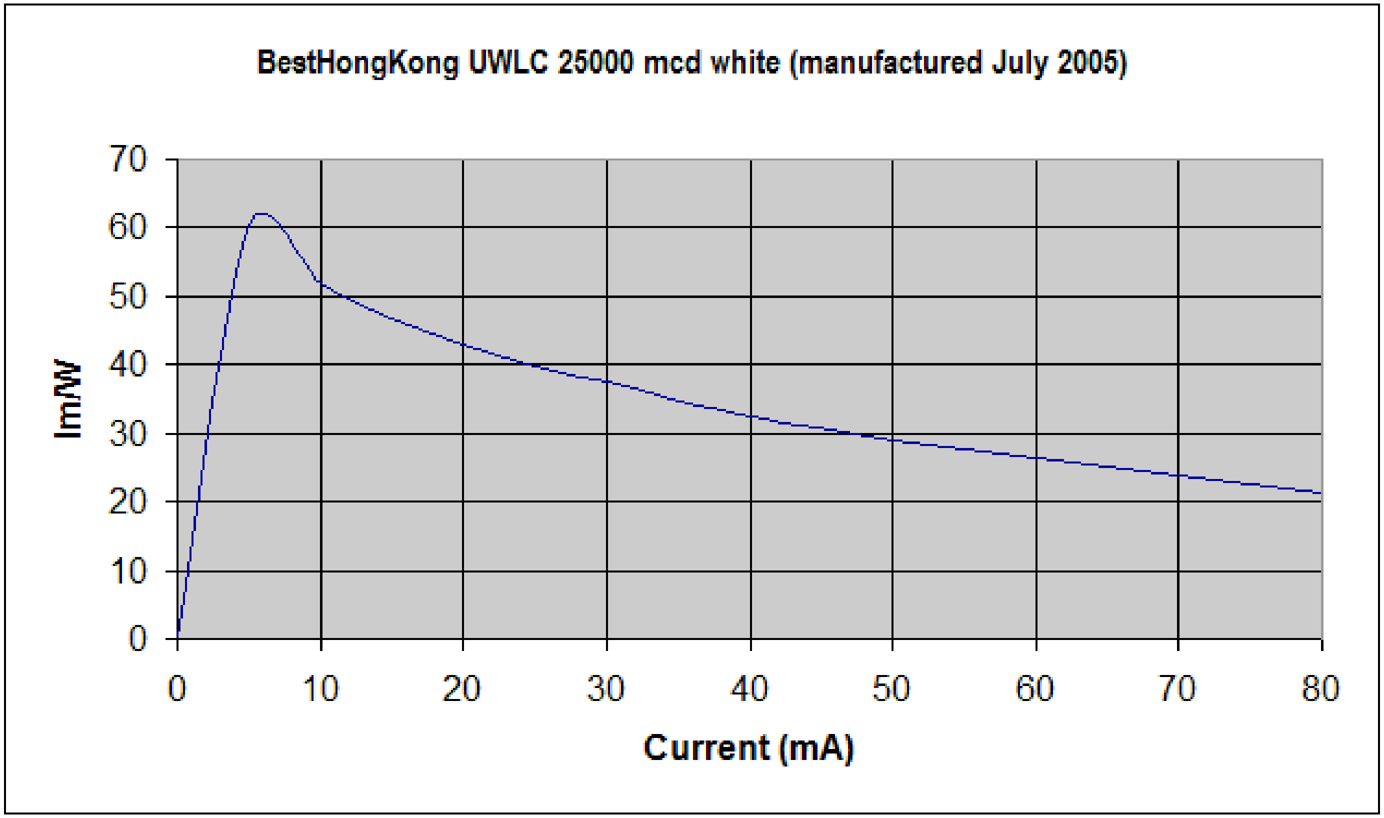

BestHongKong 10000 mcd white (manufactured February 2004)
lm/W
60
50
40
30
20
10
0
0
10
20
30
40
50
60
Current (mA)

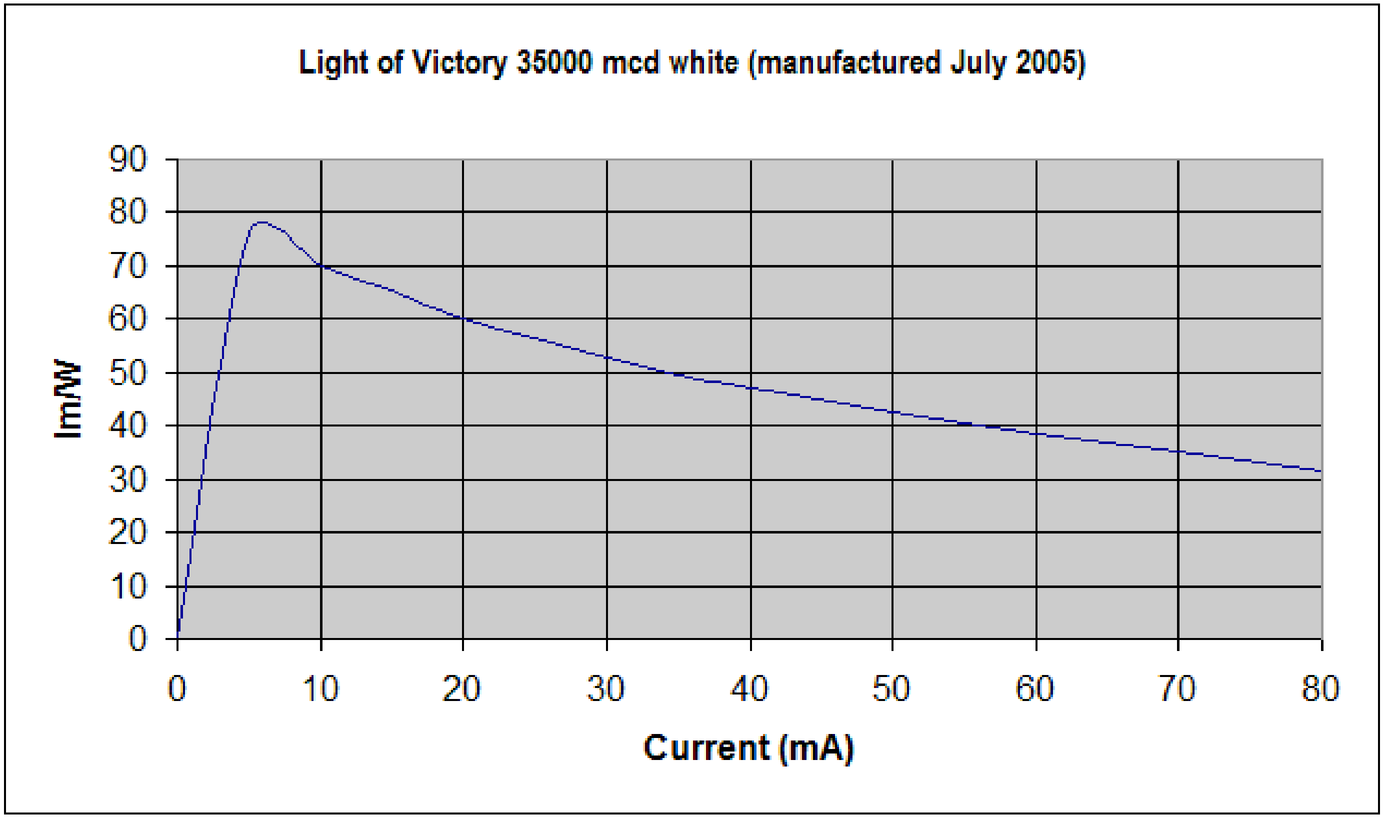

SpectrumLEDs 8000 mcd white (manufactured November 2004)
lm/W
30
25
20
15
10
5
0
0
10
20
30
40
50
60
70
80
Current (mA)

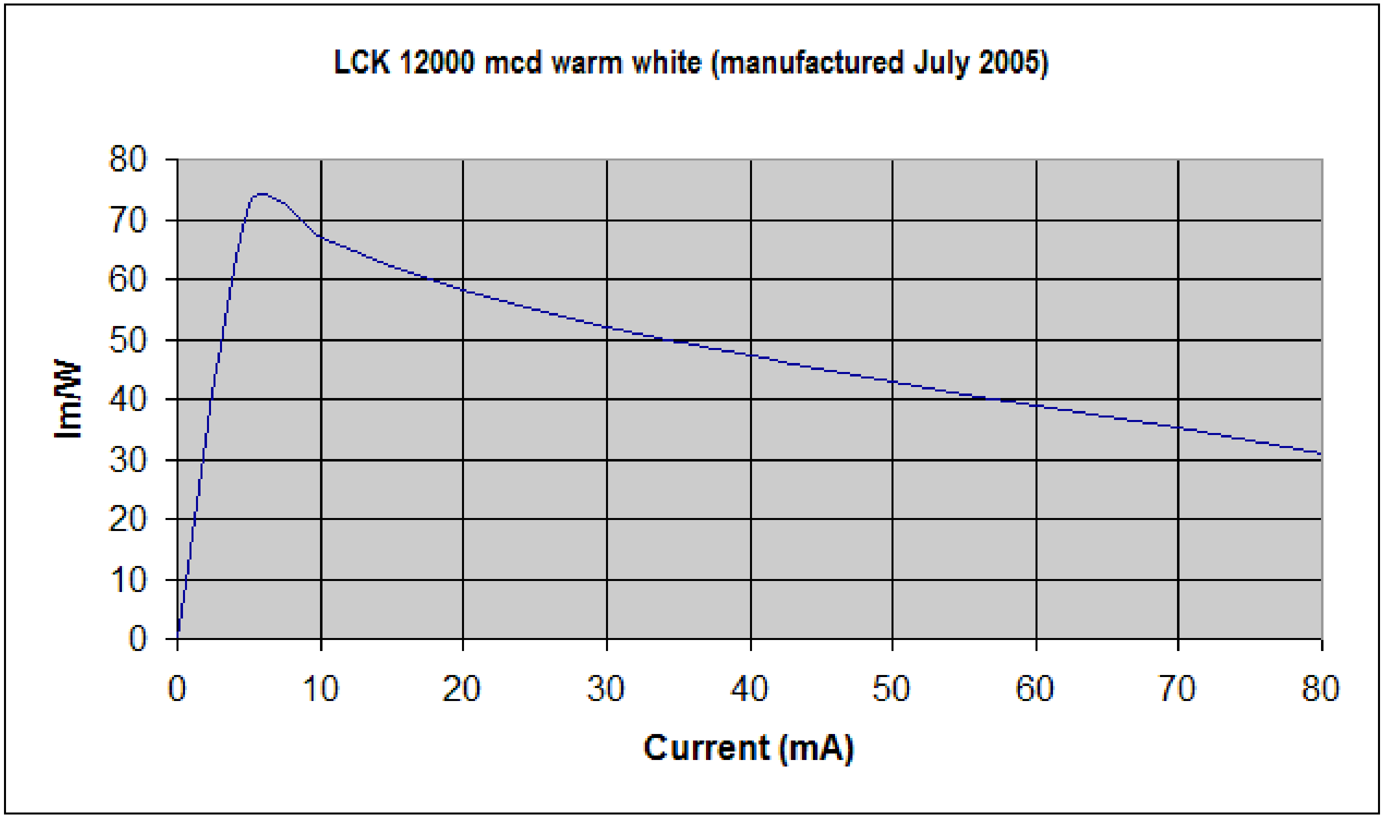

Hebei L5B47VW5C white (manufactured March 2005)
60
50
40
30
20
10
0
lm/W
0
10
20
30
40
50
60
70
80
Current (mA)

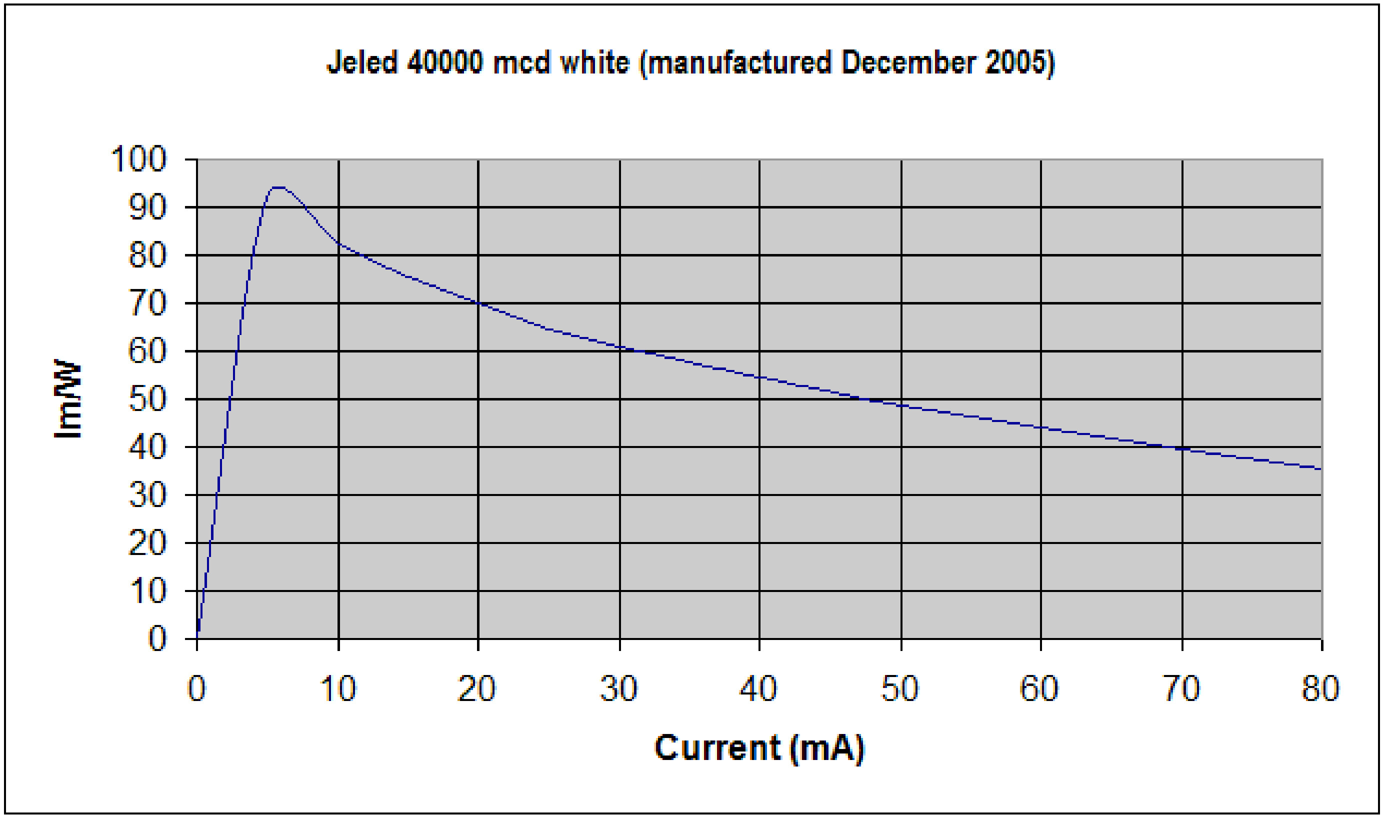

warden_jp2002 26000mcd white (manufactured February 2005)
lm/W
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
Current (mA)

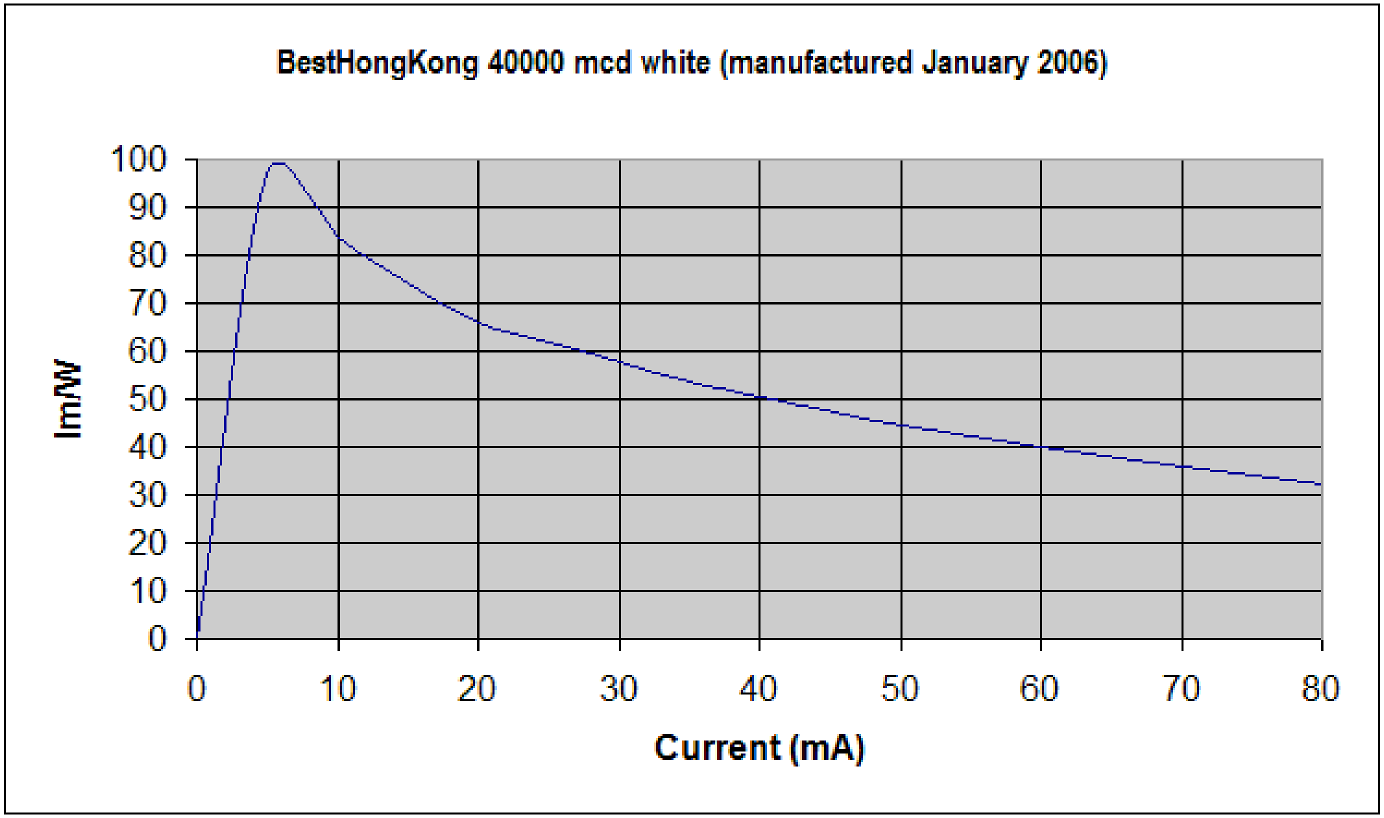

LCK 12000 mcd white (manufactured July 2005)
80
70
60
50
40
30
20
10
0
lm/W
0
10
20
30
40
50
60
70
80
Current (mA)

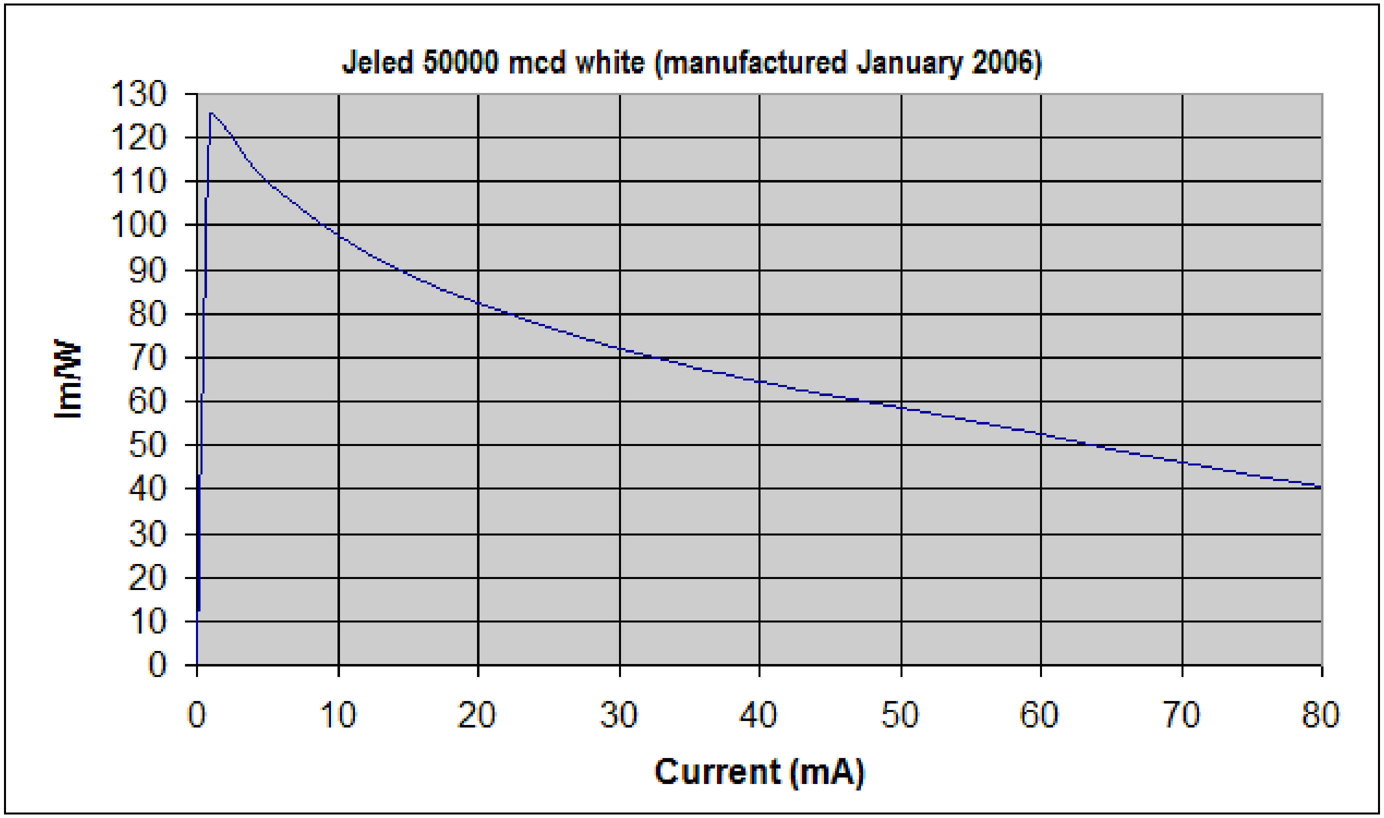

BestHongKong UWLC 25000 mcd white (manufactured July 2005)
lm/W
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
Current (mA)

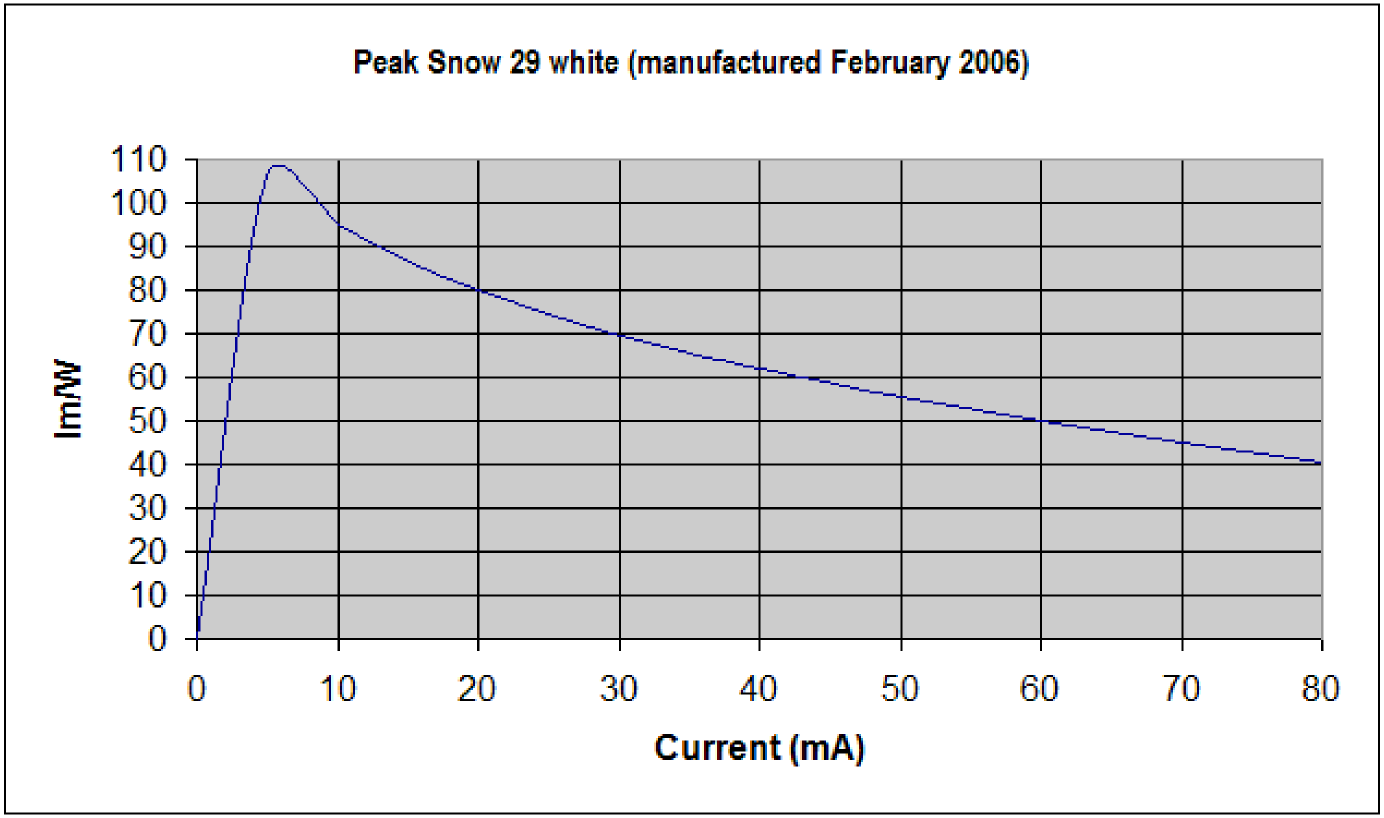

Light of Victory 35000 mcd white (manufactured July 2005)
lm/W
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
Current (mA)

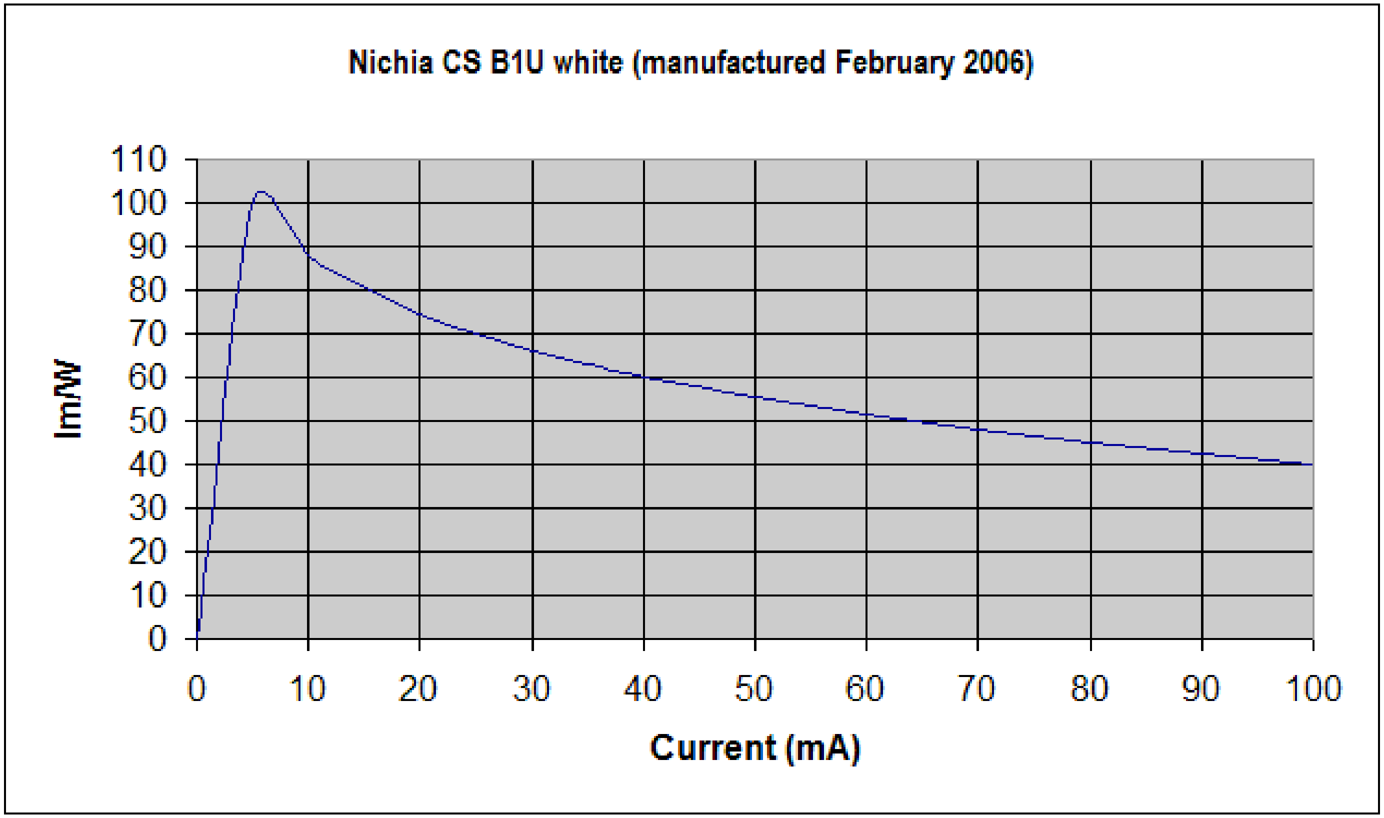

LCK 12000 mcd warm white (manufactured July 2005)
lm/W
0
10
20
30
40
50
60
70
80
Current (mA)
0
10
20
30
40
50
60
70
80

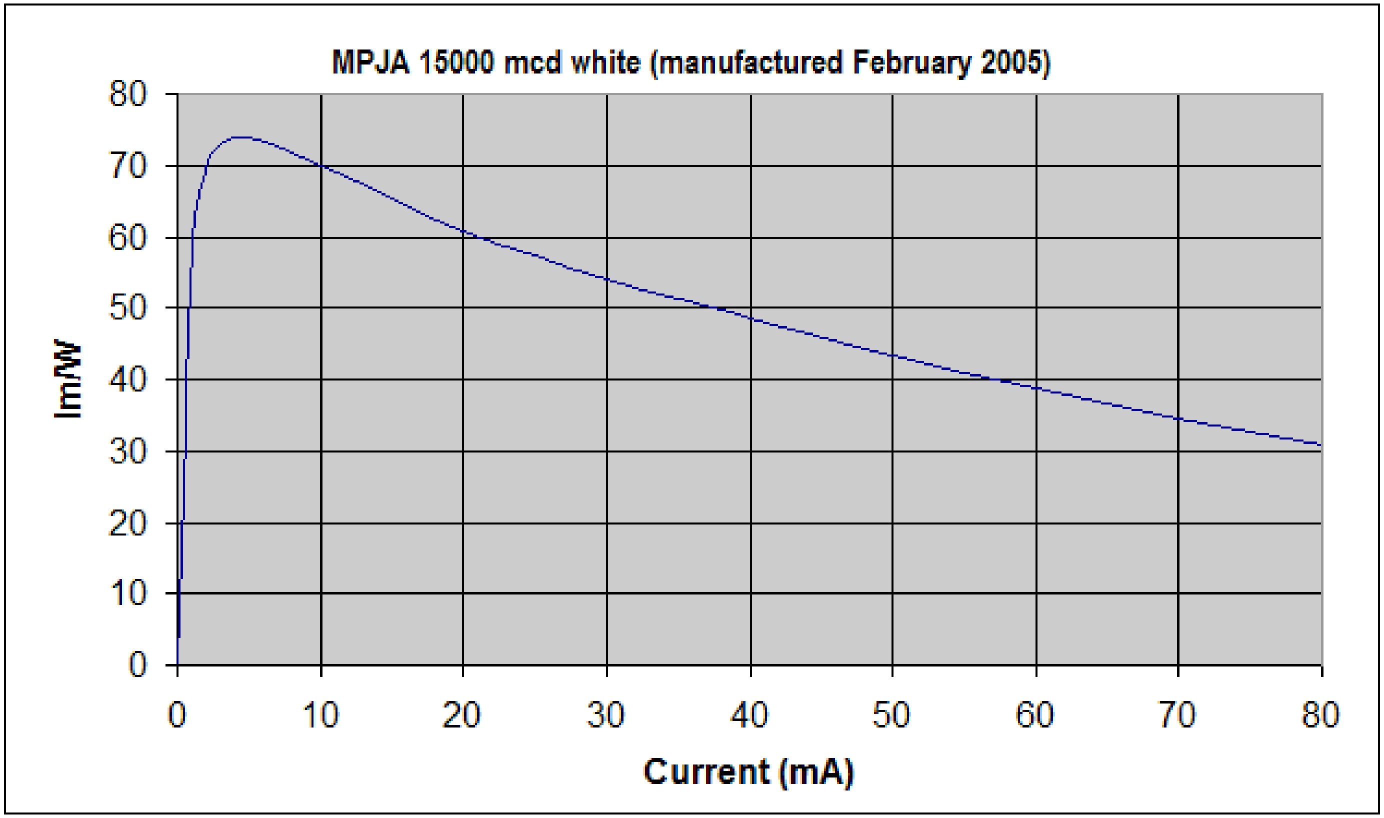

Jeled 40000 mcd white (manufactured December 2005)
lm/W
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
Current (mA)

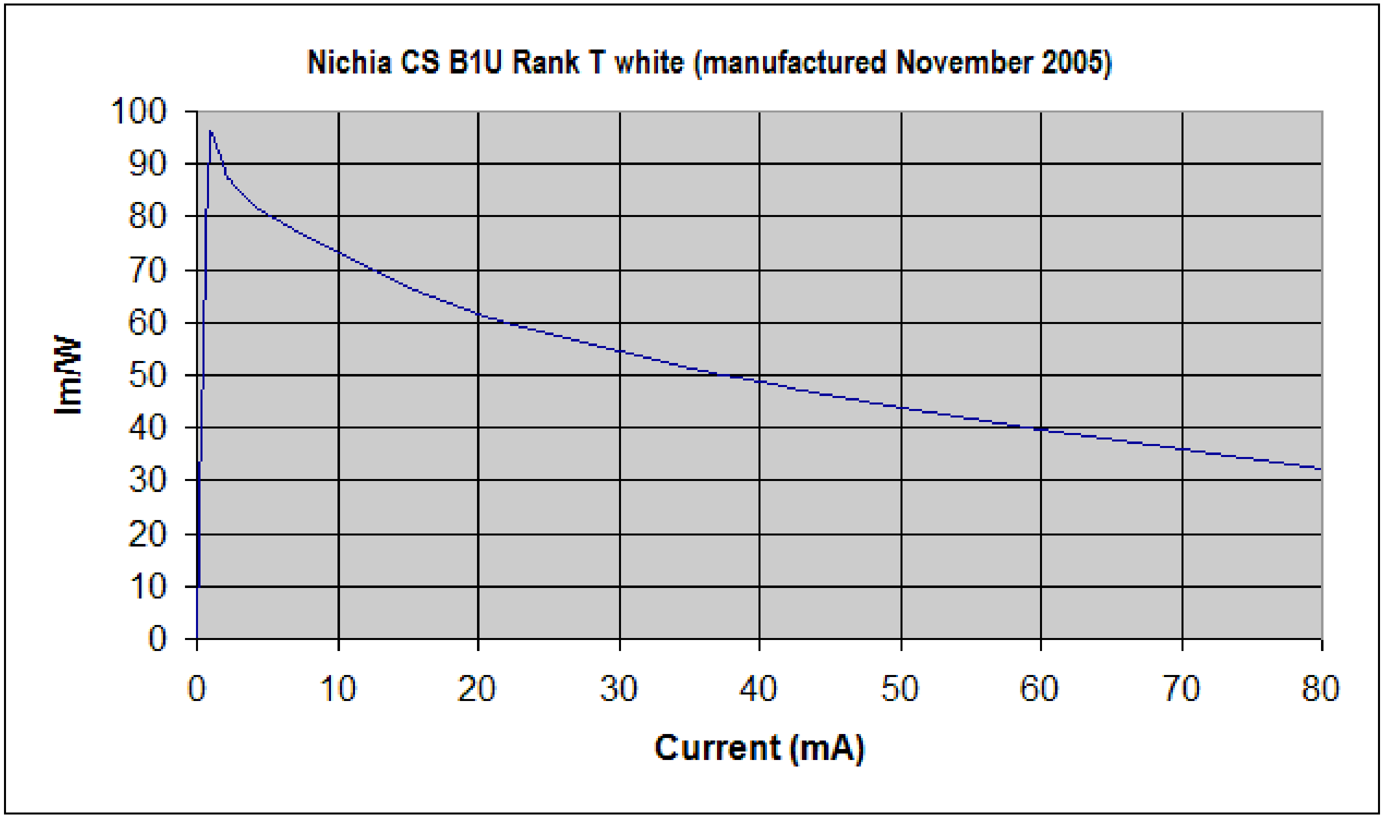

BestHongKong 40000 mcd white (manufactured January 2006)
lm/W
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
Current (mA)

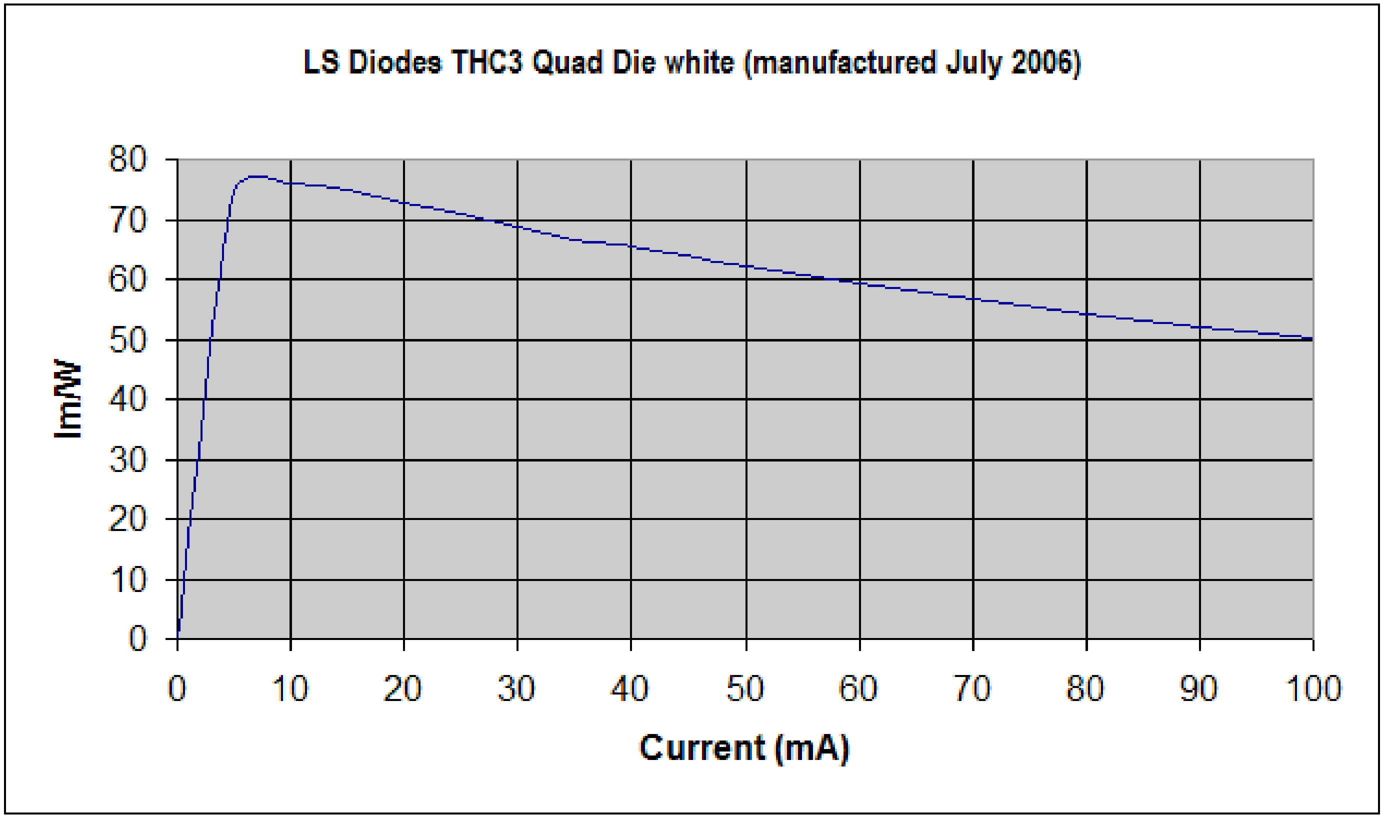

Jeled 50000 mcd white (manufactured January 2006)
lm/W
130
120
110
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
Current (mA)

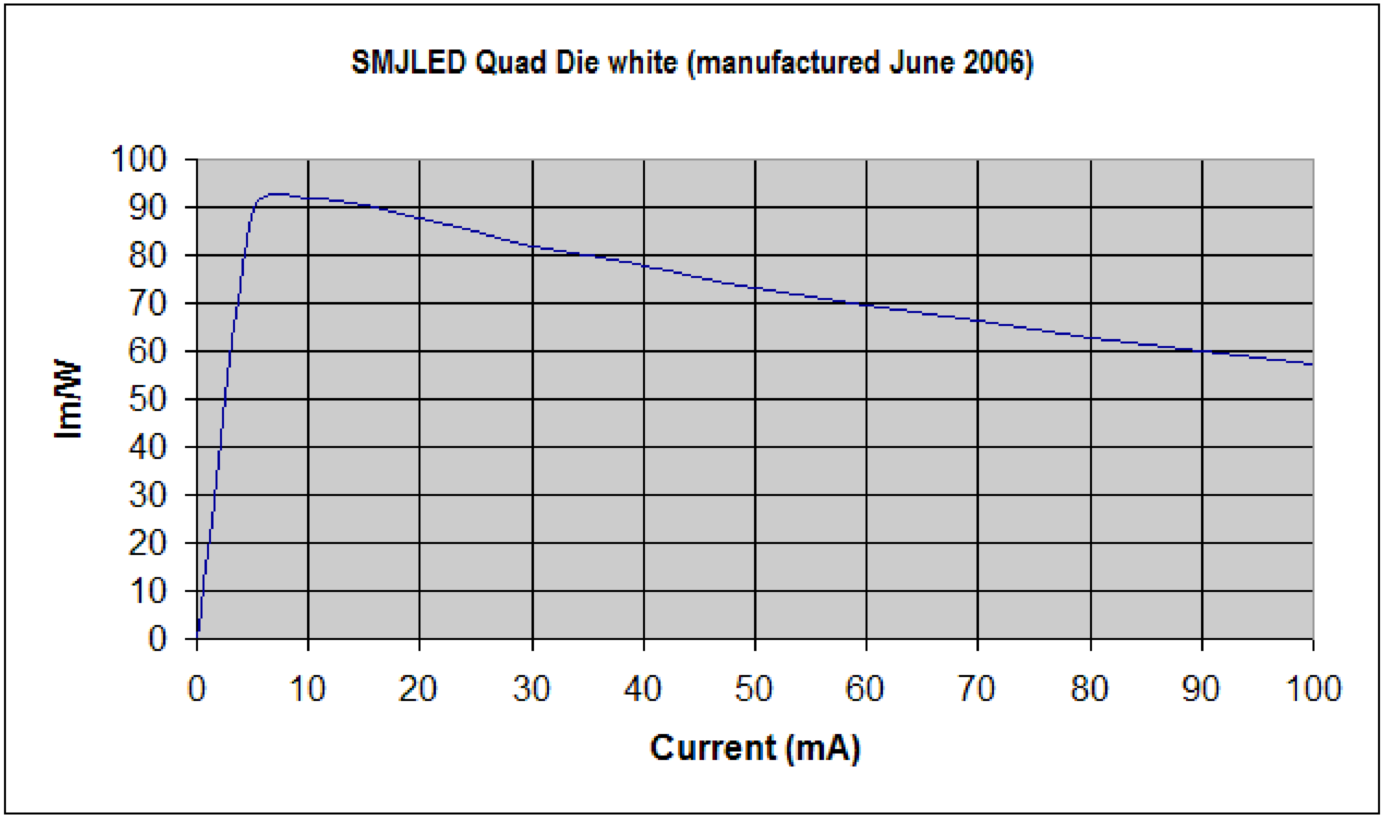

Peak Snow 29 white (manufactured February 2006)
lm/W
110
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
Current (mA)

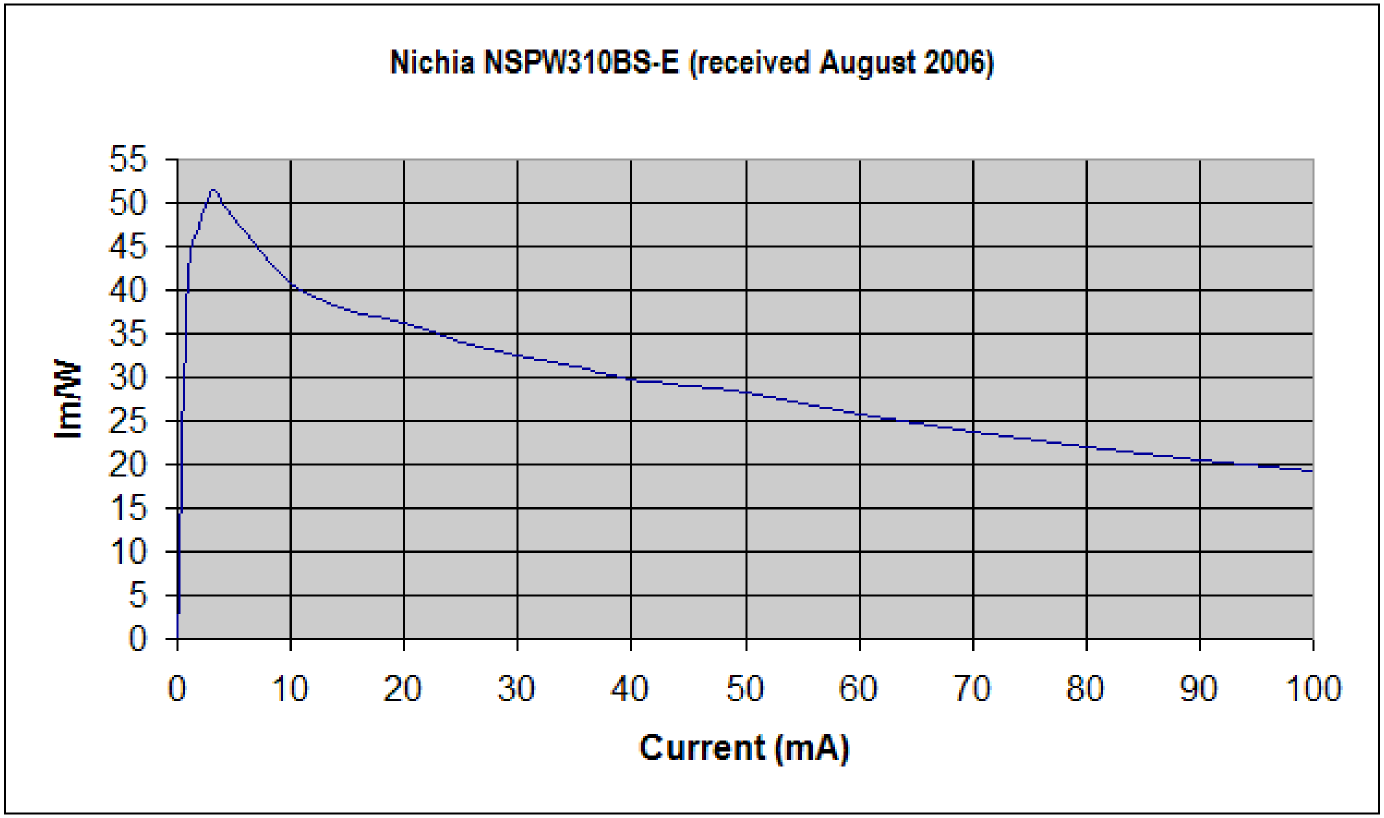

Nichia CS B1U white (manufactured February 2006)
lm/W
110
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Current (mA)

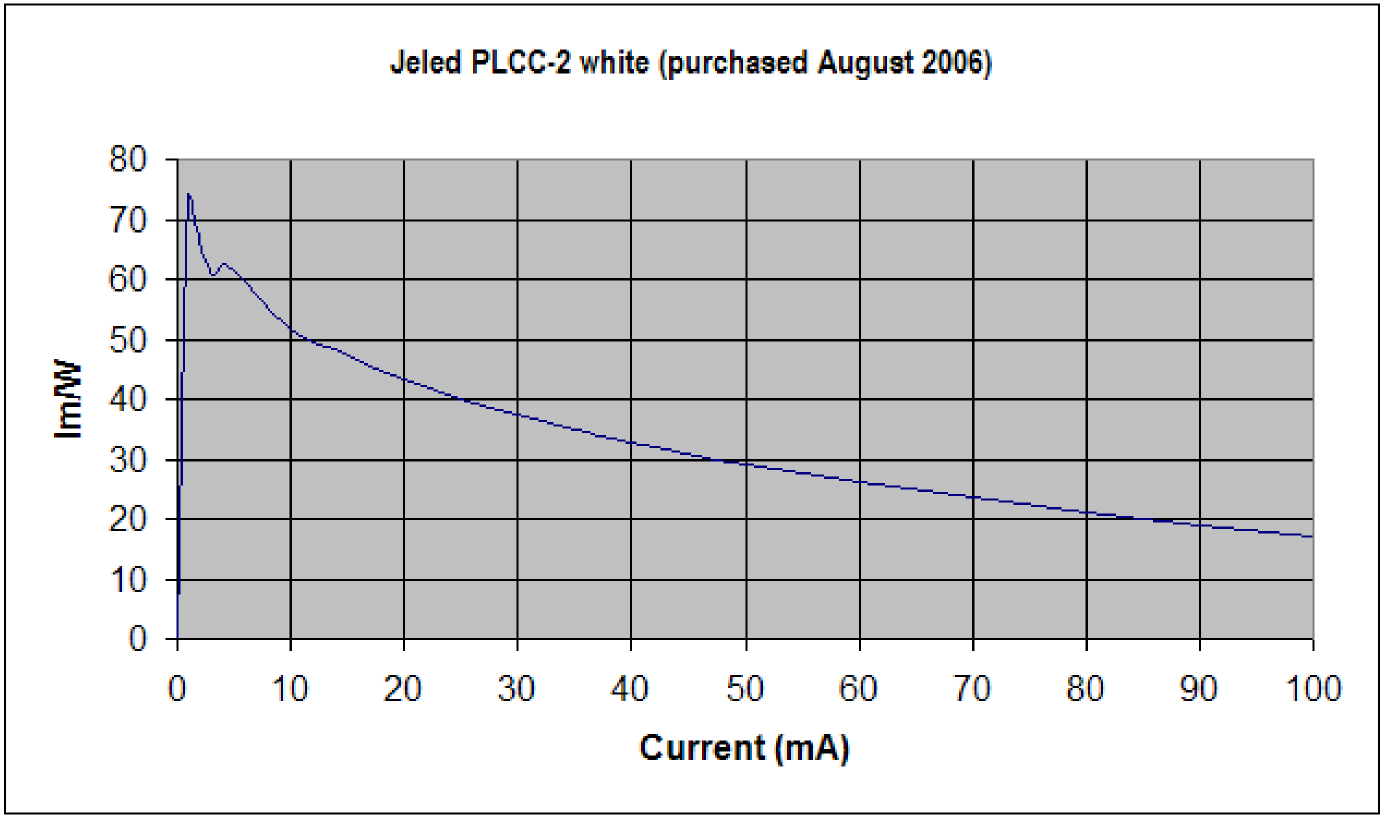

MPJA 15000 mcd white (manufactured February 2005)
lm/W
0
10
20
30
40
50
60
70
80
0
10
20
30
40
50
60
70
80
Current (mA)

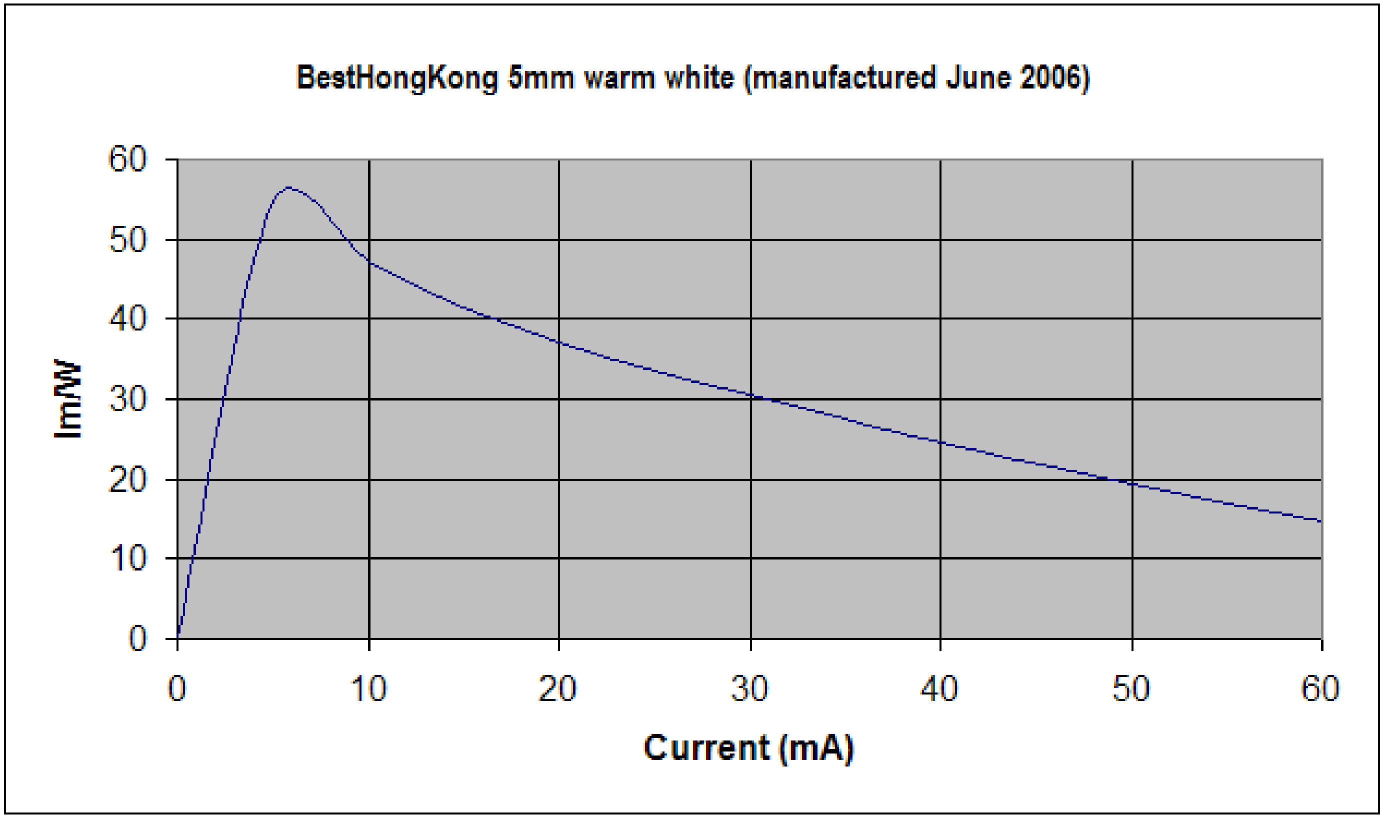

Nichia CS B1U Rank T white (manufactured November 2005)
lm/W
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
Current (mA)

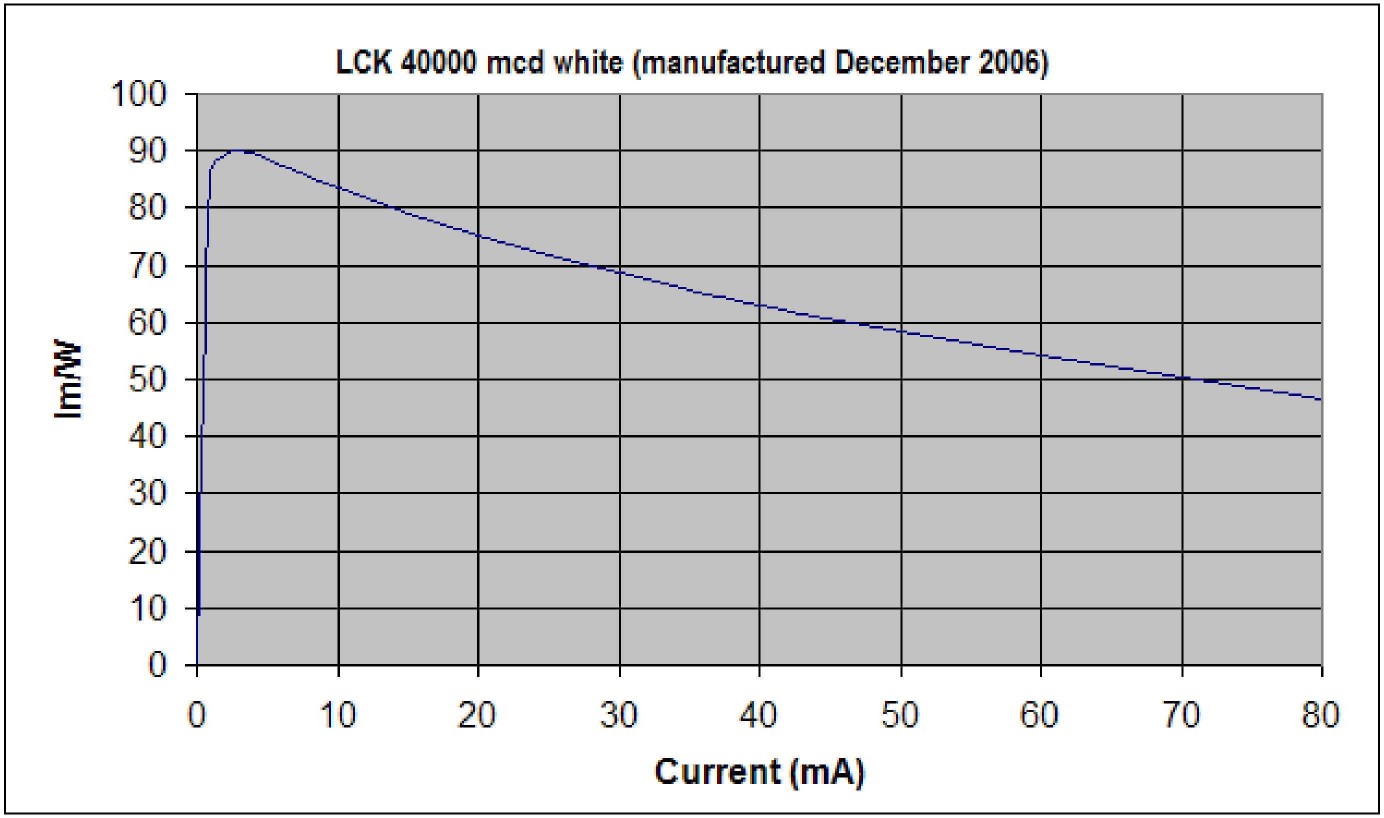

LS Diodes THC3 Quad Die white (manufactured July 2006)
lm/W
0
10
20
30
40
50
60
70
80
0
10
20
30
40
50
60
70
80
90
100
Current (mA)

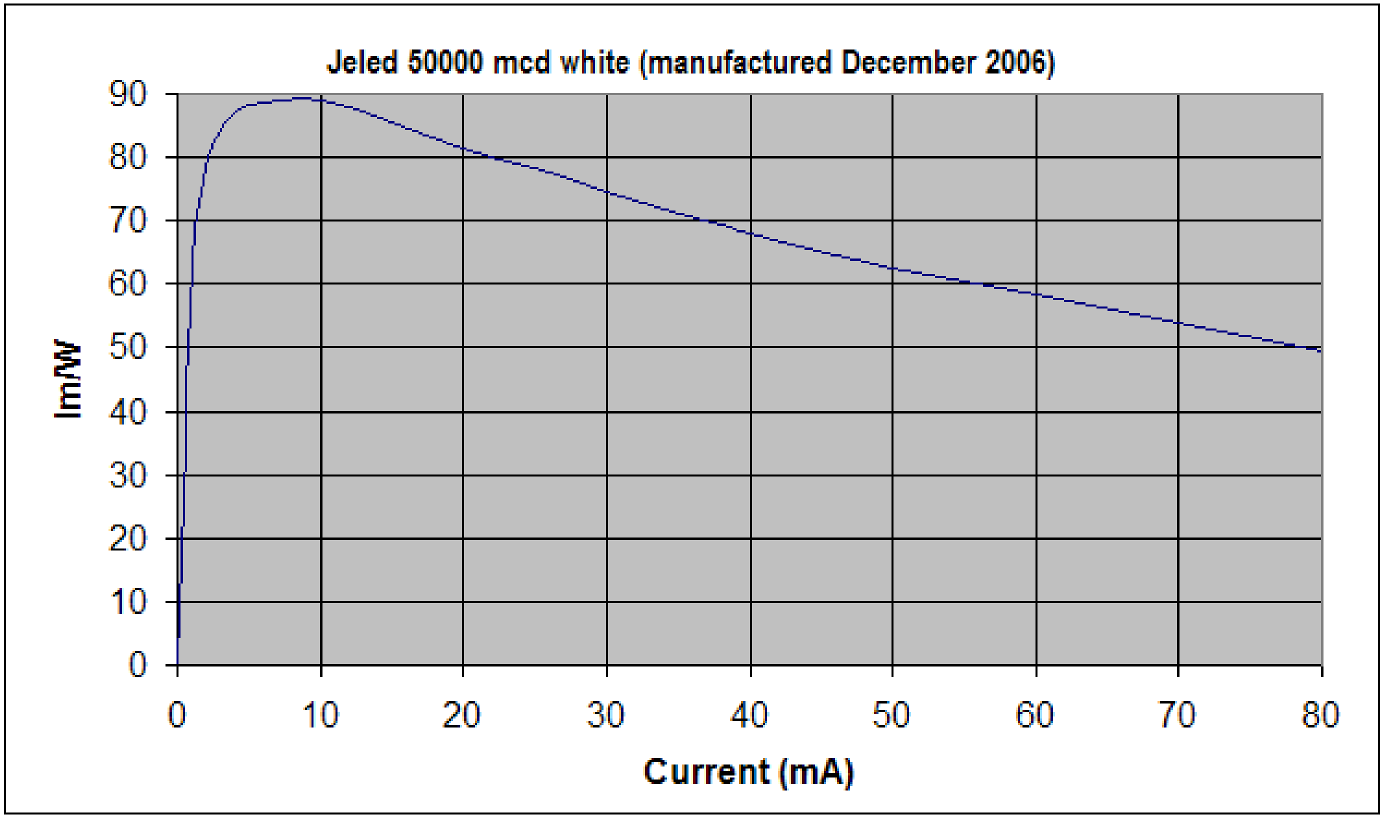

SMJLED Quad Die white (manufactured June 2006)
lm/W
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Current (mA)

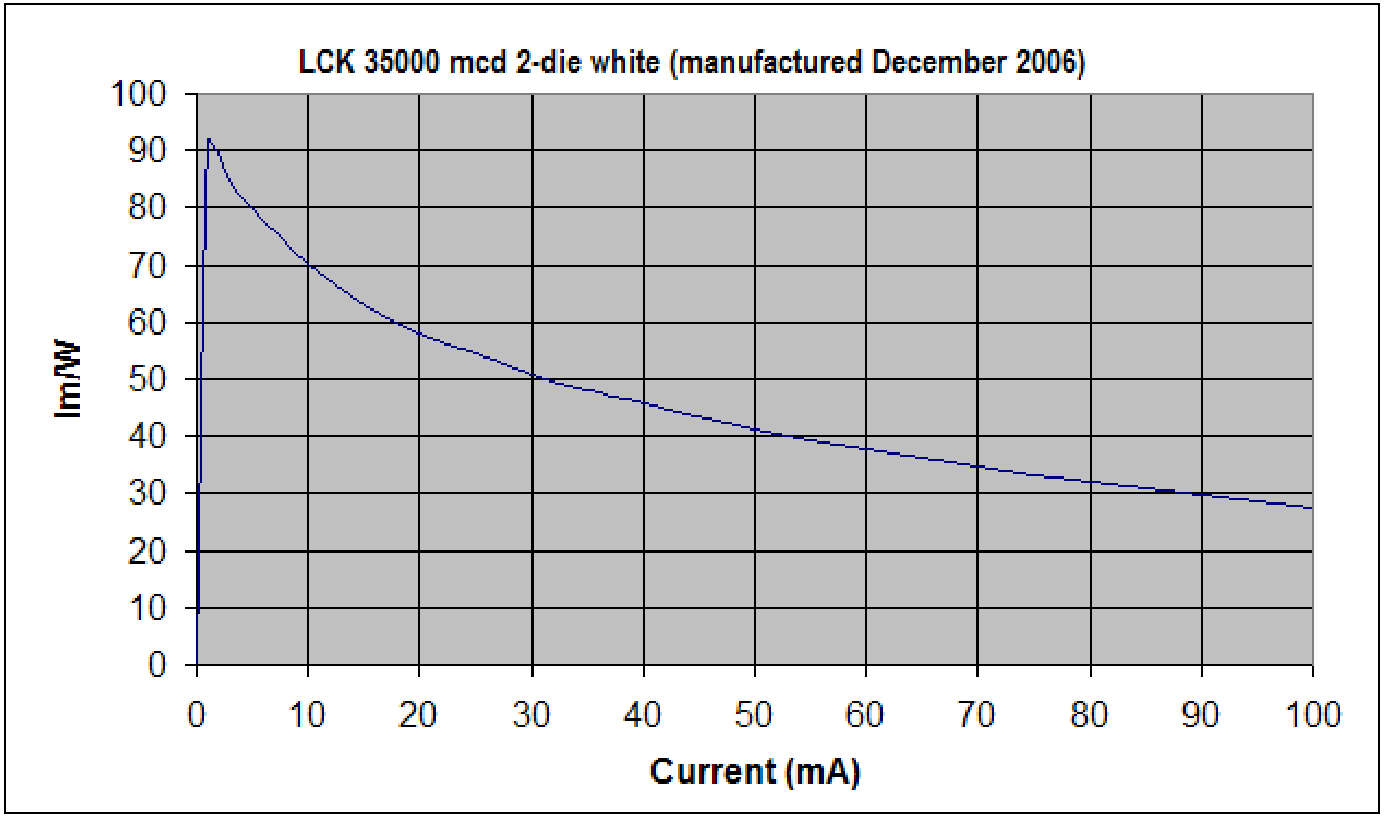

Nichia NSPW310BS-E (received August 2006)
lm/W
55
50
45
40
35
30
25
20
15
10
5
0
0
10
20
30
40
50
60
70
80
90
100
Current (mA)

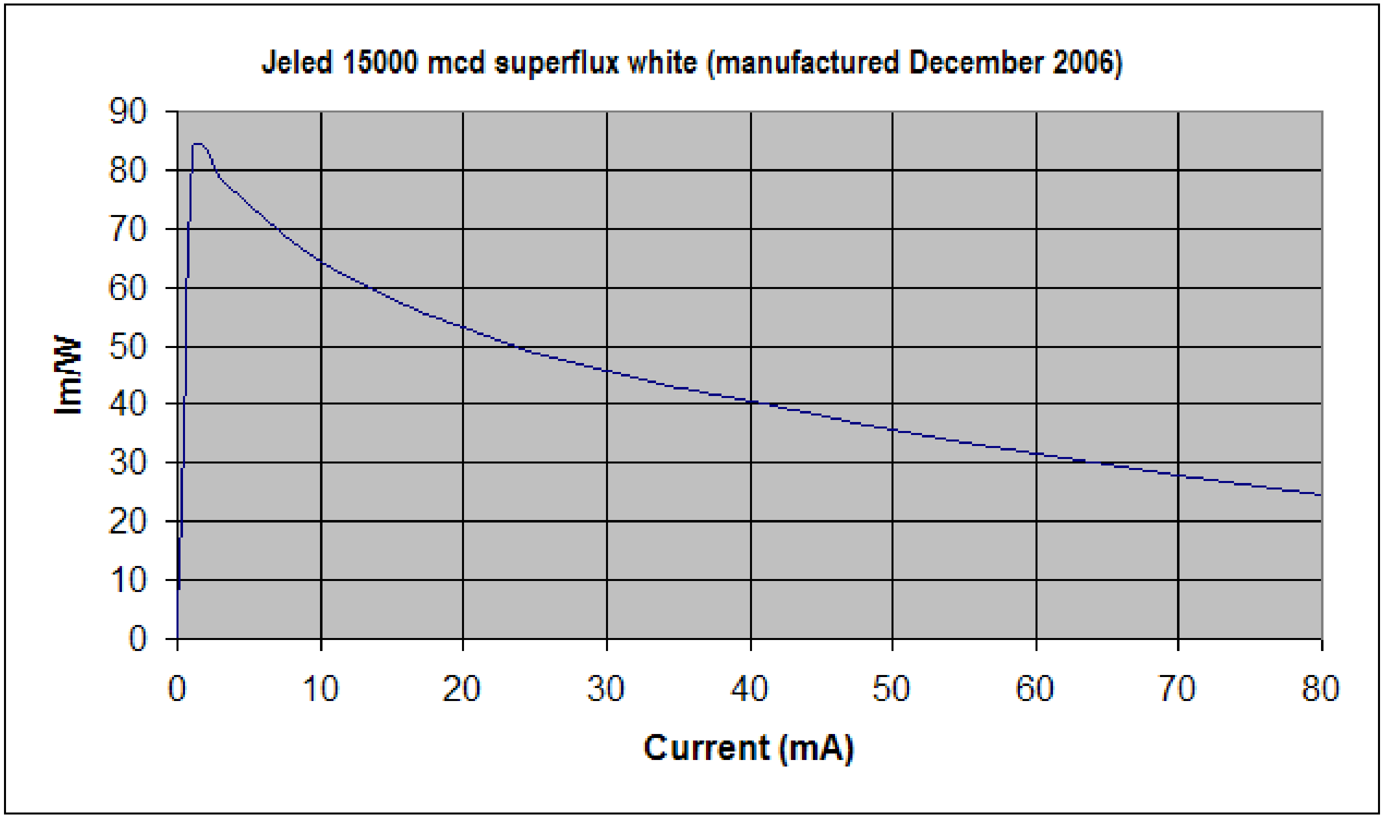

Jeled PLCC-2 white (purchased August 2006)
lm/W
0
10
20
30
40
50
60
70
80
0
10
20
30
40
50
60
70
80
90
100
Current (mA)

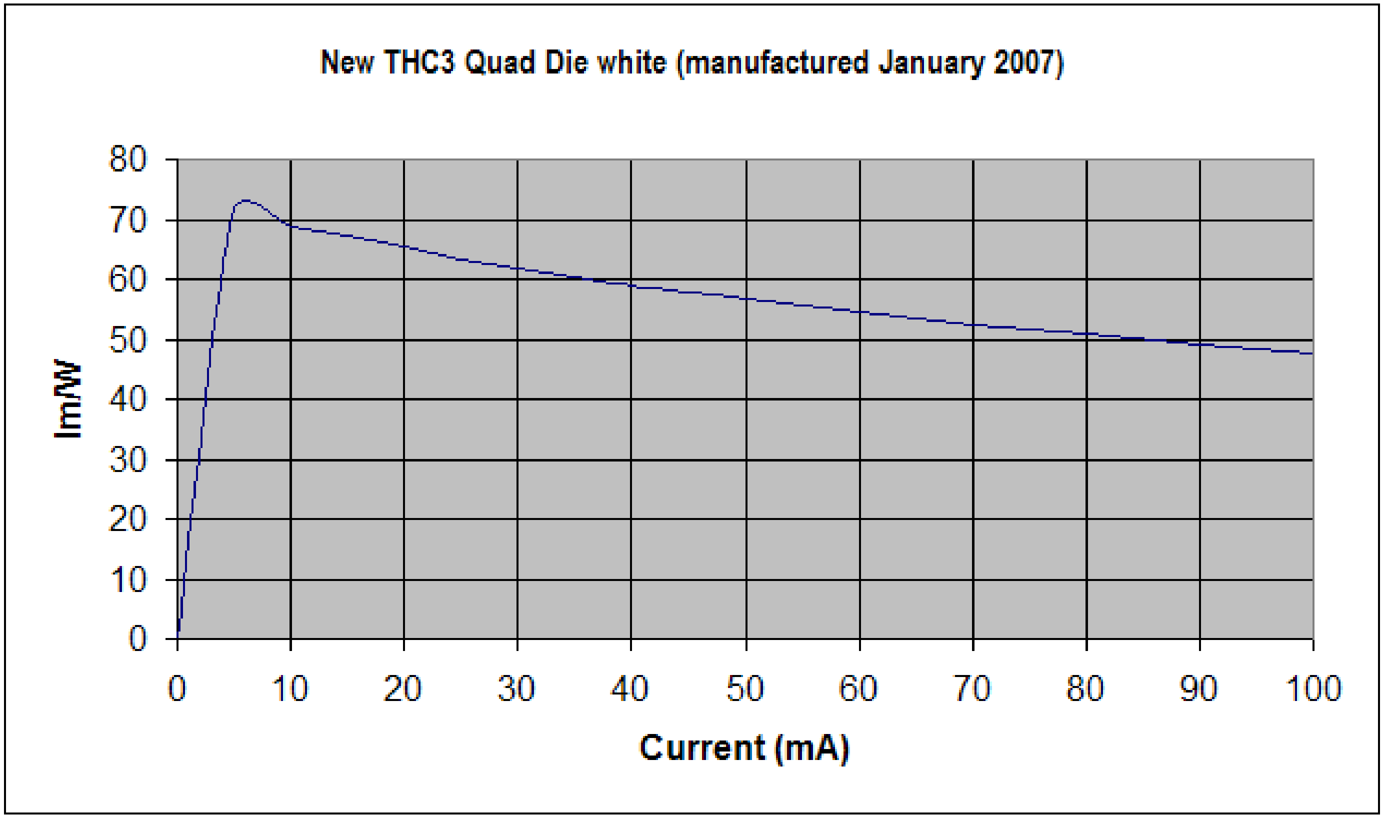

BestHongKong 5mm warm white (manufactured June 2006)
lm/W
0
10
20
30
40
50
60
0
10
20
30
40
50
60
Current (mA)

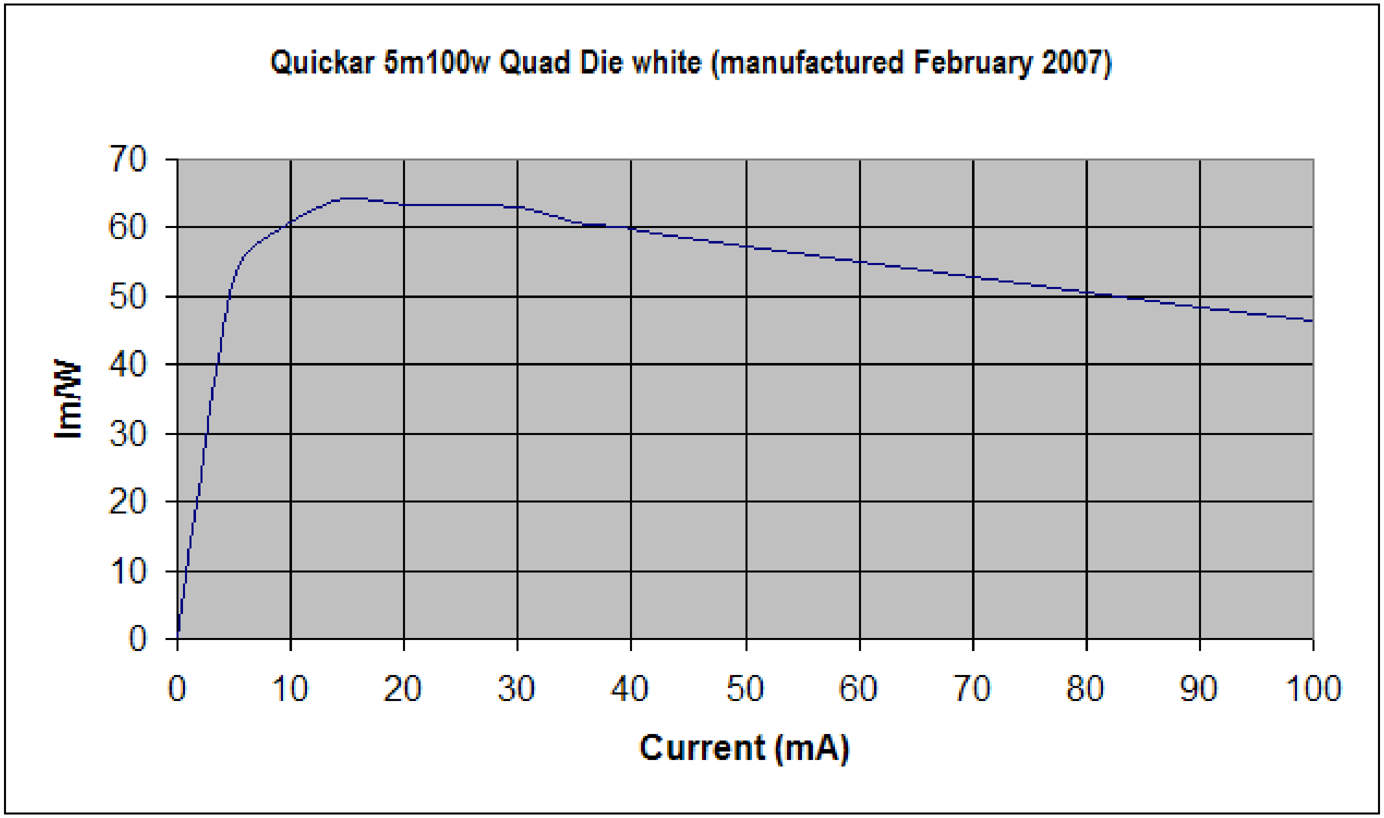

LCK 40000 mcd white (manufactured December 2006)
lm/W
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
Current (mA)

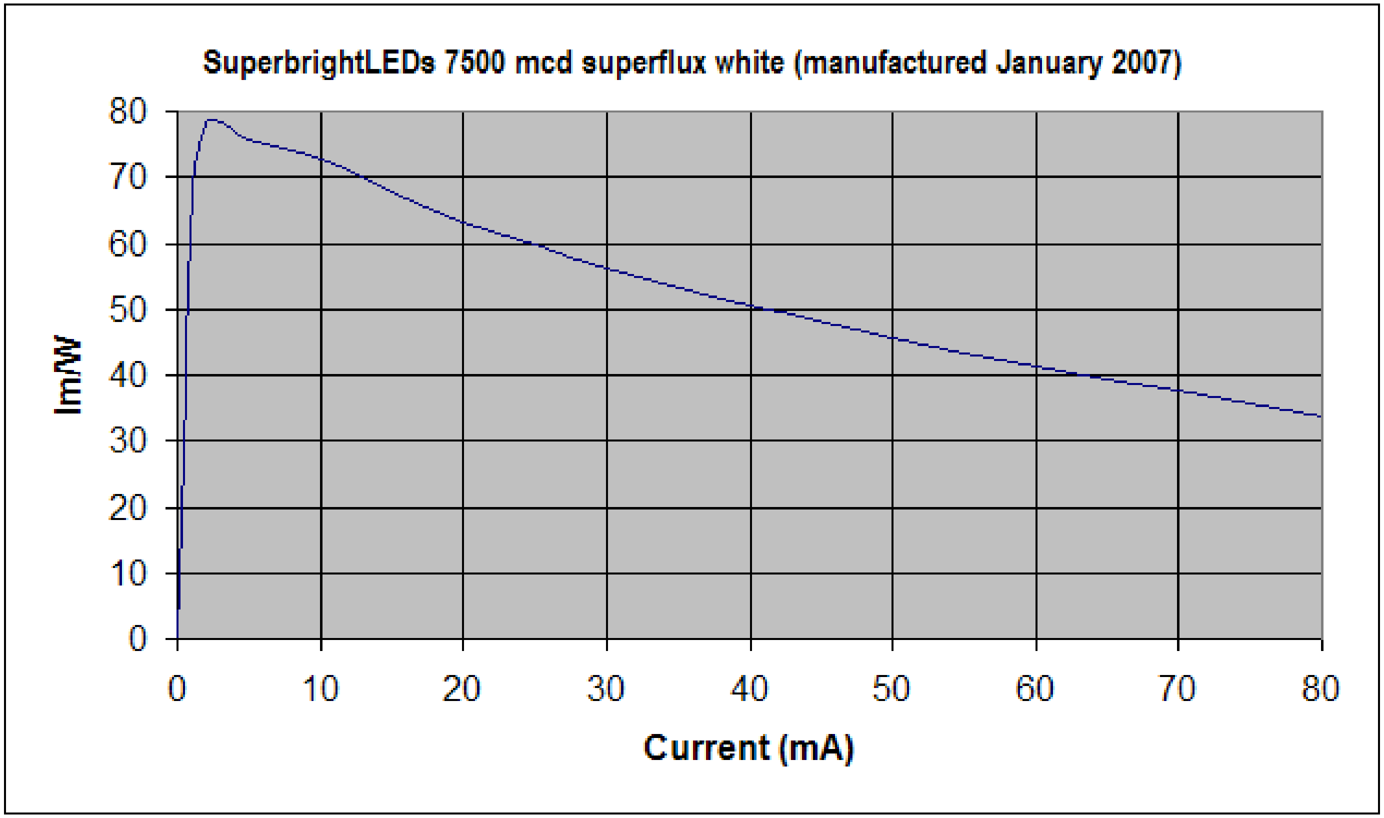

Jeled 50000 mcd white (manufactured December 2006)
lm/W
0
10
20
30
40
50
60
70
80
90
0
10
20
30
40
50
60
70
80
Current (mA)

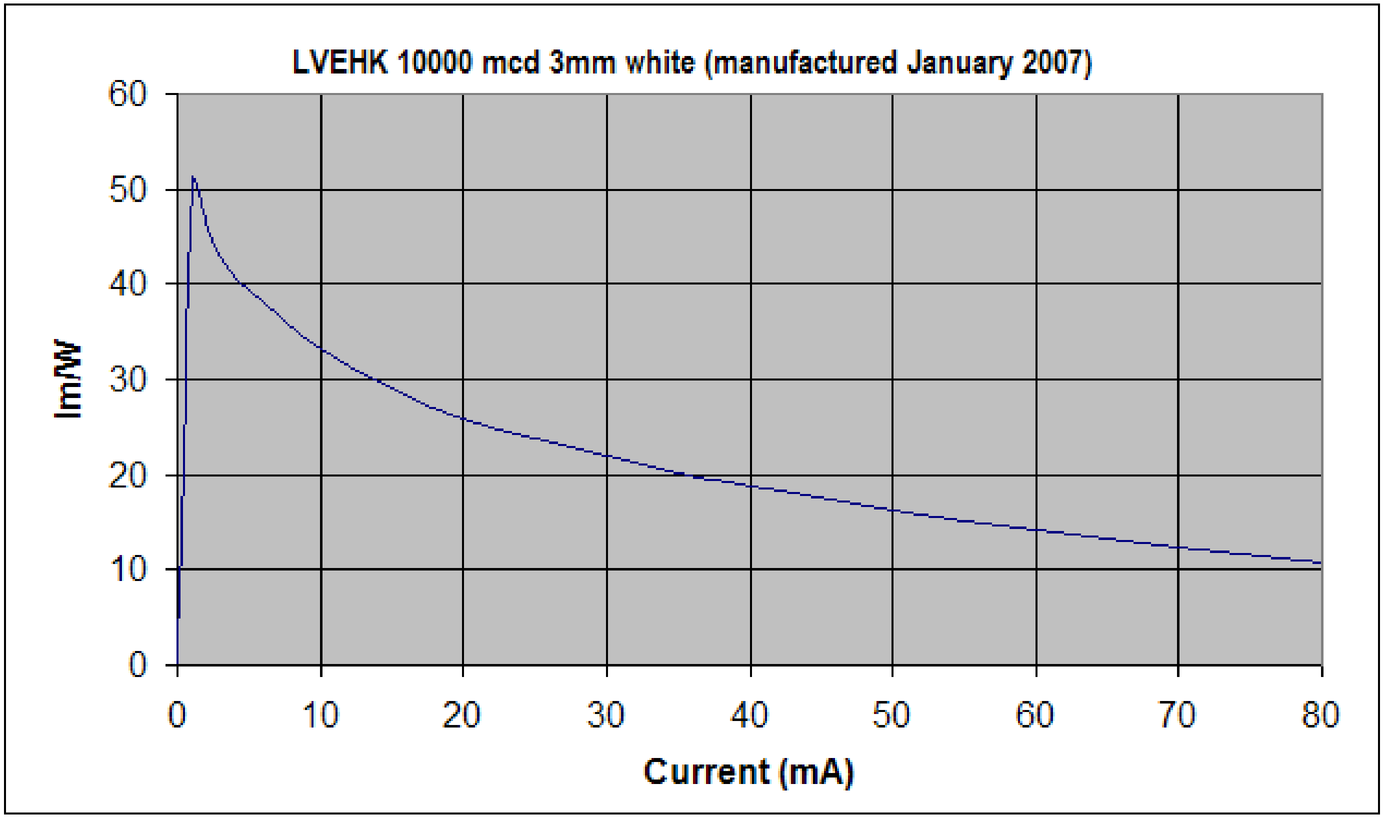

LCK 35000 mcd 2-die white (manufactured December 2006)
lm/W
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Current (mA)

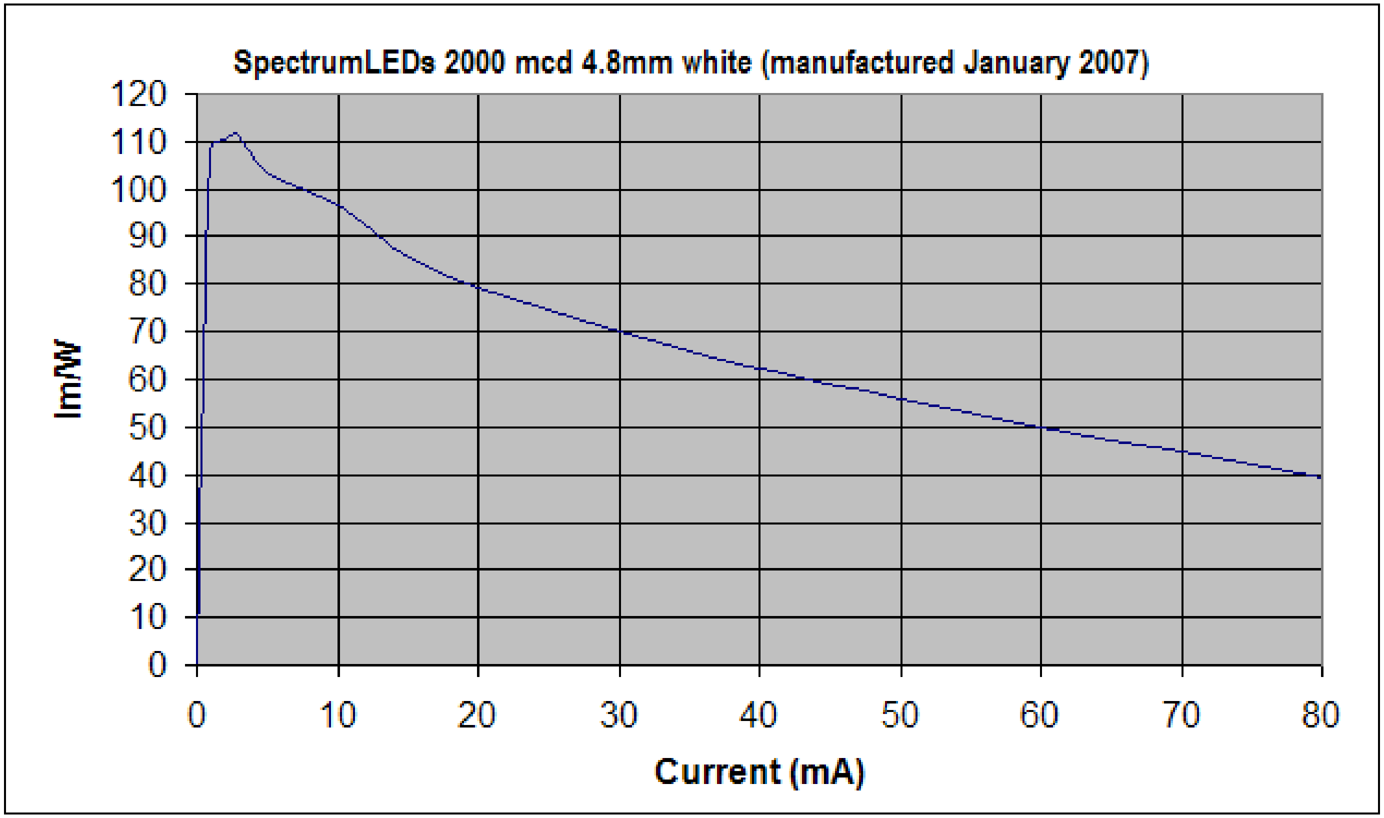

Jeled 15000 mcd superflux white (manufactured December 2006)
lm/W
0
10
20
30
40
50
60
70
80
90
0
10
20
30
40
50
60
70
80
Current (mA)

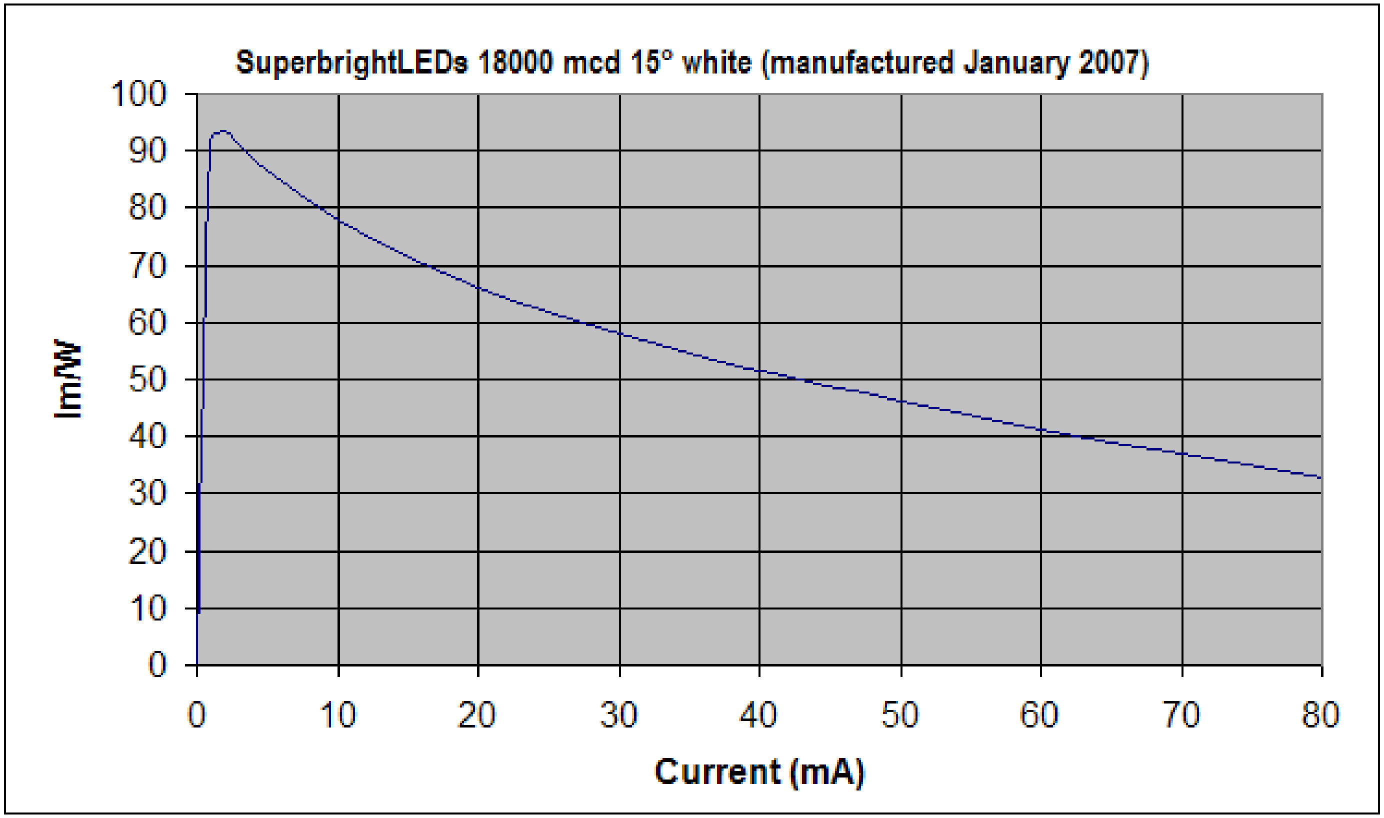

New THC3 Quad Die white (manufactured January 2007)
lm/W
0
10
20
30
40
50
60
70
80
0
10
20
30
40
50
60
70
80
90
100
Current (mA)

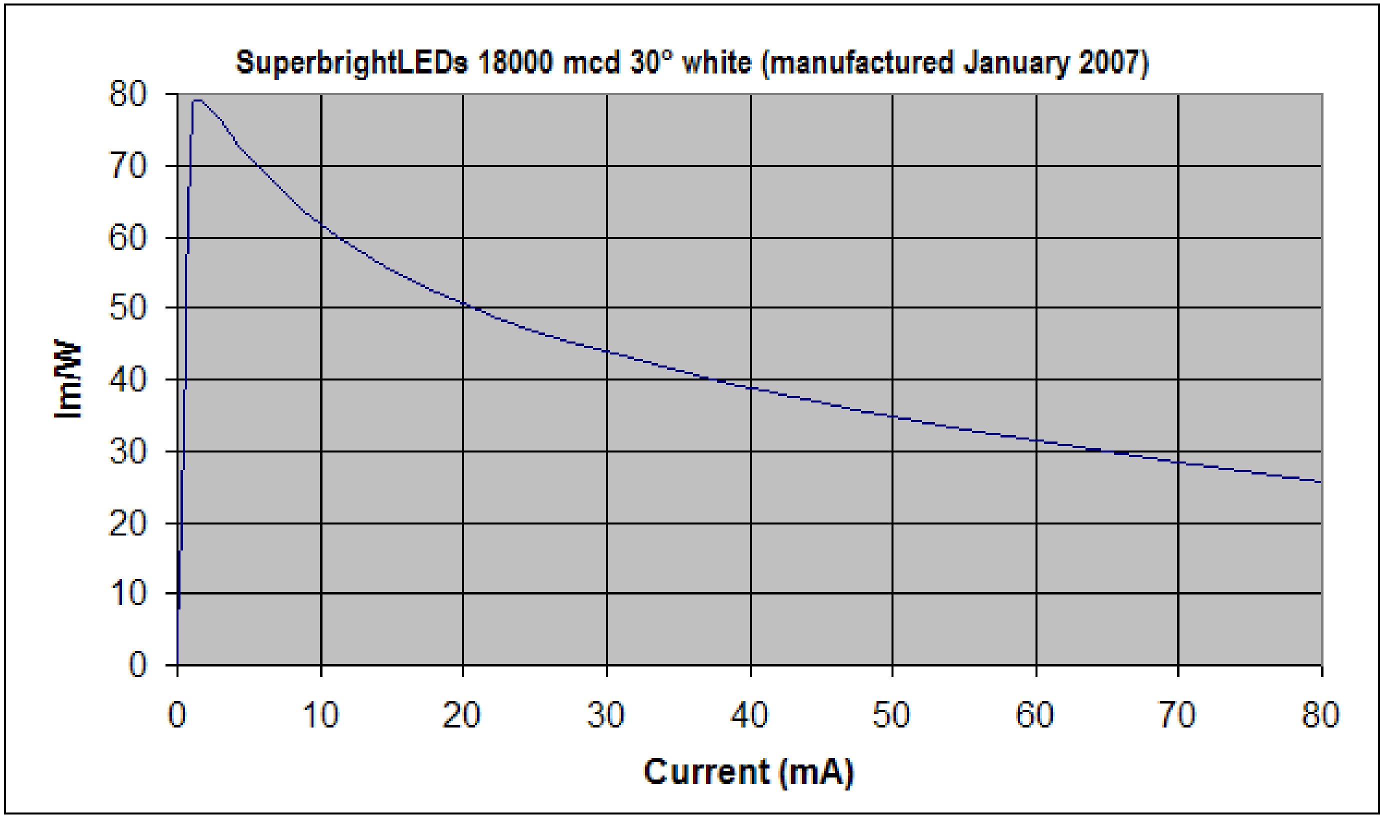

Quickar 5m100w Quad Die white (manufactured February 2007)
lm/W
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Current (mA)

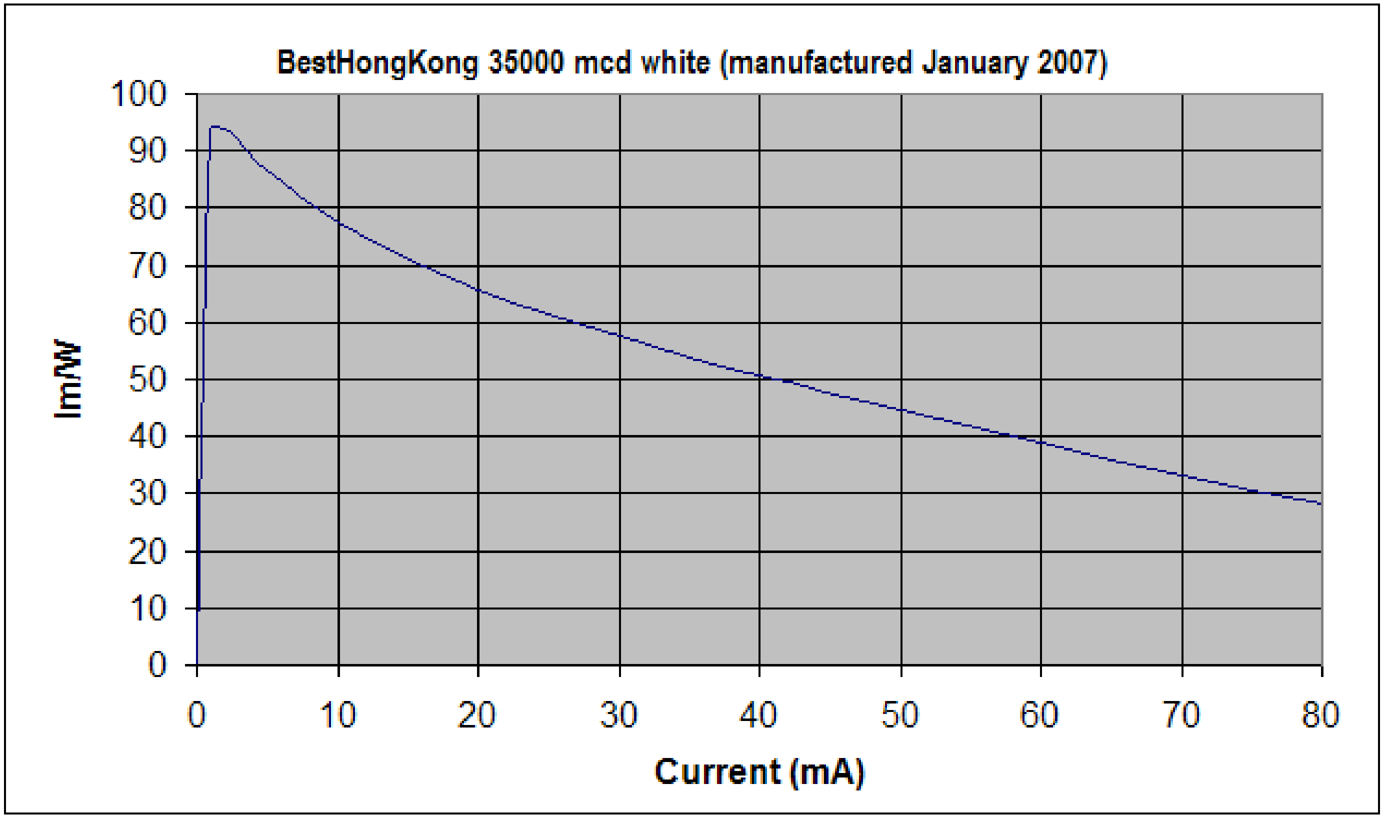

SuperbrightLEDs 7500 mcd superflux white (manufactured January 2007)
lm/W
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
Current (mA)

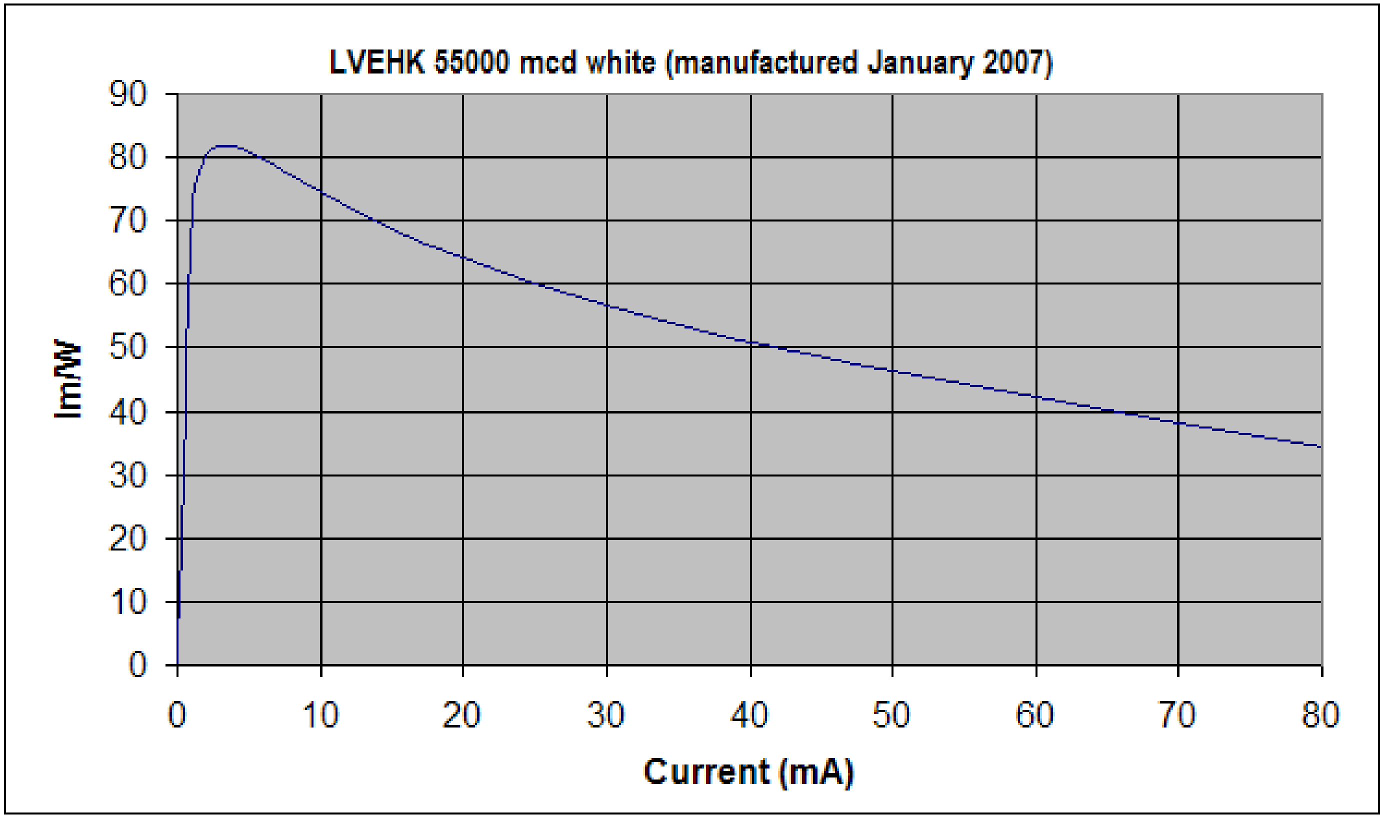

LVEHK 10000 mcd 3mm white (manufactured January 2007)
lm/W
0
10
20
30
40
50
60
0
10
20
30
40
50
60
70
80
Current (mA)

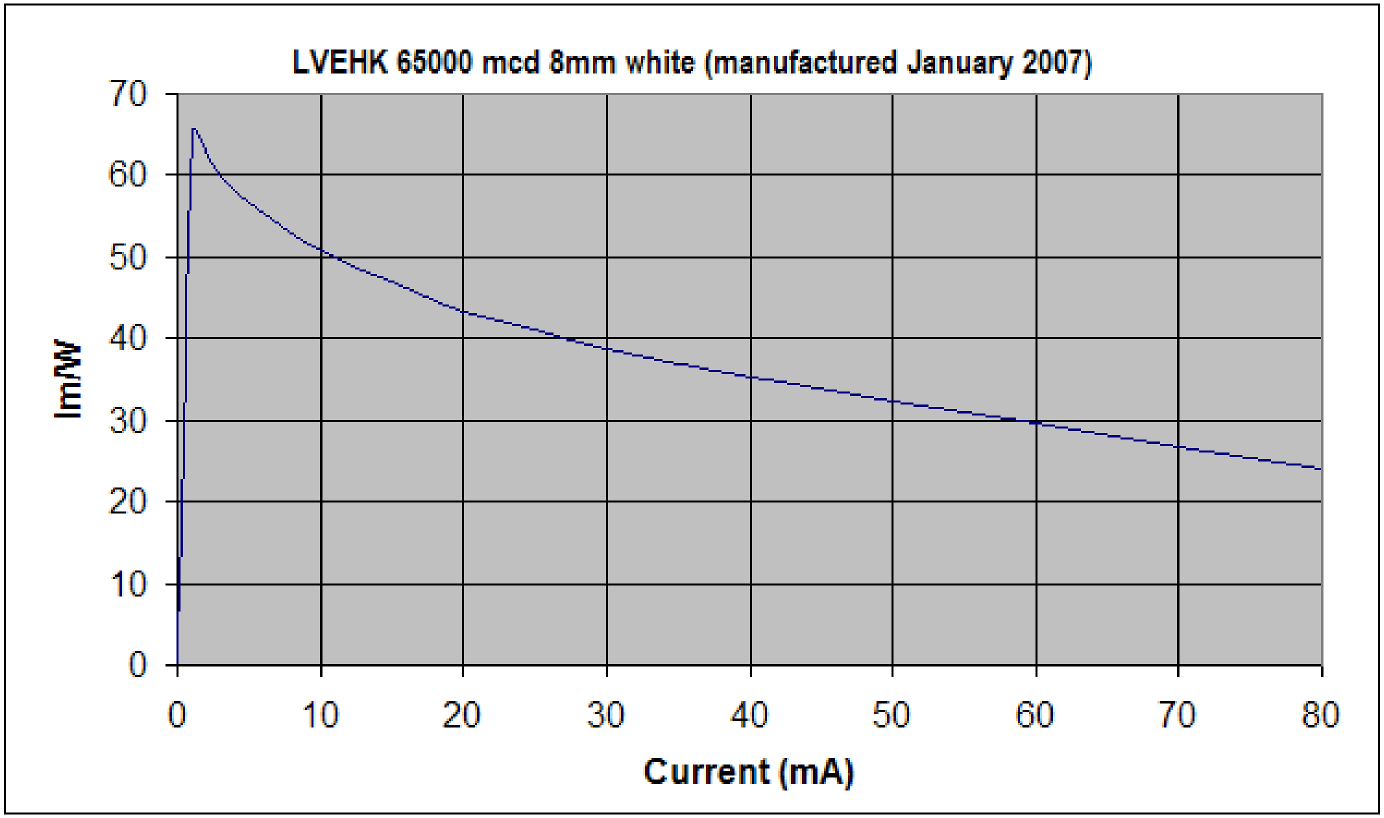

SpectrumLEDs 2000 mcd 4.8mm white (manufactured January 2007)
lm/W
120
110
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
Current (mA)

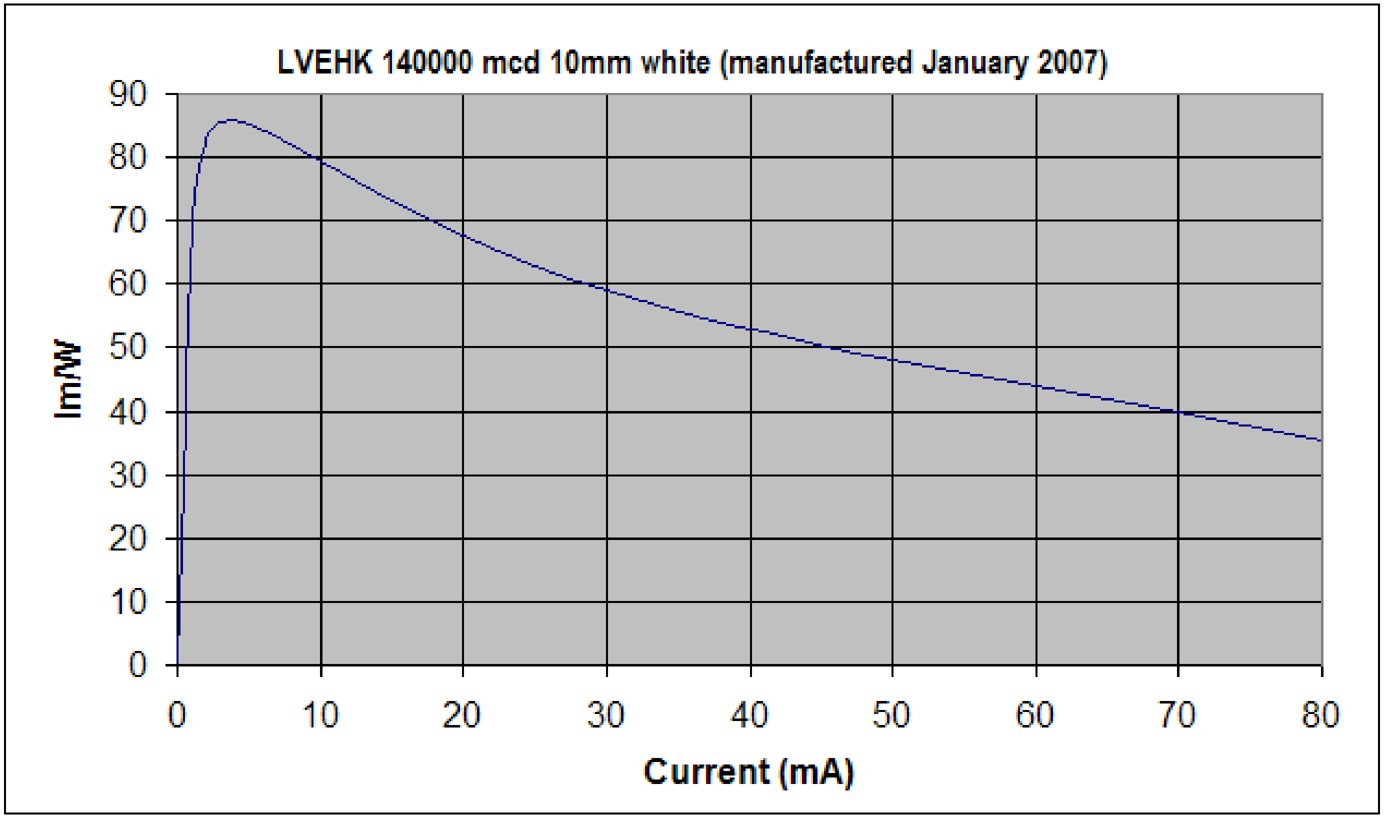

SuperbrightLEDs 18000 mcd 15° white (manufactured January 2007)
lm/W
Current (mA)
0
10
20
30
40
50
60
70
80
90
100

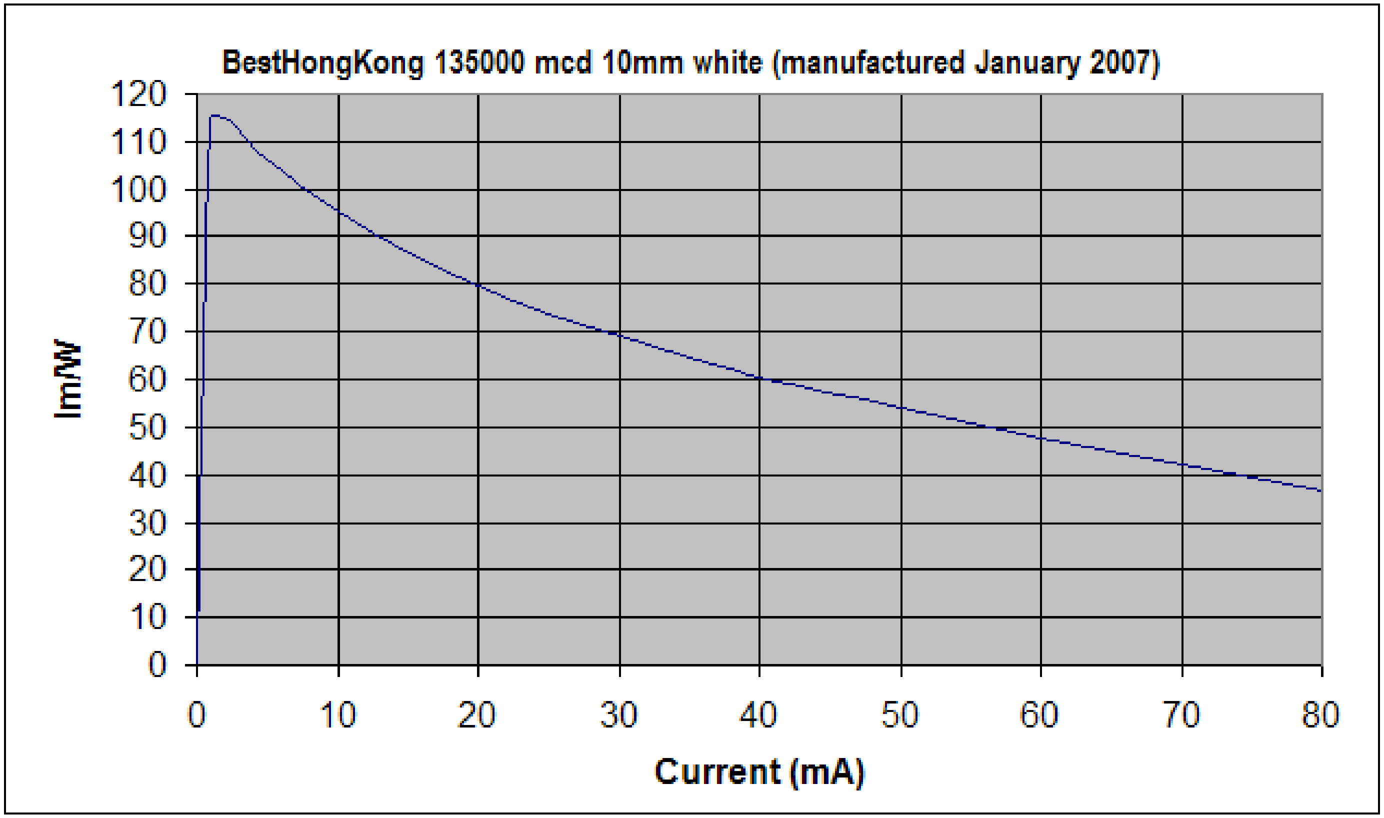

SuperbrightLEDs 18000 mcd 30° white (manufactured January 2007)
lm/W
Current (mA)
0
10
20
30
40
50
60
70
80

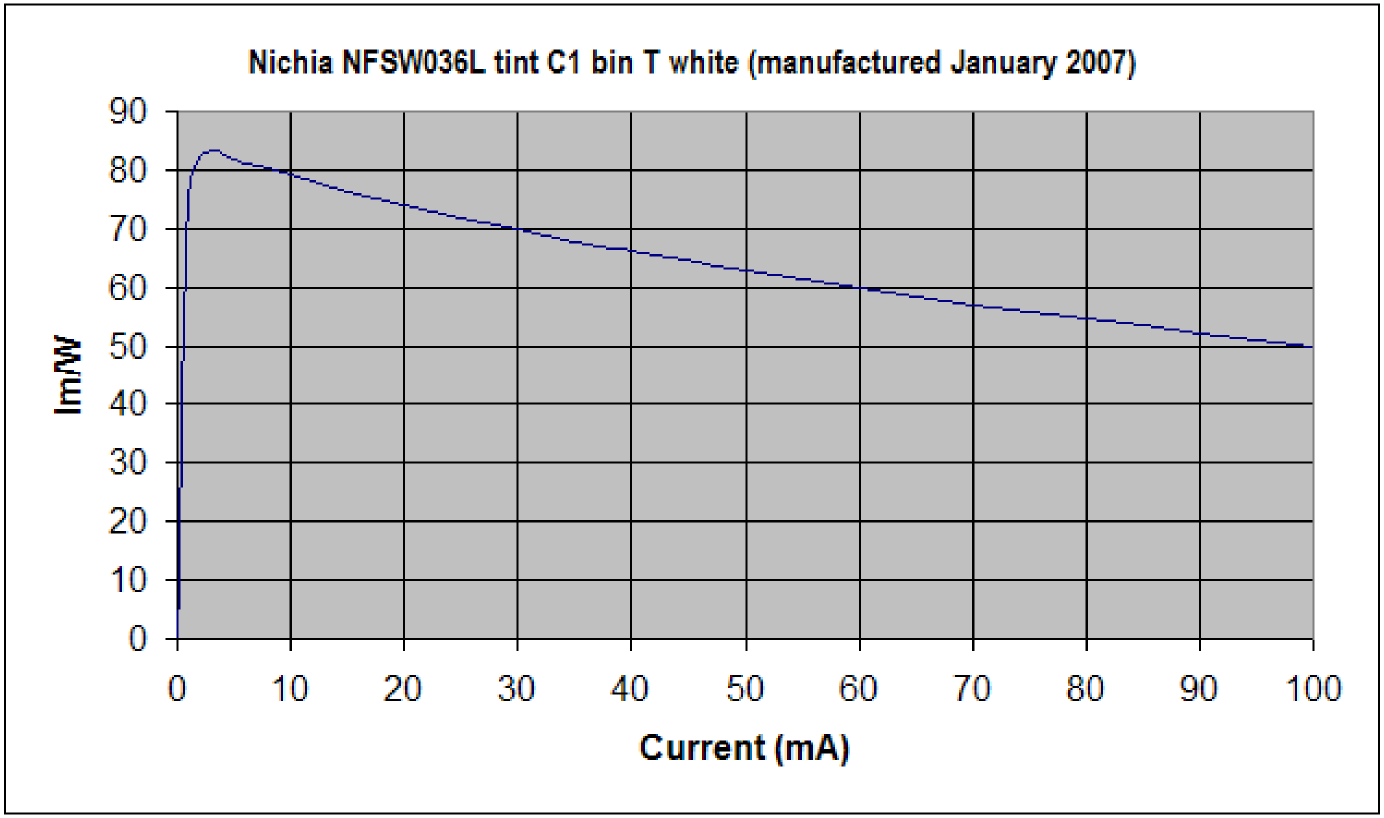

BestHongKong 35000 mcd white (manufactured January 2007)
lm/W
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
Current (mA)

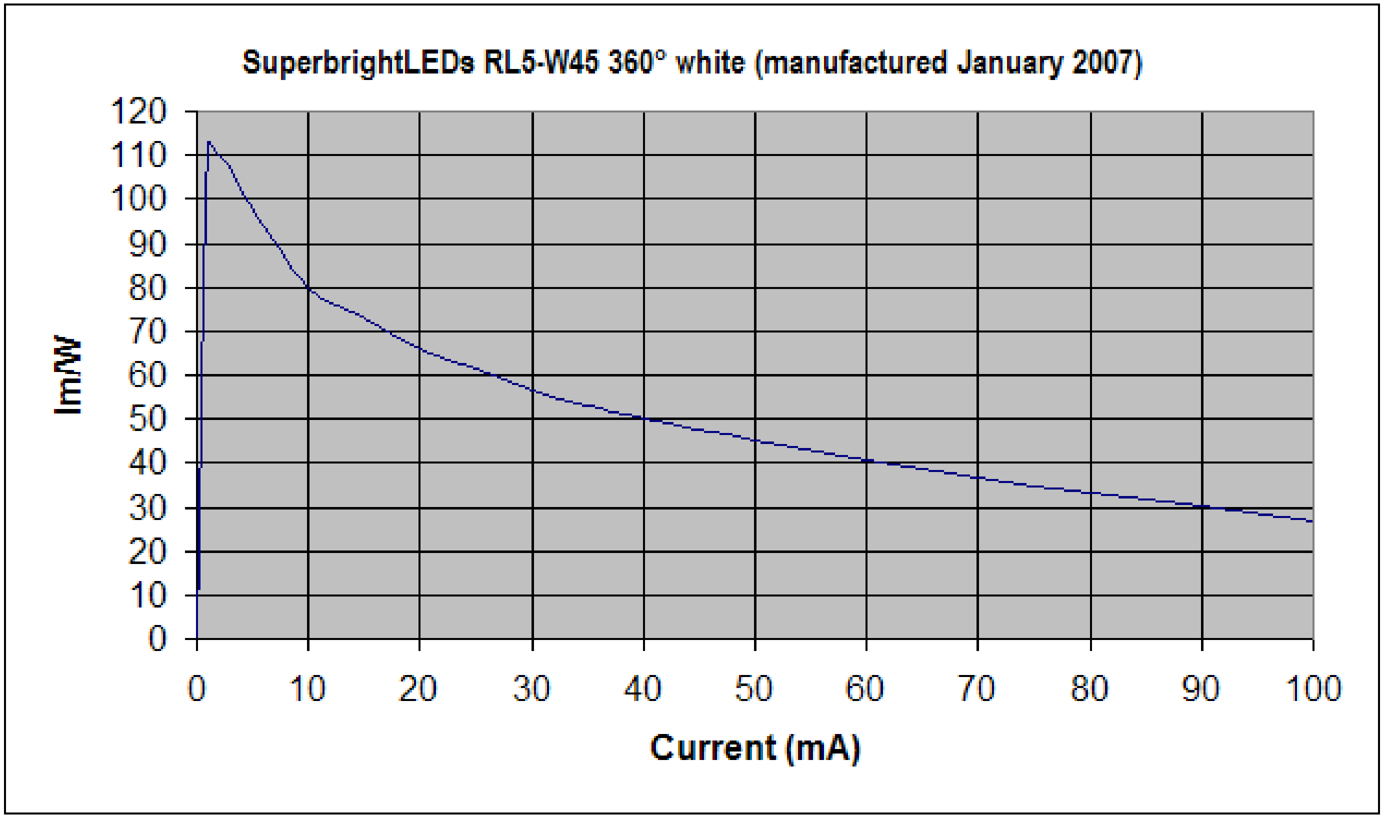

LVEHK 55000 mcd white (manufactured January 2007)
lm/W
0
10
20
30
40
50
60
70
80
90
0
10
20
30
40
50
60
70
80
Current (mA)

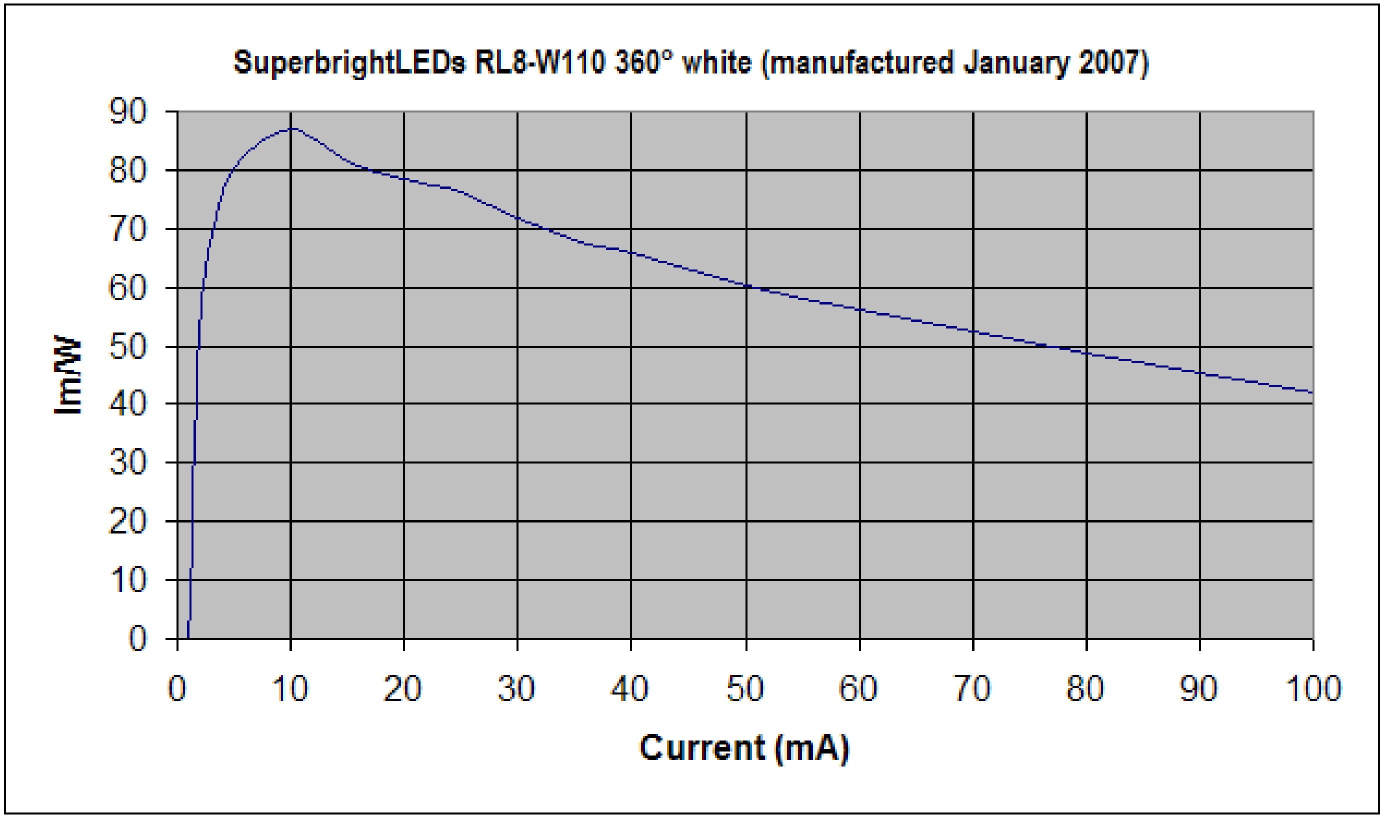

LVEHK 65000 mcd 8mm white (manufactured January 2007)
lm/W
0
10
20
30
40
50
60
70
0
10
20
30
40
50
60
70
80
Current (mA)

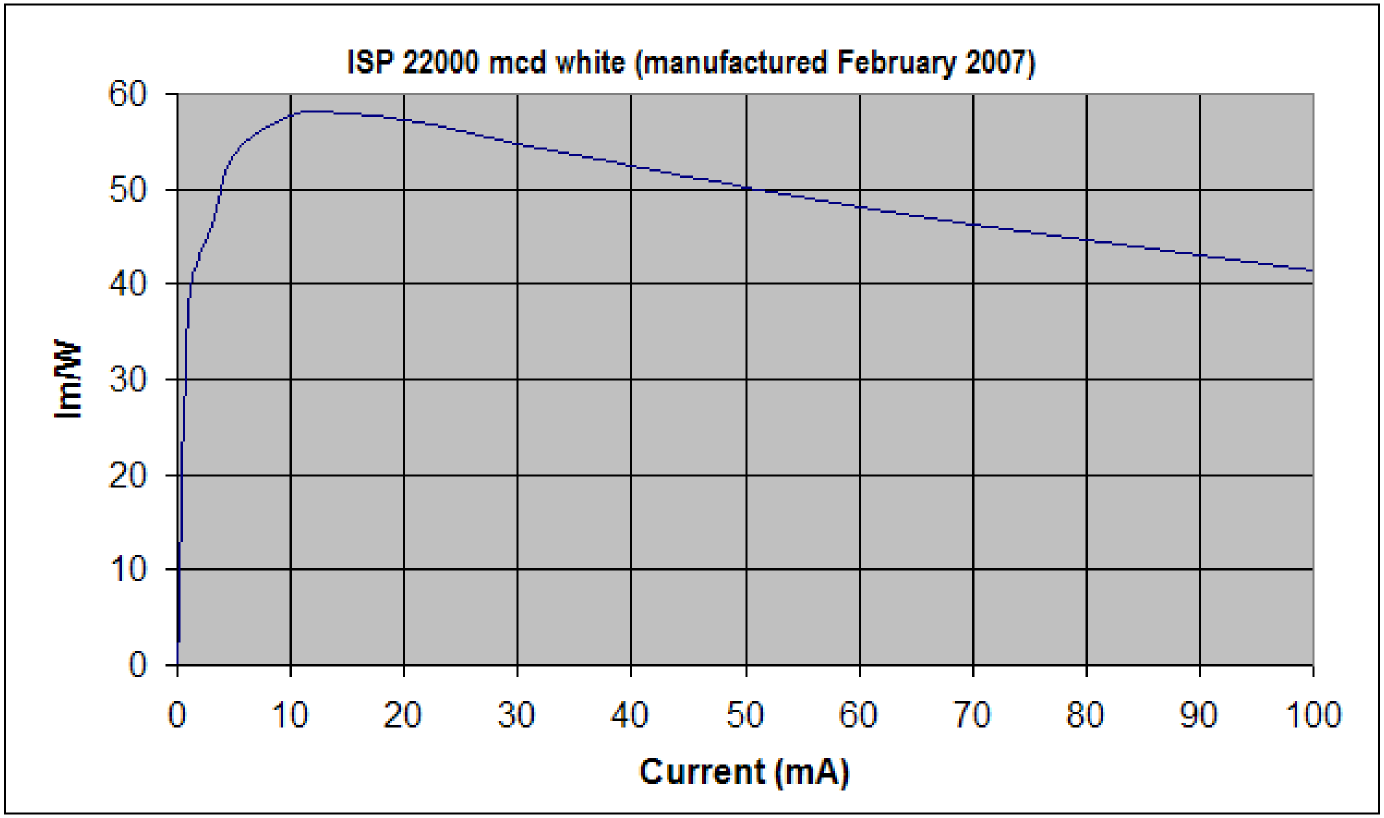

LVEHK 140000 mcd 10mm white (manufactured January 2007)
lm/W
0
10
20
30
40
50
60
70
80
90
0
10
20
30
40
50
60
70
80
Current (mA)

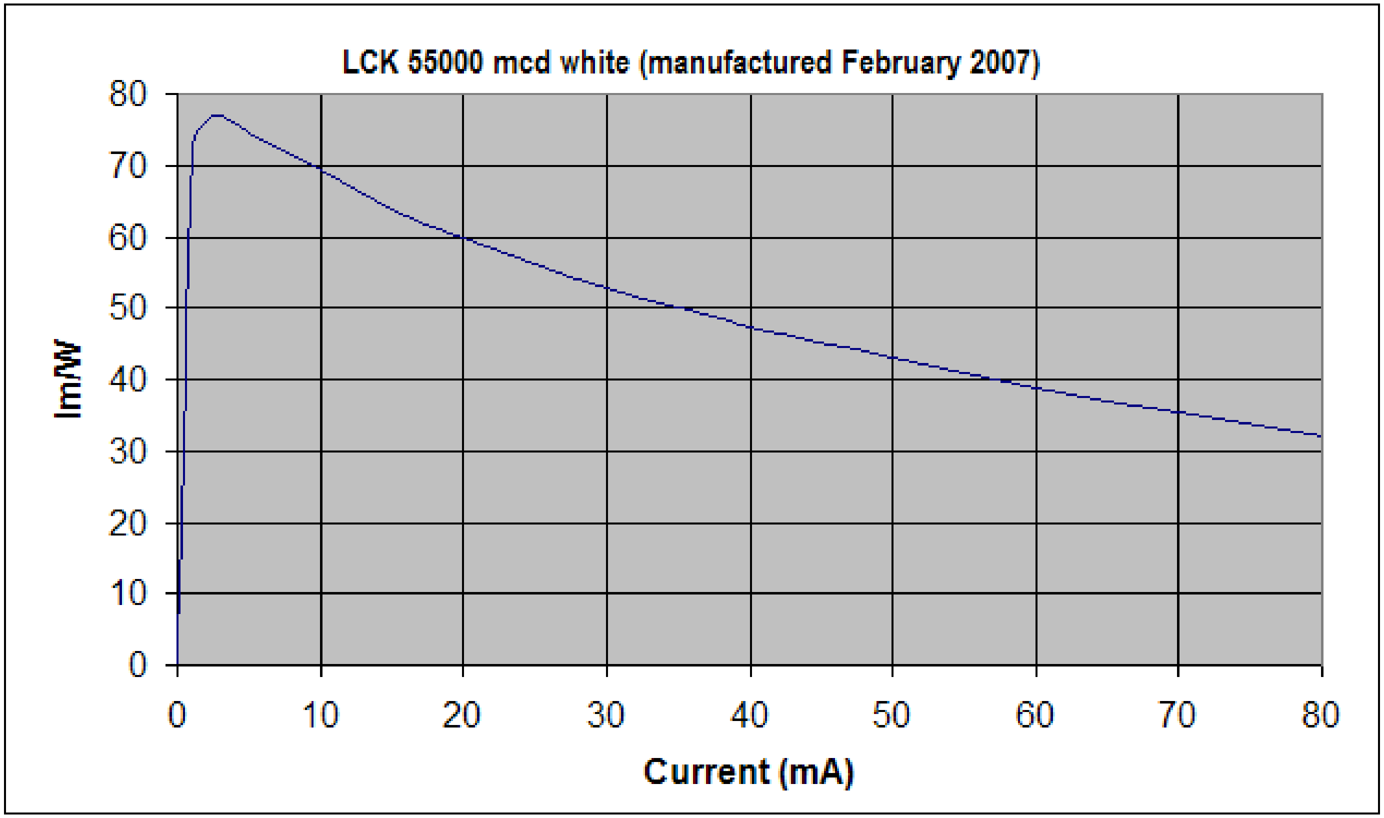

BestHongKong 135000 mcd 10mm white (manufactured January 2007)
lm/W
120
110
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
Current (mA)

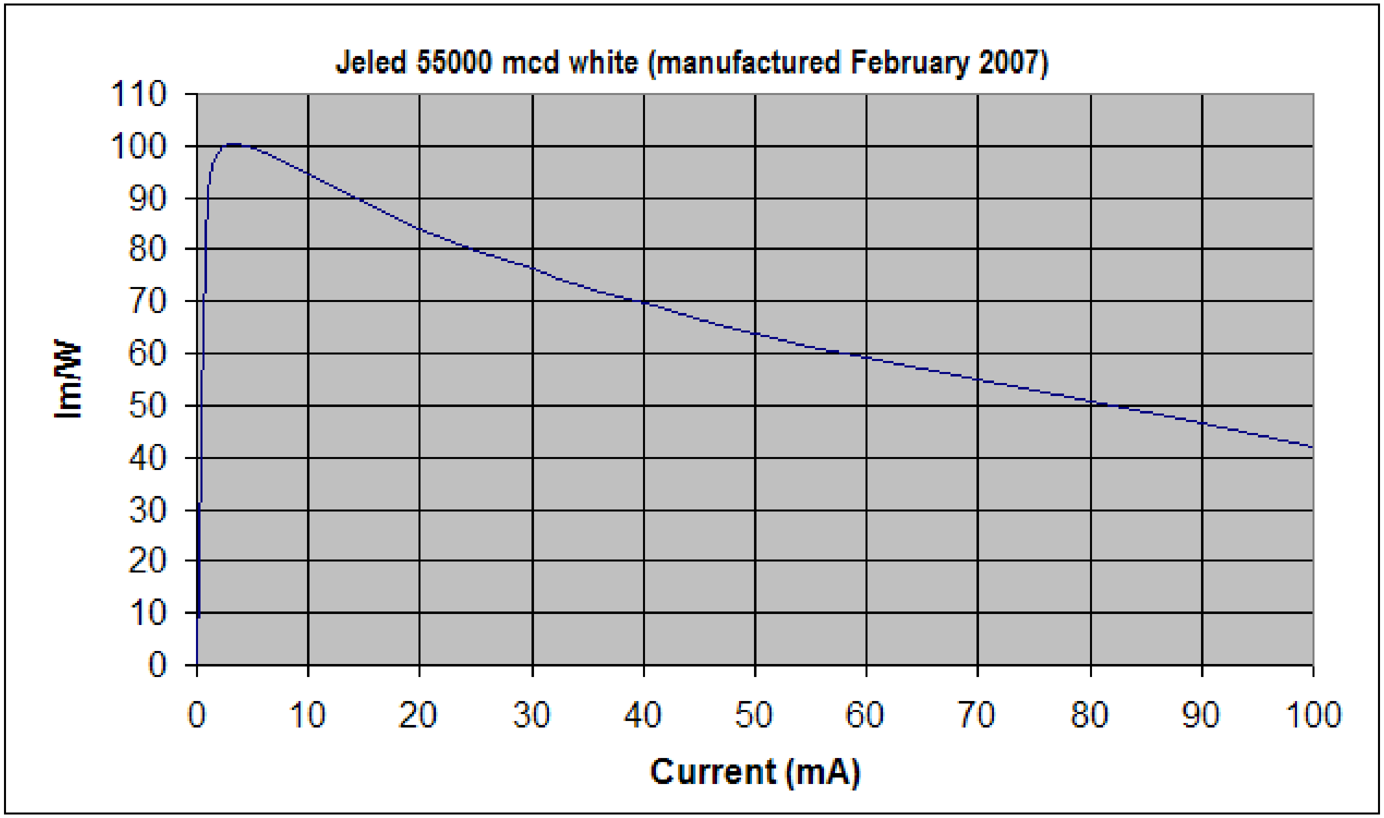

Nichia NFSW036L tint C1 bin T white (manufactured January 2007)
lm/W
0
10
20
30
40
50
60
70
80
90
0
10
20
30
40
50
60
70
80
90
100
Current (mA)

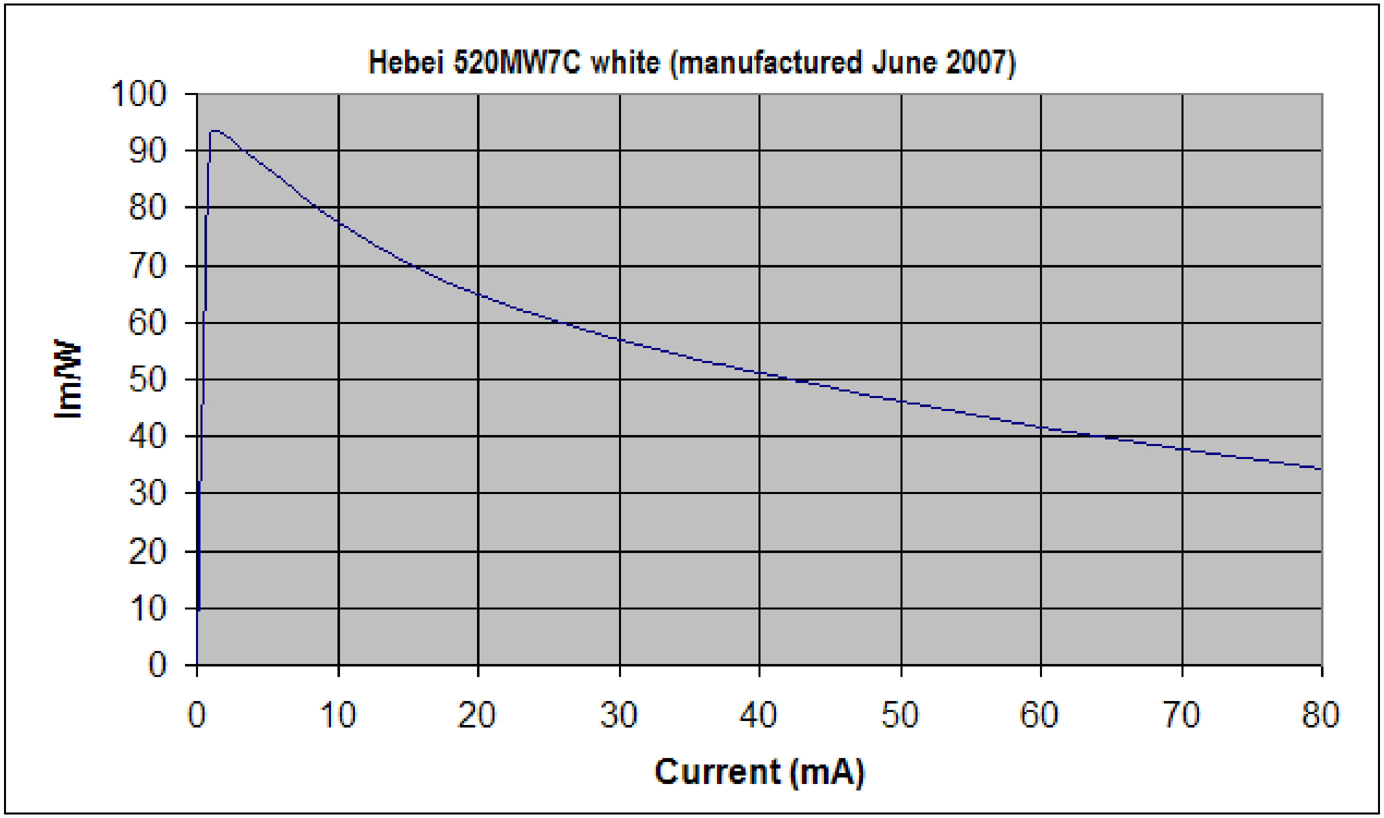

SuperbrightLEDs RL5-W45 360° white (manufactured January 2007)
lm/W
120
110
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Current (mA)

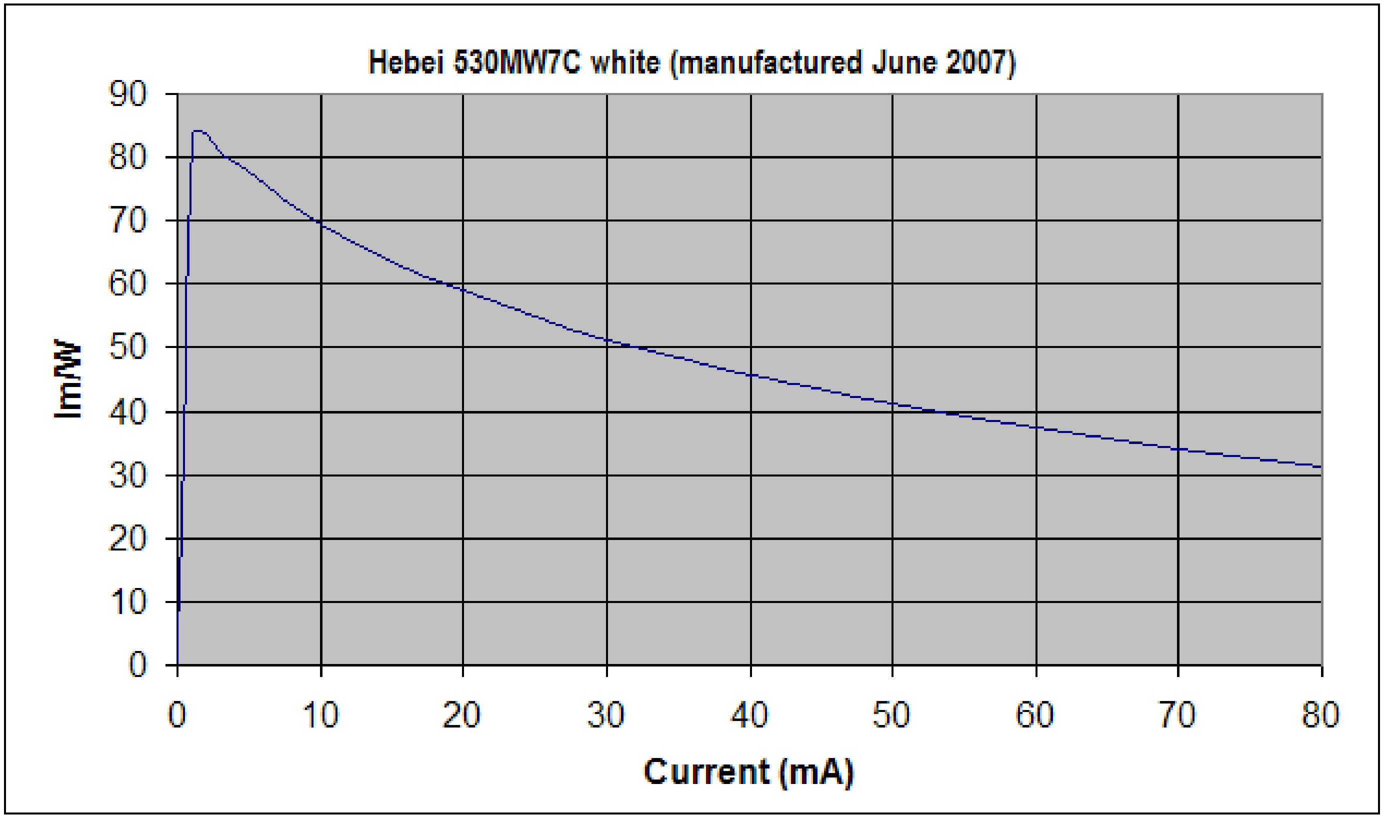

SuperbrightLEDs RL8-W110 360° white (manufactured January 2007)
lm/W
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Current (mA)

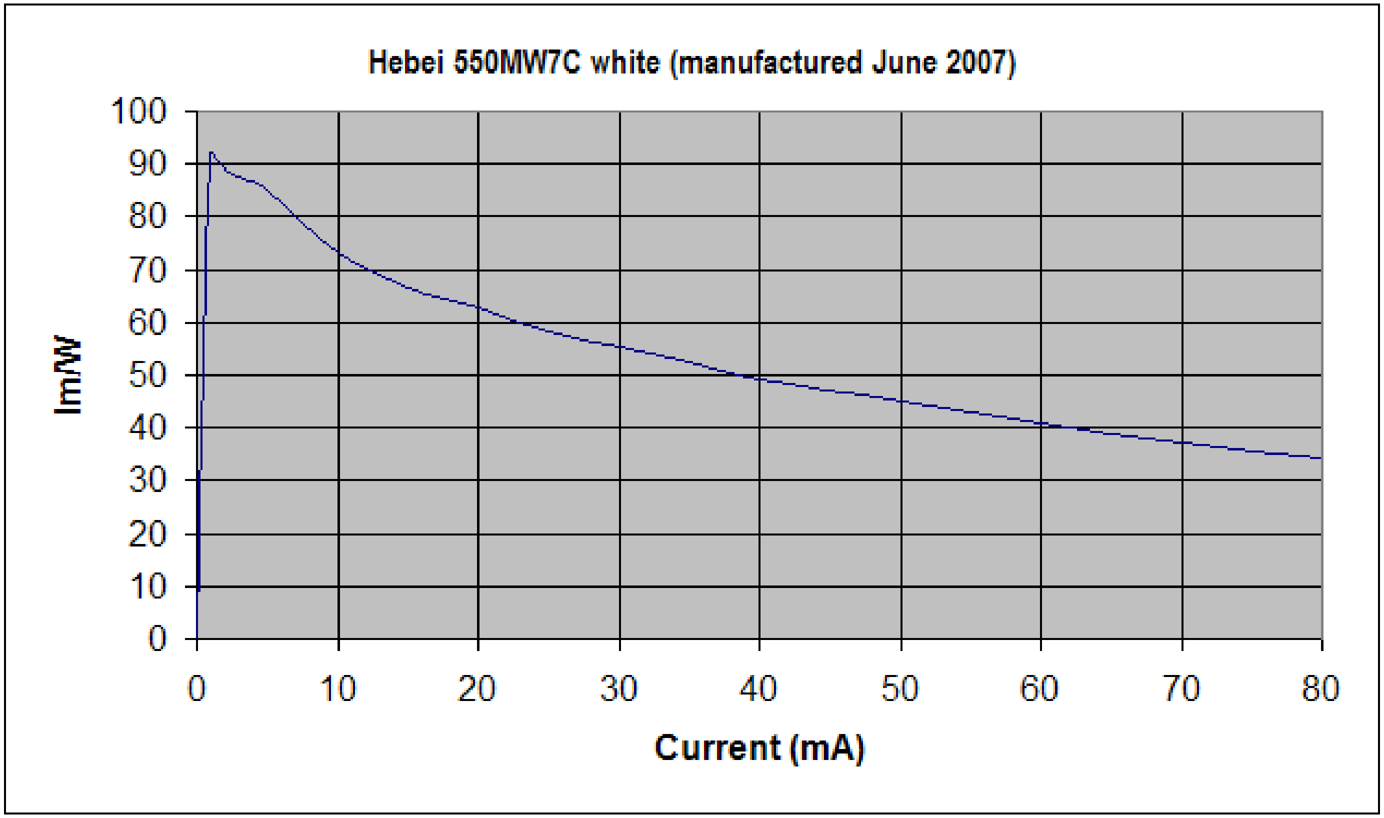

ISP 22000 mcd white (manufactured February 2007)
lm/W
0
10
20
30
40
50
60
0
10
20
30
40
50
60
70
80
90
100
Current (mA)

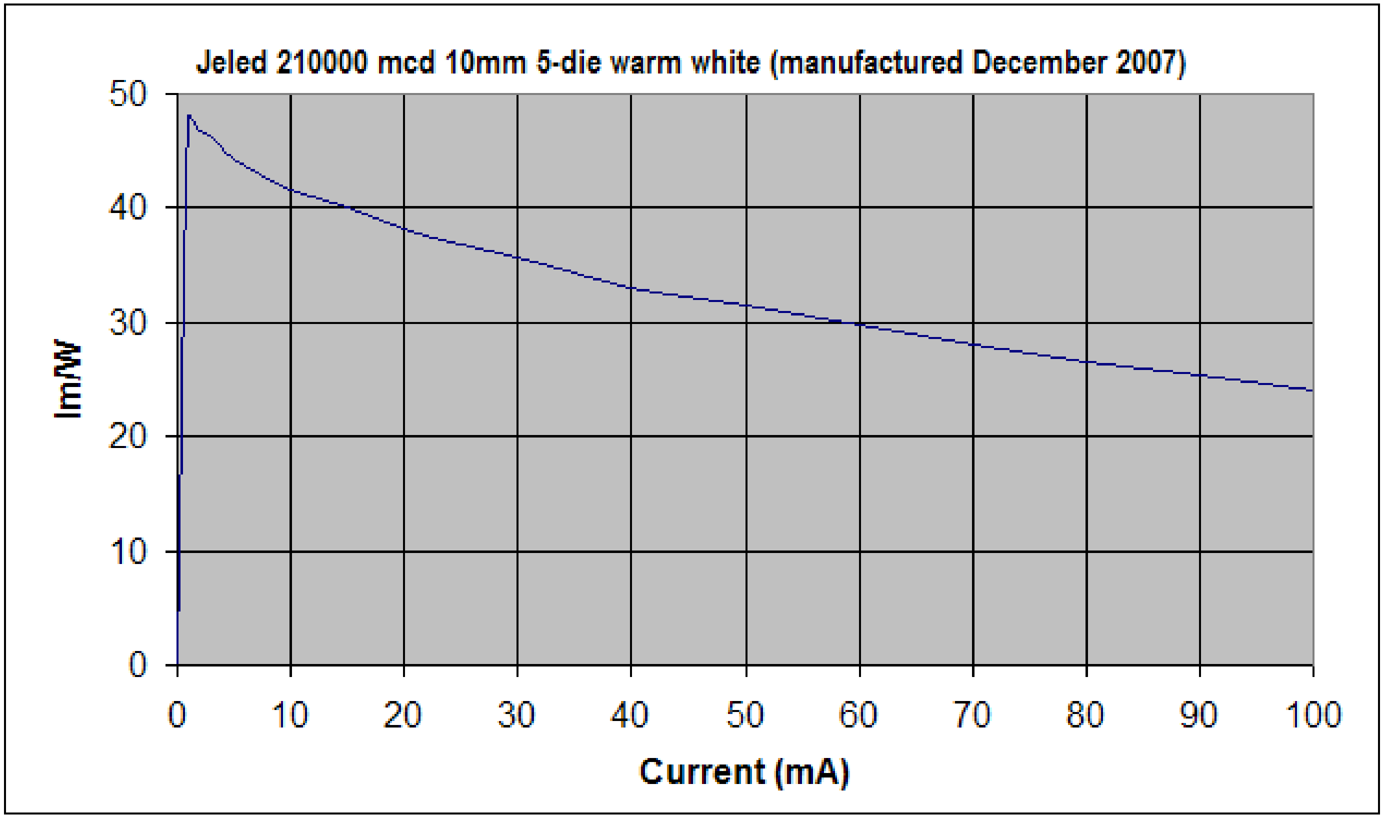

LCK 55000 mcd white (manufactured February 2007)
lm/W
0
10
20
30
40
50
60
70
80
0
10
20
30
40
50
60
70
80
Current (mA)

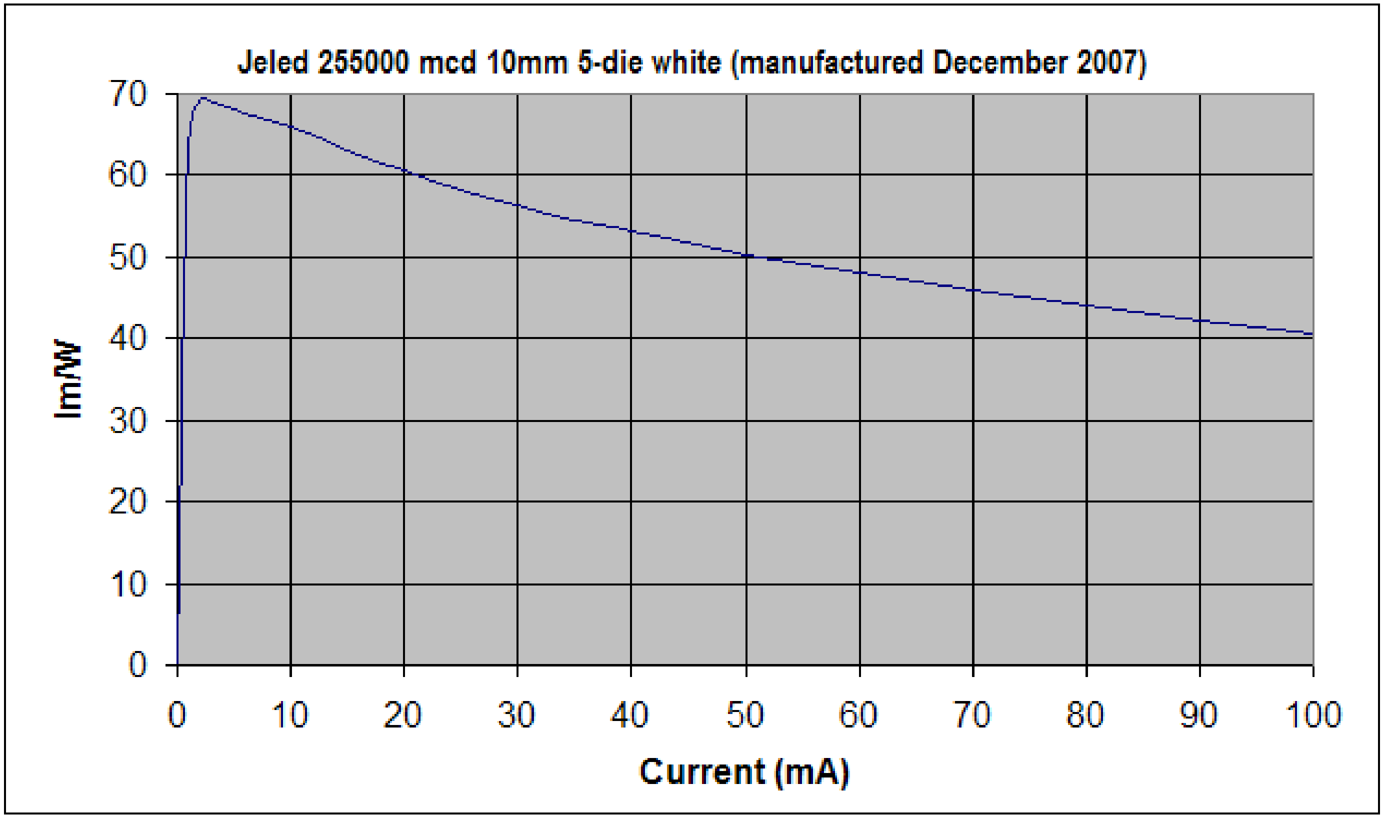

Jeled 55000 mcd white (manufactured February 2007)
lm/W
110
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Current (mA)

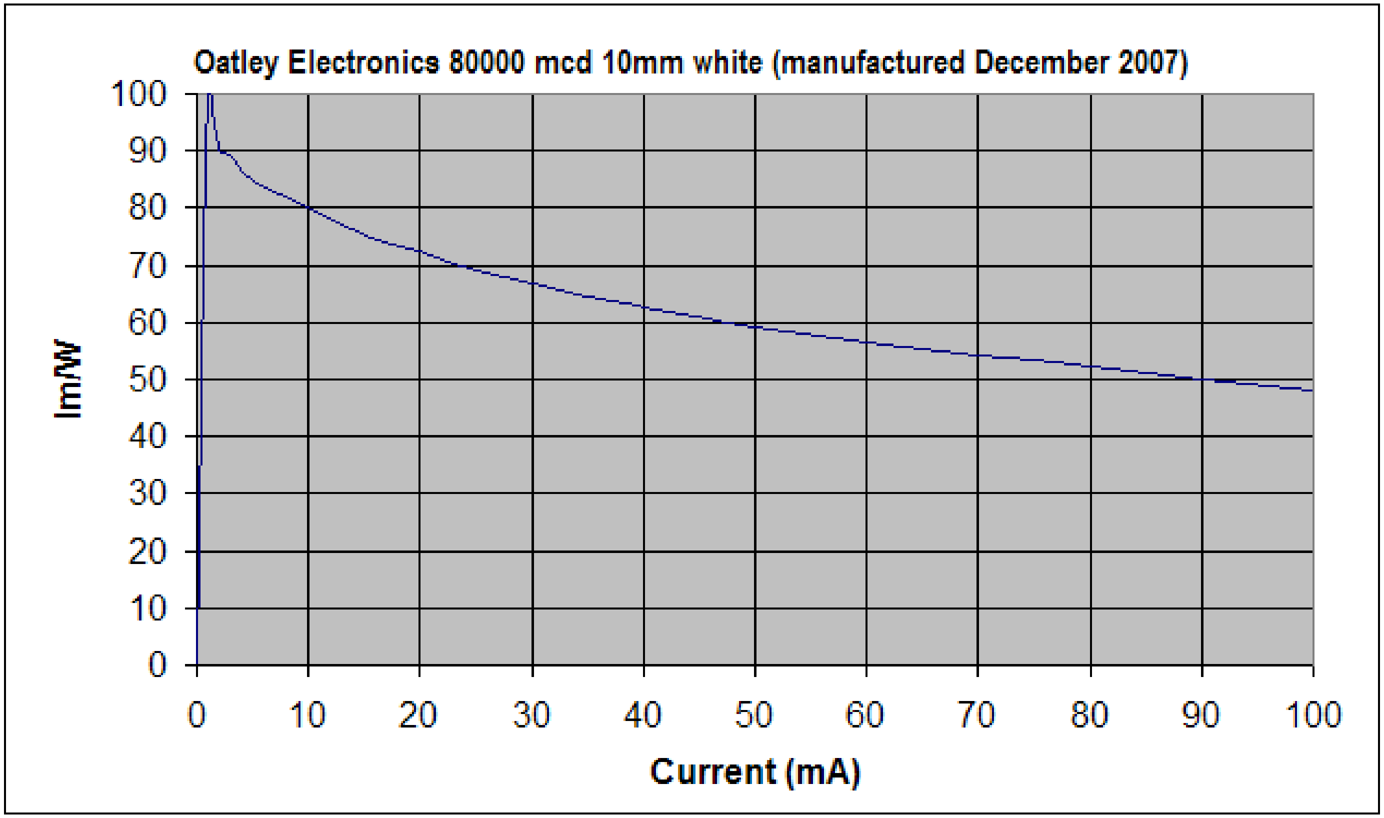

Hebei 520MW7C white (manufactured June 2007)
lm/W
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
Current (mA)

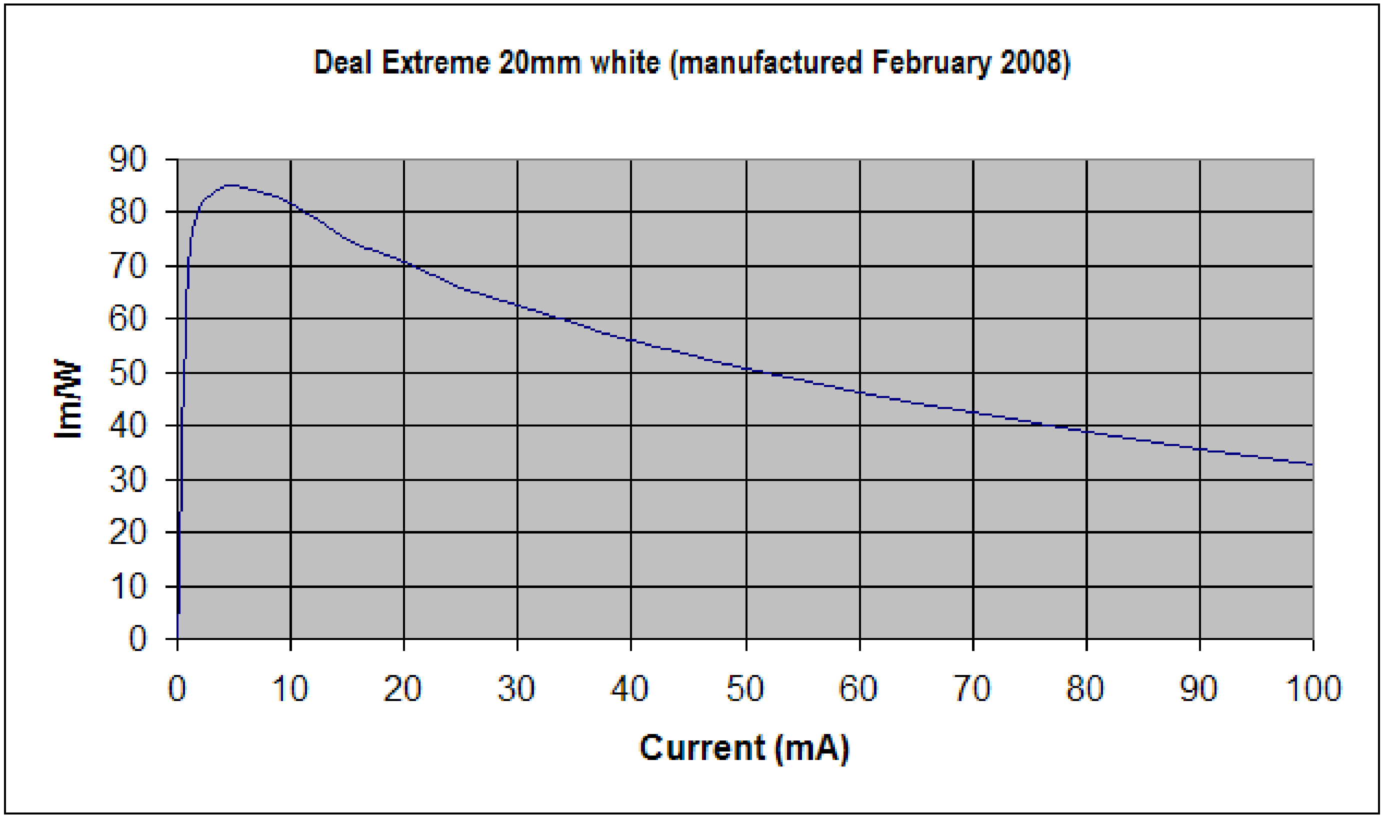

Hebei 530MW7C white (manufactured June 2007)
lm/W
0
10
20
30
40
50
60
70
80
90
0
10
20
30
40
50
60
70
80
Current (mA)

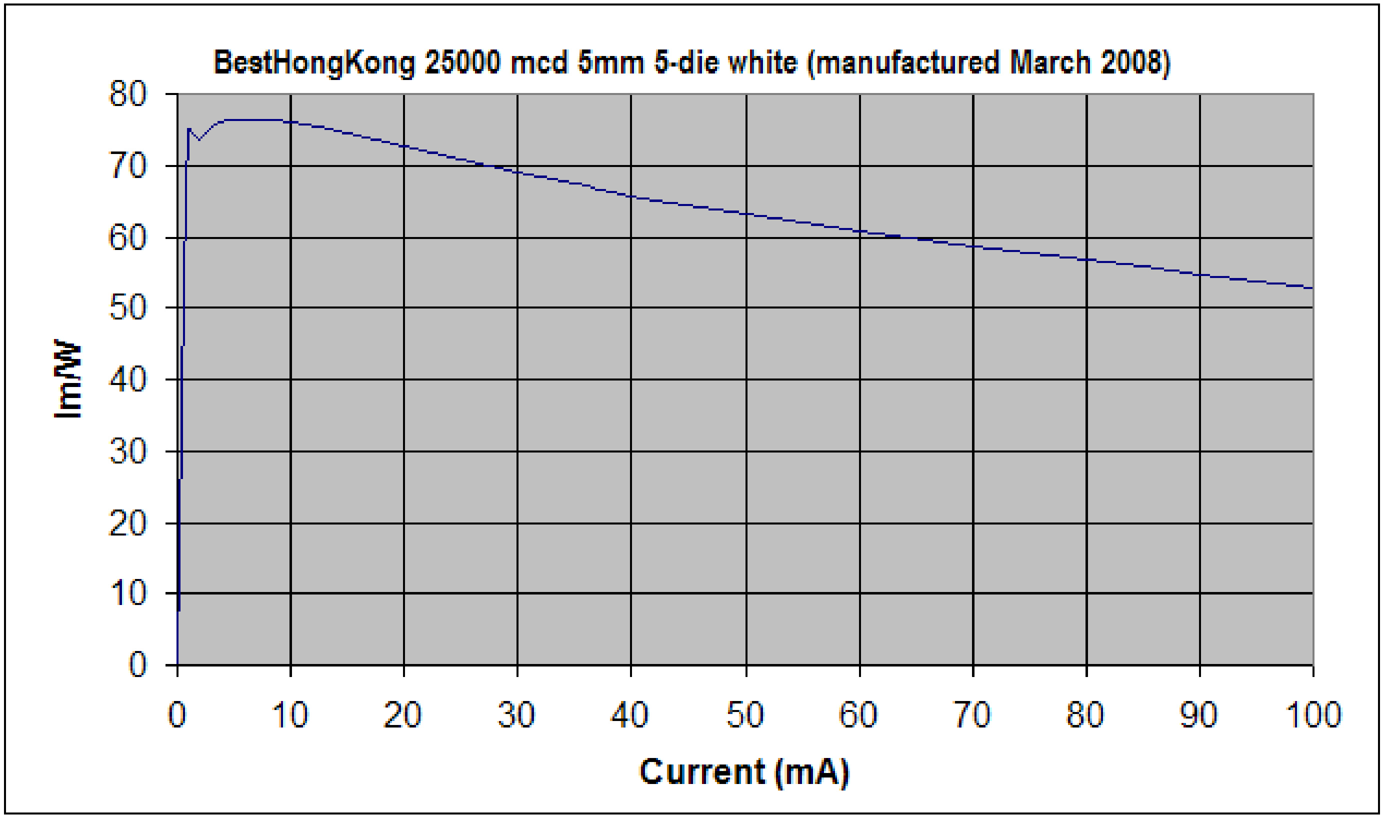

Hebei 550MW7C white (manufactured June 2007)
lm/W
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
Current (mA)

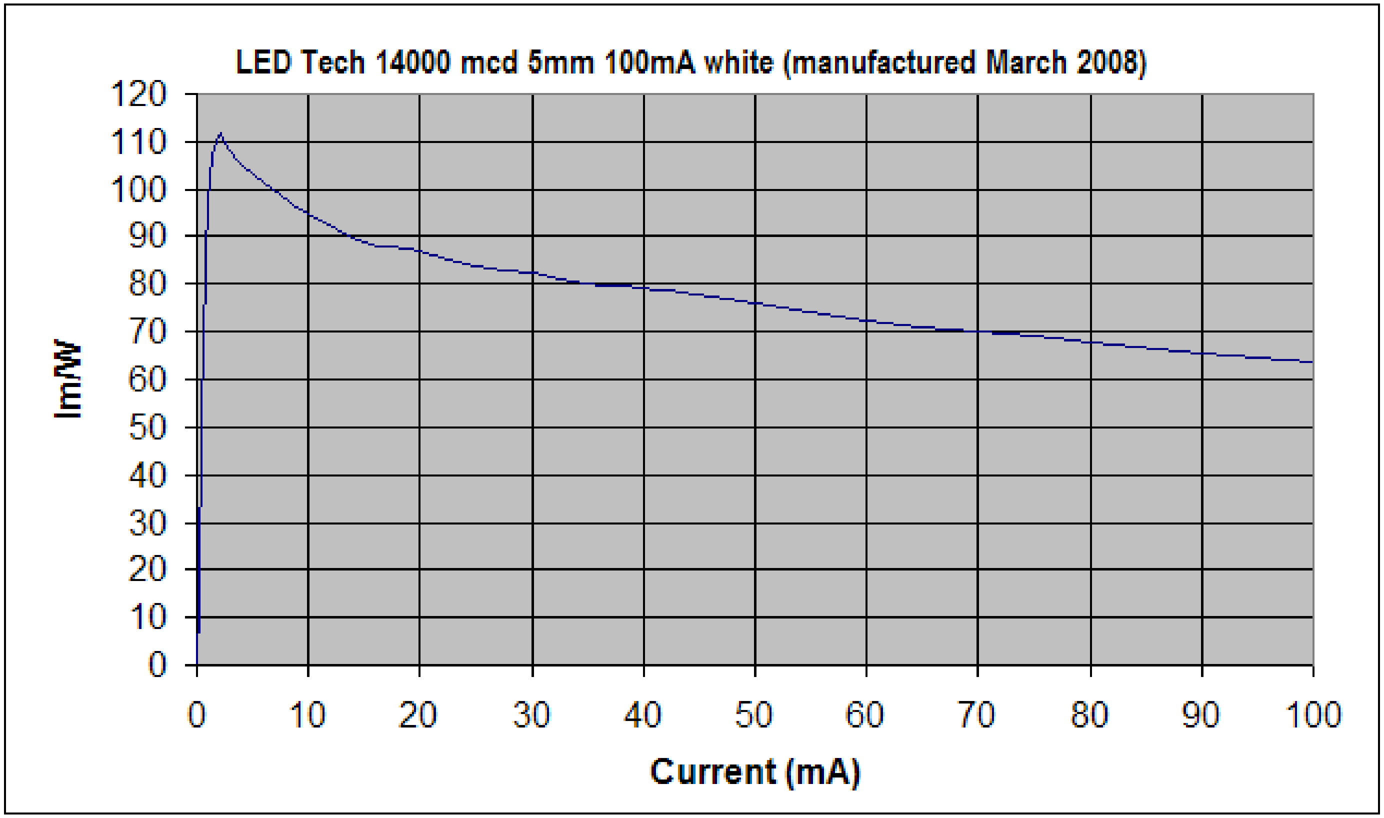

Jeled 210000 mcd 10mm 5-die warm white (manufactured December 2007)
lm/W
0
10
20
30
40
50
0
10
20
30
40
50
60
70
80
90
100
Current (mA)

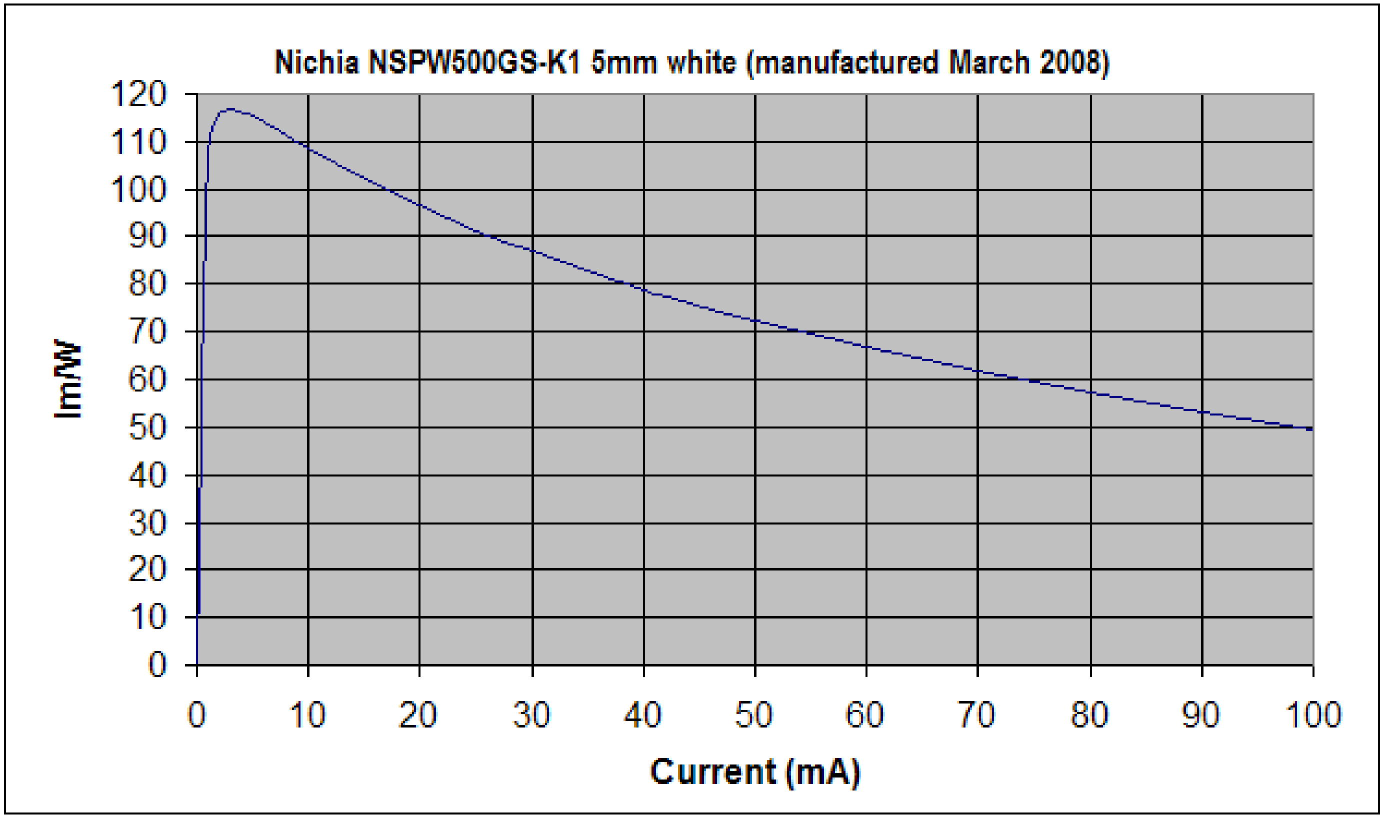

Jeled 255000 mcd 10mm 5-die white (manufactured December 2007)
lm/W
0
10
20
30
40
50
60
70
0
10
20
30
40
50
60
70
80
90
100
Current (mA)

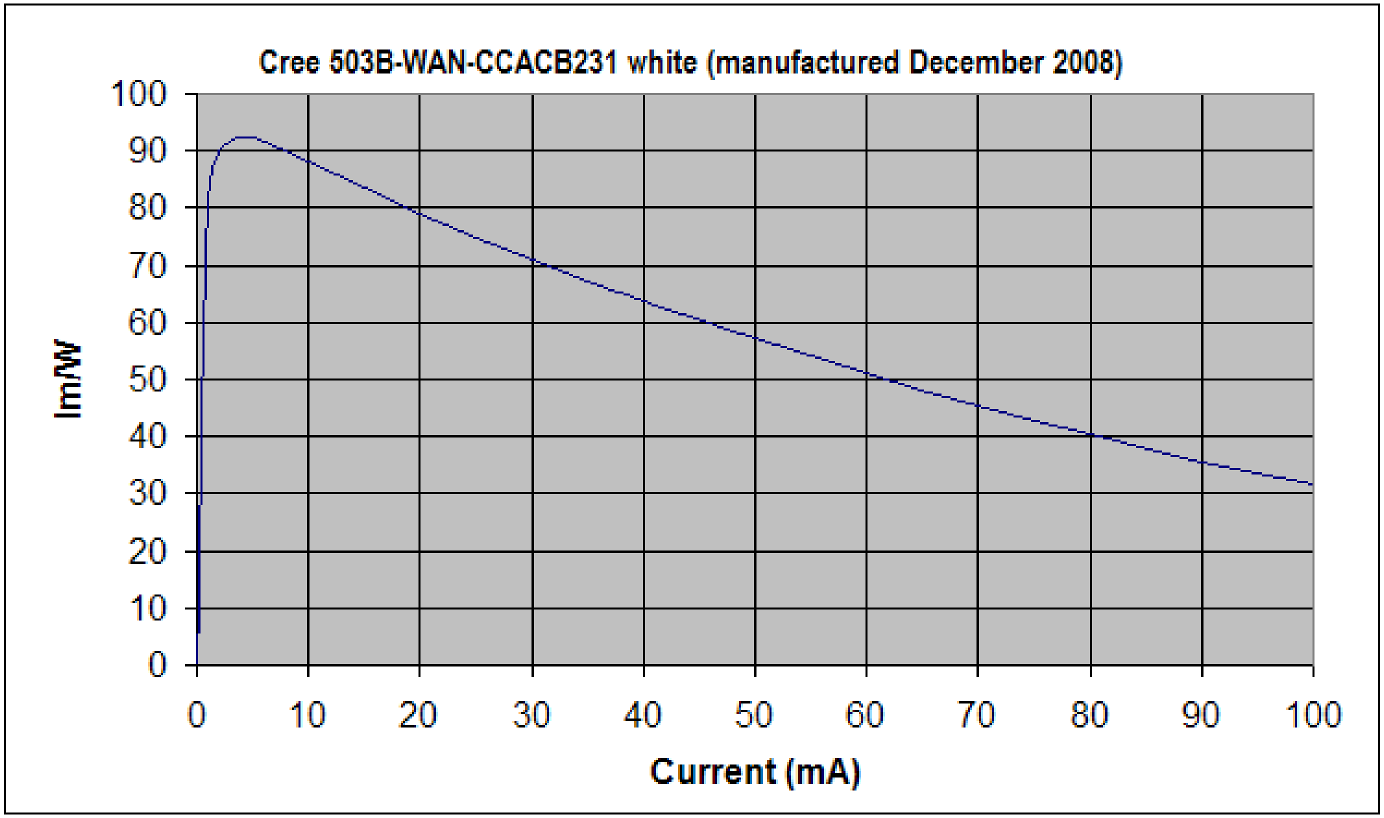

Oatley Electronics 80000 mcd 10mm white (manufactured December 2007)
lm/W
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Current (mA)

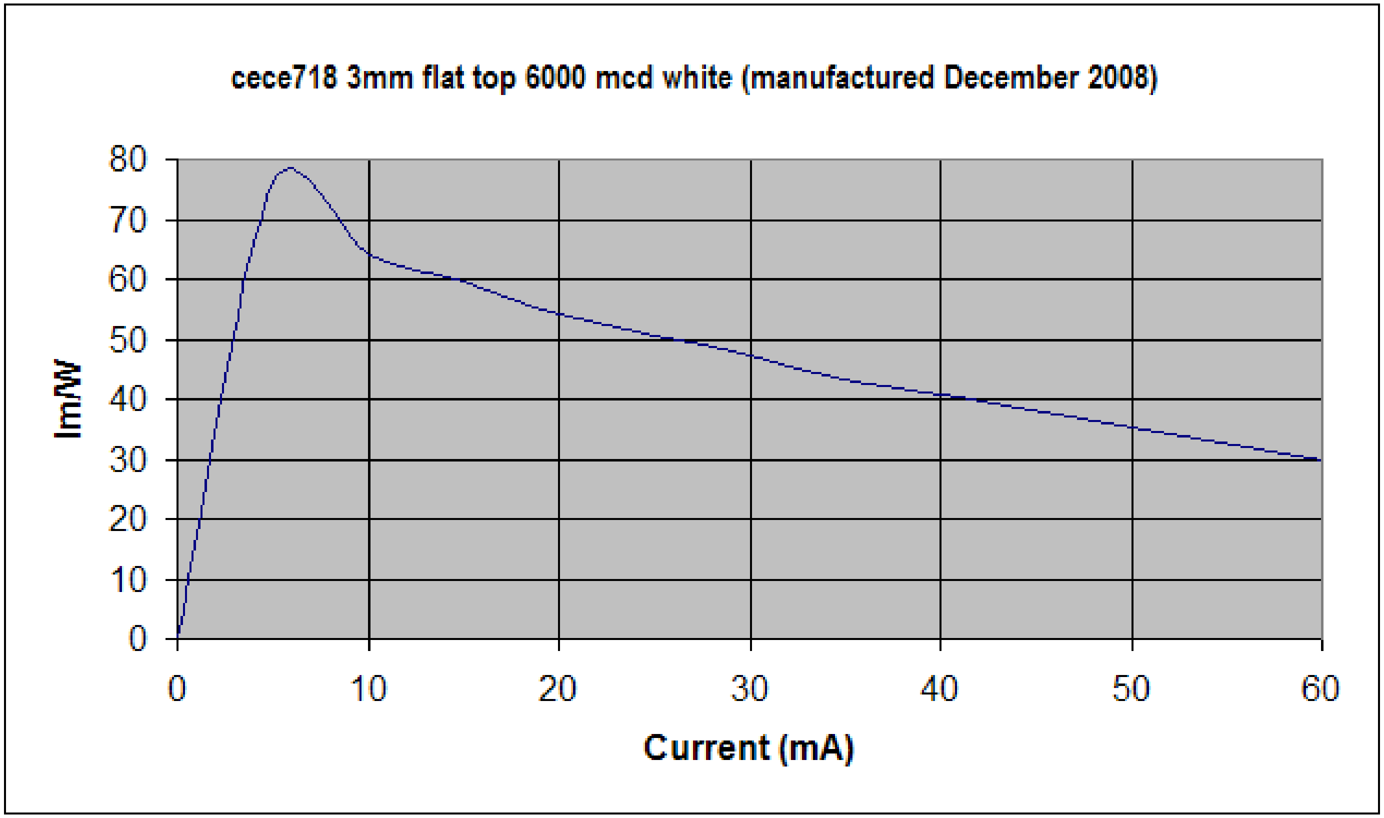

Deal Extreme 20mm white (manufactured February 2008)
lm/W
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Current (mA)

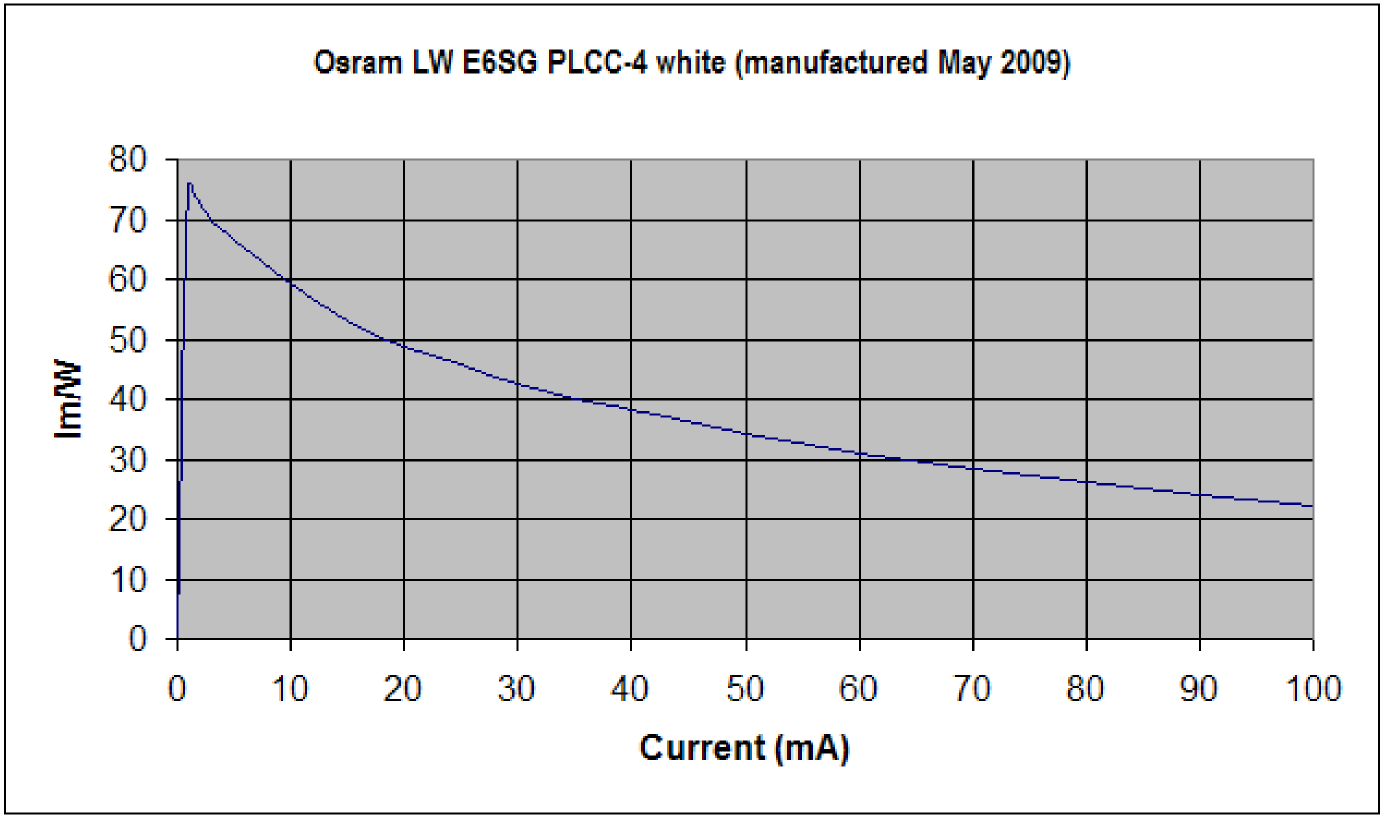

BestHongKong 25000 mcd 5mm 5-die white (manufactured March 2008)
lm/W
0
10
20
30
40
50
60
70
80
0
10
20
30
40
50
60
70
80
90
100
Current (mA)


LED Tech 14000 mcd 5mm 100mA white (manufactured March 2008)
lm/W
0
10
20
30
40
50
60
70
80
90
100
110
120
0
10
20
30
40
50
60
70
80
90
100
Current (mA)

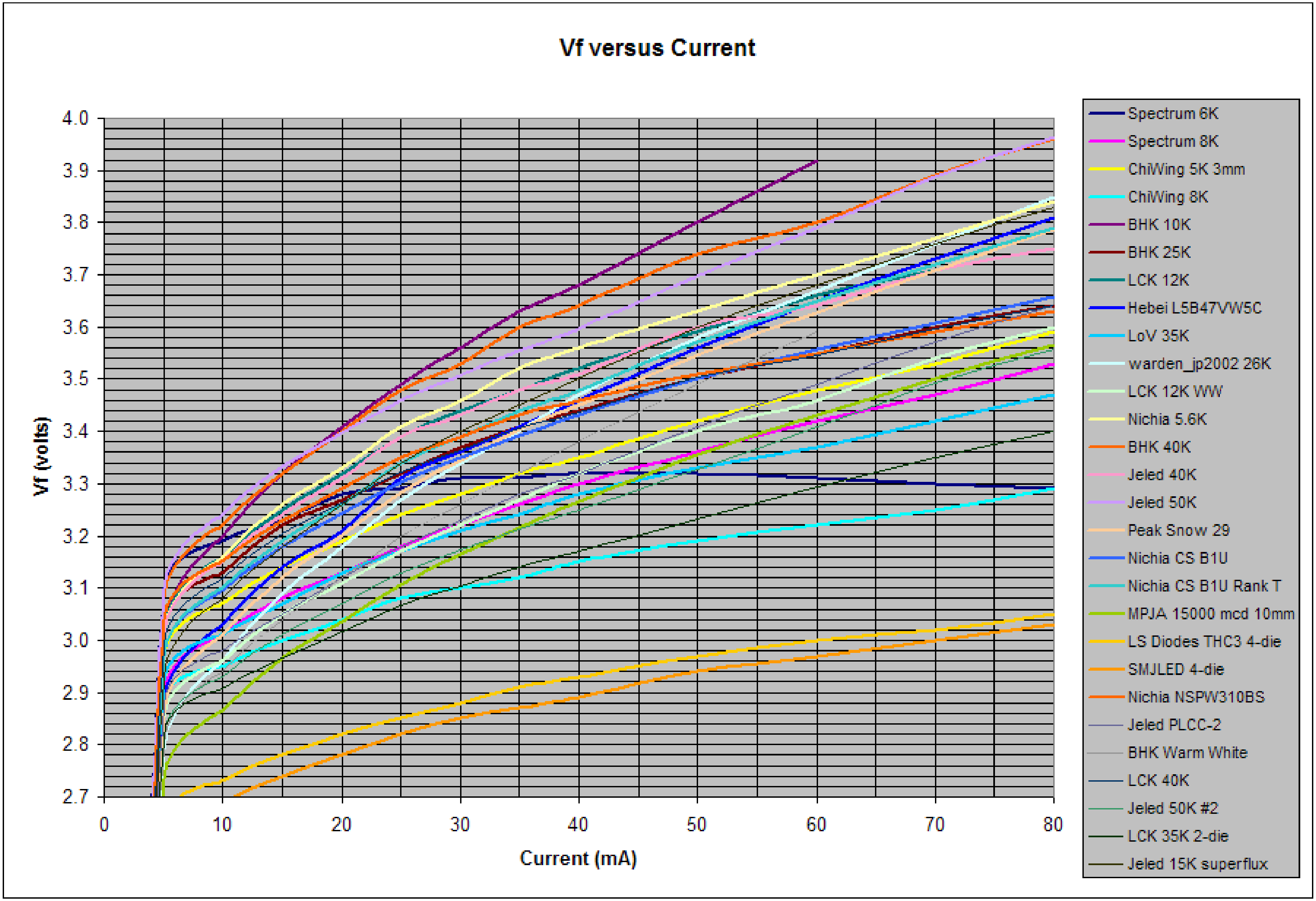

Nichia NSPW500GS-K1 5mm white (manufactured March 2008)
lm/W
120
110
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Current (mA)

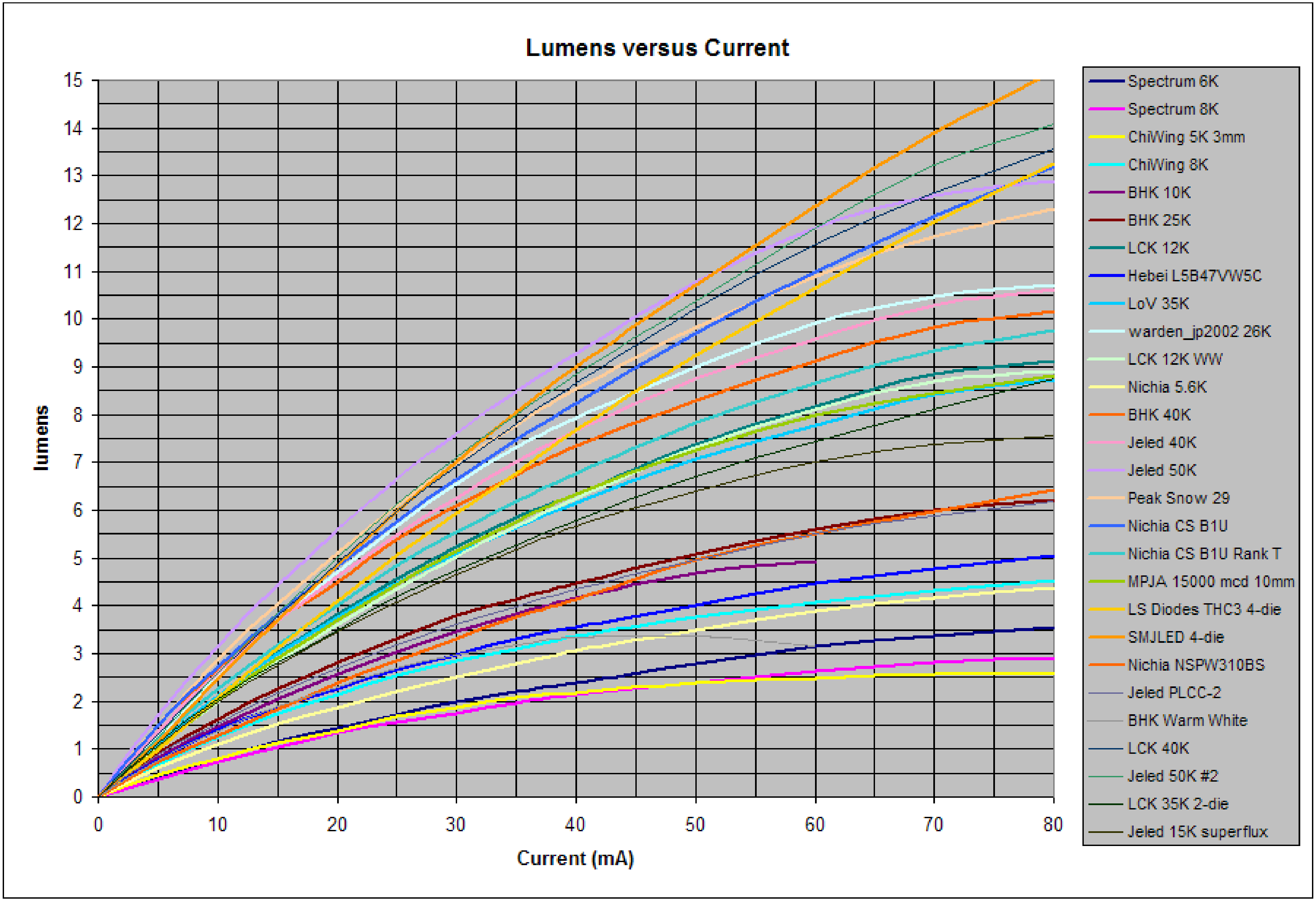

Cree 503B-WAN-CCACB231 white (manufactured December 2008)
lm/W
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Current (mA)

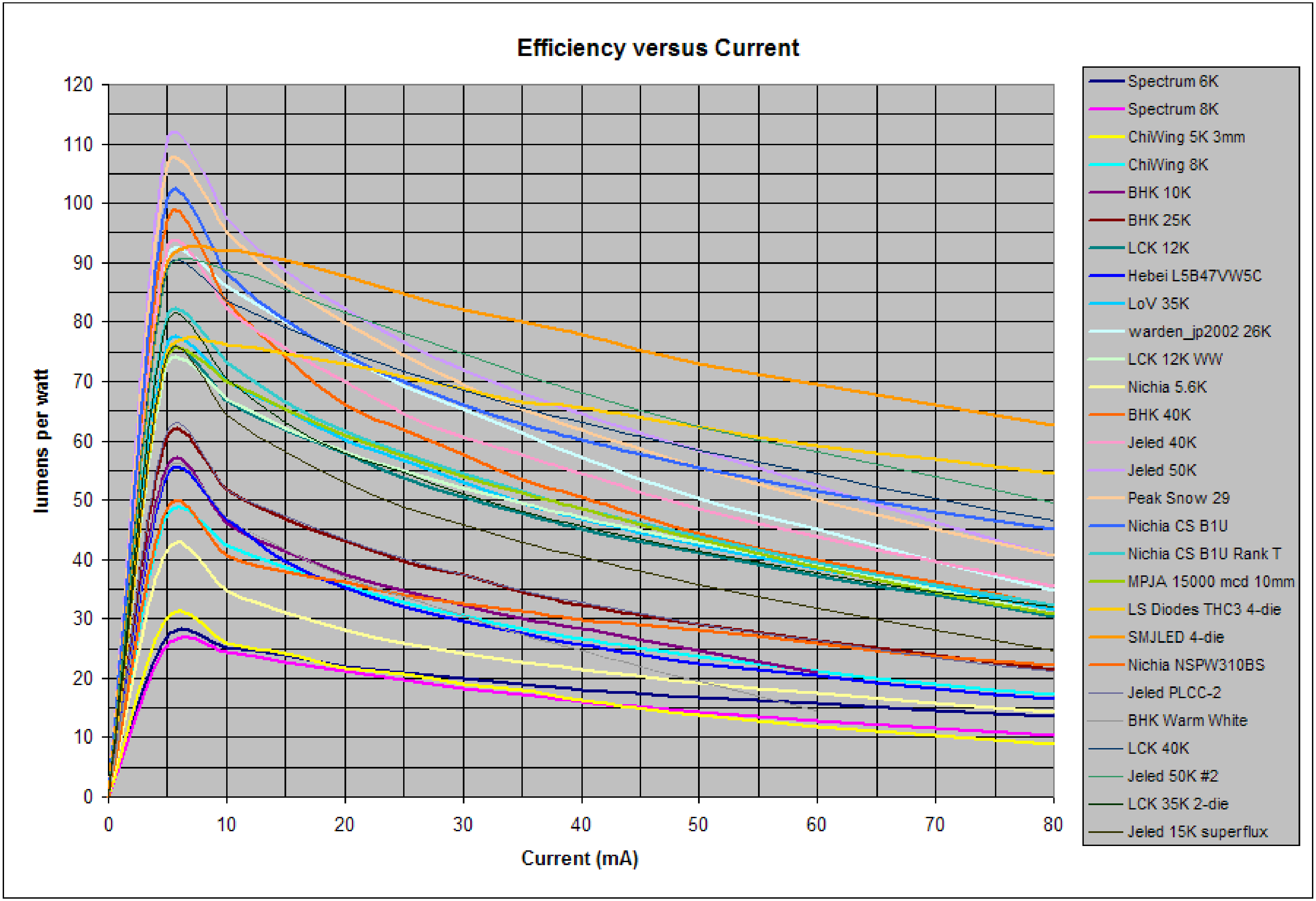

cece718 3mm flat top 6000 mcd white (manufactured December 2008)
lm/W
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
Current (mA)

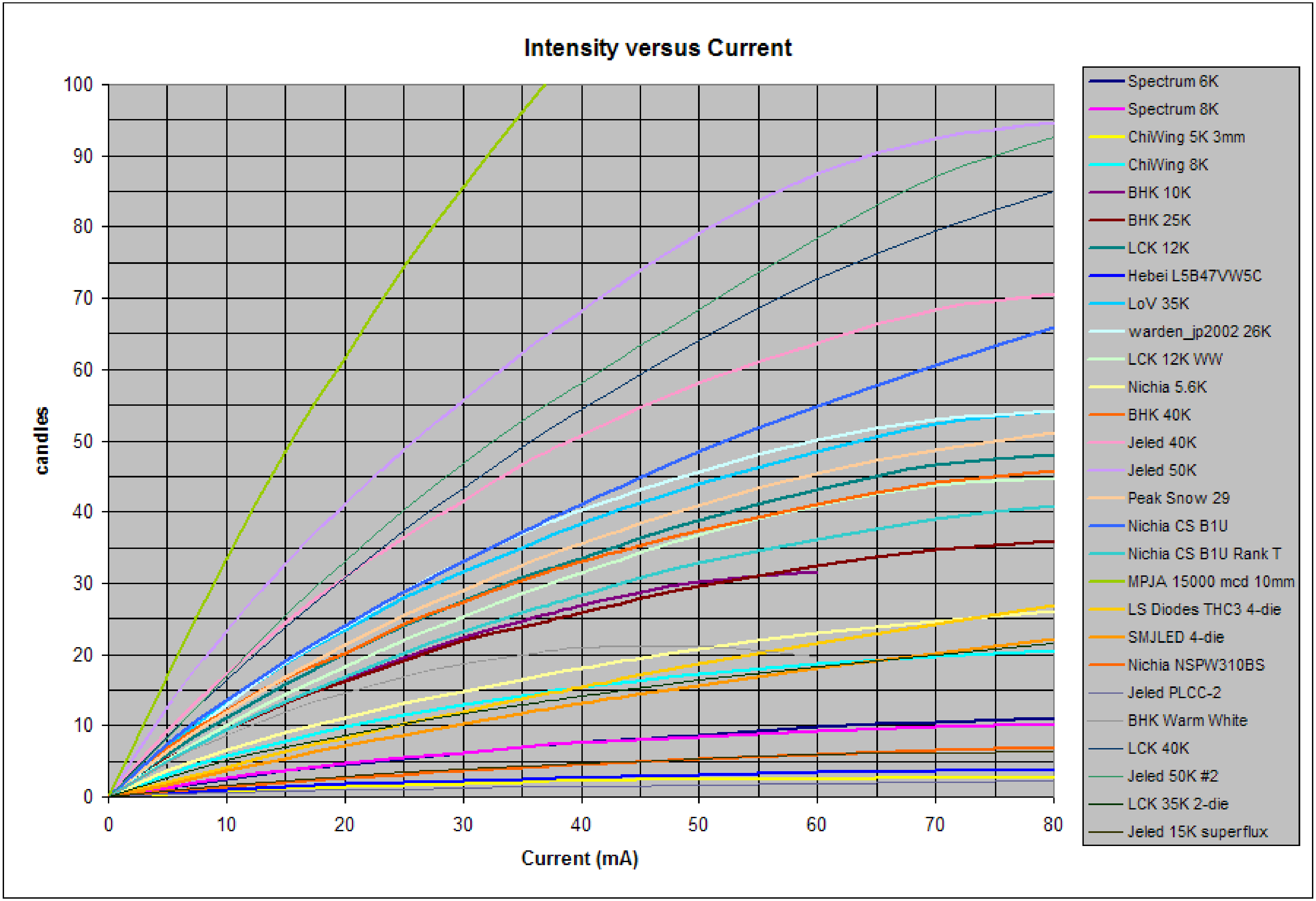


[/SIZE]
Here is a series of head-to-head comparisons of all the LEDs for a number of different parameters:


Vf versus Current
Vf (volts)
4.0
3.9
3.8
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3.0
2.9
2.8
2.7
0
10
20
30
40
50
60
70
80
Current (mA)
Spectrum 6K
Spectrum 8K
ChiWing 5K 3mm
ChiWing 8K
BHK 10K
BHK 25K
LCK 12K
Hebei L5B47VW5C
LoV 35K
warden_jp2002 26K
LCK 12K WW
Nichia 5.6K
BHK 40K
Jeled 40K
Jeled 50K
Peak Snow 29
Nichia CS B1U
Nichia CS B1U Rank T
MPJA 15000 mcd 10mm
LS Diodes THC3 4-die
SMJLED 4-die
Nichia NSPW310BS
Jeled PLCC-2
BHK Warm White
LCK 40K
Jeled 50K #2
LCK 35K 2-die
Jeled 15K superflux


Lumens versus Current
lumens
Current (mA)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
0
10
20
30
40
50
60
70
80
Spectrum 6K
Spectrum 8K
ChiWing 5K 3mm
ChiWing 8K
BHK 10K
BHK 25K
LCK 12K
Hebei L5B47VW5C
LoV 35K
warden_jp2002 26K
LCK 12K WW
Nichia 5.6K
BHK 40K
Jeled 40K
Jeled 50K
Peak Snow 29
Nichia CS B1U
Nichia CS B1U Rank T
MPJA 15000 mcd 10mm
LS Diodes THC3 4-die
SMJLED 4-die
Nichia NSPW310BS
Jeled PLCC-2
BHK Warm White
LCK 40K
Jeled 50K #2
LCK 35K 2-die
Jeled 15K superflux


Efficiency versus Current
lumens per watt
120
110
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
Current (mA)
Spectrum 6K
Spectrum 8K
ChiWing 5K 3mm
ChiWing 8K
BHK 10K
BHK 25K
LCK 12K
Hebei L5B47VW5C
LoV 35K
warden_jp2002 26K
LCK 12K WW
Nichia 5.6K
BHK 40K
Jeled 40K
Jeled 50K
Peak Snow 29
Nichia CS B1U
Nichia CS B1U Rank T
MPJA 15000 mcd 10mm
LS Diodes THC3 4-die
SMJLED 4-die
Nichia NSPW310BS
Jeled PLCC-2
BHK Warm White
LCK 40K
Jeled 50K #2
LCK 35K 2-die
Jeled 15K superflux



Note how there is more or less (with the exception of the SpectrumLEDs 8000 mcd white) a steady improvement in efficiency from 2003 until the present. Most of the LEDs clustered together in the efficiency graphs were purchased at roughly the same time.

Here is a chart summarizing the results at 20 mA test current:

LED	Beam angle	Vf (volts)	Intensity (mcd)	Output (lumens)	Efficiency (lm/W)	Date Tested	Date of Manufacture
Nichia 5600 mcd 5mm	13.9°	3.33	11100	1.87	28.1	July 2005	2001
Spectrum LEDs 6000 mcd 5mm	17.3°	3.28	4500	1.44	22.0	July 2005	May 2003
ChiWing 5000 mcd 3mm	32.6°	3.19	1400	1.38	21.7	July 2005	July 2003
ChiWing 8000 mcd 5mm	15.2°	3.04	9800	2.15	35.4	July 2005	July 2003
BestHongKong 10000 mcd 5mm	11.8°	3.41	16500	2.56	37.5	July 2005	February 2004
Spectrum LEDs 8000 mcd 5mm	16.0°	3.13	4700	1.33	21.3	July 2005	November 2004
wardenjp_2002 26000 mcd 5mm	16.0°	3.18	23900	4.72	74.2	July 2005	February 2005
Hebei L5B47VW5C 60° 5mm	61.3°	3.21	1750	2.26	35.2	July 2005	March 2005
LCK 12000 mcd 5mm	13.3°	3.32	20200	3.84	57.8	July 2005	July 2005
BestHongKong 25000 mcd 5mm UWLC series	14.5°	3.27	16300	2.81	43.0	July 2005	July 2005
Light of Victory 35000 mcd 5mm	13.7°	3.13	23400	3.76	60.1	July 2005	July 2005
LCK warm white 12000 mcd 5mm	15.5°	3.11	18200	3.61	58.1	July 2005	July 2005
Jeled 40000 mcd 5mm	13.2°	3.31	30800	4.64	70.0	December 2005	December 2005
BestHongKong 40000 mcd 5mm	16.9°	3.40	20200	4.50	66.1	January 2006	January 2006
Jeled 50000 mcd 5mm	12.8°	3.40	41100	5.59	82.3	January 2006	January 2006
Peak Snow 29 5mm	16.7°	3.20	21300	5.11	79.8	February 2006	February 2006
Nichia CS bin B1U 5mm	16.2°	3.24	24100	4.83	74.5	February 2006	February 2006
MPJA 15000 mcd 10mm	8.4°	3.04	61700	3.69	60.9	July 2006	February 2005
unknown 26000 mcd 5mm	17.2°	3.26	16800	4.02	61.6	July 2006	November 2005
LS Diodes THC3 quad-die 5mm	27.4°	2.82	8300	4.11	72.8	July 2006	July 2006
SMJLED quad-die 5mm	31.6°	2.78	7100	4.88	87.8	July 2006	June 2006
Nichia NSPW310BS-E 60° 3mm	50.9°	3.29	2600	2.38	36.2	August 2006	August 2006
Jeled PLCC-2 white	112.0°	3.12	950	2.71	43.4	August 2006	August 2006
BestHongKong 5mm warm white	11.9°	3.12	14500	2.31	37.4	December 2006	June 2006
LCK 40000 mcd 5mm	15.1°	3.26	30800	4.91	75.2	January 2007	December 2006
Jeled 50000 mcd 5mm (test 2)	13.5°	3.07	33000	5.01	81.5	January 2007	December 2006
LCK 35000 mcd 2-die 5mm	21.3°	3.02	8600	3.50	58.0	January 2007	December 2006
Jeled 15000 mcd superflux	60.6°	3.26	2900	3.46	53.1	January 2007	December 2006
LS Diodes THC3 quad-die 5mm (new)	29.4°	2.88	6400	3.77	65.5	February 2007	January 2007
Quickar 5m100w quad-die 5mm	33.9°	2.77	5600	3.50	63.2	February 2007	February 2007
LVEHK 10000 mcd 3mm	29.7°	3.22	3200	1.67	25.9	February 2007	January 2007
Spectrum LEDs 2000 mcd 4.8mm	105.6°	3.22	1800	5.10	79.2	February 2007	January 2007
SuperbrightLEDs 18000 mcd 15° 5mm	15.3°	3.02	24030	3.99	66.0	February 2007	January 2007
SuperbrightLEDs 18000 mcd 30° 5mm	19.2°	3.14	12870	3.19	50.7	February 2007	January 2007
BestHongKong 35000 mcd 5mm	14.7°	3.44	29200	4.53	65.8	February 2007	January 2007
LVEHK 55000 mcd 5mm	14.0°	3.23	28900	4.15	64.1	February 2007	January 2007
LVEHK 65000 mcd 8mm	31.1°	3.55	6500	3.06	43.2	February 2007	January 2007
LVEHK 140000 mcd 10mm	7.5°	3.29	61030	4.44	67.6	February 2007	January 2007
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

BestHongKong 135000 mcd 10mm	6.7°	3.23	146700	5.14	79.6	February 2007	January 2007
SuperbrightLEDs 7500 mcd superflux	72.0°	3.04	2600	3.83	63.0	February 2007	January 2007
Nichia NFSW036L bin T	51.3°	2.72	3340	4.02	73.9	February 2007	January 2007
SuperbrightLEDs RL5-W45-360	360.0°	3.16	280	4.18	66.2	February 2007	January 2007
SuperbrightLEDs RL8-W110-360	360.0°	2.85	280	4.48	78.6	February 2007	January 2007
ISP 22000 mcd 25° 5mm	25.7°	2.94	6700	3.37	57.3	March 2007	February 2007
LCK 55000 mcd 5mm	10.6°	3.17	27570	3.79	59.8	March 2007	February 2007
Jeled 55000 mcd 5mm	14.1°	3.05	33800	5.11	83.9	March 2007	February 2007
Hebei 520MW7C 20° 5mm	19.3°	3.06	15200	3.98	65.1	June 2007	September 2007
Hebei 530MW7C 30° 5mm	22.1°	3.01	11900	3.55	58.9	June 2007	September 2007
Hebei 550MW7C 50° 5mm	47.9°	3.12	4830	4.14	66.5	June 2007	September 2007
Deal Extreme 20mm	39.1°	2.99	6600	4.23	70.7	March 2008	February 2008
Jeled 210000 mcd warm white 10mm	26.7°	2.88	5400	2.20	38.1	March 2008	December 2007
Jeled 255000 mcd 10mm	24.2°	2.87	10030	3.48	60.6	March 2008	December 2007
Oatley Electronics 80000 mcd 10mm	38.8°	2.94	6300	4.26	72.4	March 2008	December 2007
BestHongKong 25000 mcd 5-die 5mm	34.7°	2.80	6470	4.07	72.8	April 2008	March 2008
LED Tech 14000 mcd 100 mA 5mm	77.1°	2.95	2930	5.12	86.8	April 2008	March 2008
Nichia NSPW500GS-K1	13.4°	3.18	38330	6.15	96.7	April 2008	March 2008
Cree 503B-WAN-CCACB231	15.9°	3.11	26170	4.93	79.2	January 2009	January 2009
cece718 6000 mcdflat top 3mm	129.0°	3.22	800	3.49	54.1	December 2008	January 2009
Osram LW E6SG PLCC-4	119.0°	3.23	1010	3.15	48.8	May 2009	July 2009

As to the accuracy of my results, for a sanity check the Light of Victory 35,000 mcd seem a close match to the Nichia CS in terms of intensity and lumens, and the Nichias are supposed to have efficiencies in the 60 lm/W area at 20 mA. This is exactly where the Light of Victory 35,000 mcd falls. The warden_jp2002 actually is around 74 lm/W at 20 mA. I'm guessing someone got a supply a Cree's XT-24 chips for those. Nothing else could give efficiencies that high. Also note how these same LEDs break 90 lm/W at 5 mA. (Nothing thus far has beat these LEDs, which were available for a fairly short time on eBay.) - Note: *The warden_jp2002 LEDs were finally beaten by the Jeled 50000 mcd ones, but they held the record for nearly a year.*

Update 04/10/2008: The Nichia NSPW500GS-K1 takes the crown now at 96.7 lm/W-tantalizingly close to the magic 100 lm/W mark.

Last edited by jtr1962; 11-09-2009 at 11:41 AM.

Quote

jtr1962

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#2

08-07-2005, 10:43 AM

chimo
Flashaholic*

Join Date: Sep 2004
Location: Ottawa, Canada
Posts: 2,257

Re: White LED lumen testing

---

jtr1962, great work! I d/l'd the zip file but I got errors in it. Could you check it out? I would like to compare you data to mine. Thanks,

Pual

Quote

chimo

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#**3**

08-07-2005, 10:51 AM

jtr1962
Flashaholic*

Join Date: Nov 2003
Location: Flushing, NY
Posts: 4,835

Re: White LED lumen testing

Yeah, were right about the error Paul. I fixed it so just download it again.

Quote

jtr1962

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#4

08-07-2005, 10:59 AM

chimo

Flashaholic*

Join Date: Sep 2004

Location: Ottawa, Canada

Posts: 2,257

Re: White LED lumen testing

Got the new copy. Thanks!

Paul

Quote

chimo

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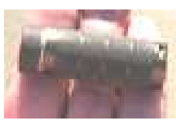
#5

08-07-2005, 11:24 AM



tvodrd

Flashaholic

CPF Diamond Supporter

Join Date: Dec 2002

Location: Hawthorne, NV

Posts: 5,874

Re: White LED lumen testing

Wow! [img]/ubbthreads/images/graemlins/thumbsup.gif[/img] and thanks!

Larry

Quote

tvodrd

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#6

08-07-2005, 11:50 AM

evan9162

Flashaholic*

Join Date: Apr 2002

Location: Boise, ID

Posts: 2,714

Re: White LED lumen testing

How are you generating a lumens value from the set of lux measurements? Are you doing a series of spherical caps, and summing up the intensity/area for each cap to get a total lumen output?

I was thinking of doing this a while ago, but never got around to it - I wanted to see how accurate my lumens coefficient was, and how close the lumileds datasheet was in reagards to the beam pattern of a luxeon high done.

Quote

evan9162

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#7

08-07-2005, 12:08 PM

jtr1962

Flashaholic*

Join Date: Nov 2003

Location: Flushing, NY

Posts: 4,835

Re: White LED lumen testing

Yes evan9162, that's exactly how I'm doing it. For example, I take the relative lux readings for 0° and 5°, average them, multiply by the area in steradians, and then multiply by the intensity in candelas. After that, I'll do the same with the 5° and 10° values, etc, and add this to my running total. It's interesting that for narrow viewing angle (i.e. 15° or 20°) LEDs the traditional methods of calculating lumens in the main beam grossly underestimates the output. One can see why by examining the radiation pattern of one of these LEDs. Some light falls outside the main beam but this decreases in intensity rather quickly. Still, since the spherical area is larger as the angle increases, this spill still makes significant contributions to the output. After that you usually have a bright ring about 60° off axis. This shows up clearly in the graphs in my spreadsheets. While the intensity might only be 2% or 3% of the maximum intensity, it is spread over a large area and contributes a good 15% to 20% of the total output. Finally, a great deal of light actually makes it out the back because of reflection off the front lens. This could easily add another 10% to 15% to total output. I was honestly amazed by this myself although it makes sense. For example, using the usual way of figuring lumens, and assuming a 20° beam angle, I might have guestimated about 2.3 lumens for the Light of Victory 35,000 mcd LED based on it's peak intensity reading of ~24,000 mcd at 20 mA (the 35,000 mcd spec is at 30 mA according to the manufacturer). I usually multiplied this by 1.25 to account for spill outside the main beam, giving me a final estimate of 2.9 lumens. The actual measurements come out to 3.75 to 3.9 based on a few samples, or over 30% more. I guess I'll revise my adhoc mutliplier to about 1.65 to give a more realistic estimate.

I'll also add that since the dial is just screwed to the tester and easily removeable, I might make another one up complete with a heat sink and mounting area to test Luxeons, Lamina BL-2000s, and other power LEDs. My constant current source can supply up to 2 amps if need be. I can verify my methodology if I get lumen measurements in the mid 30s with my Q-bin Luxeons.

Quote

jtr1962

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#**8**

08-07-2005, 02:43 PM

PeterB

Flashaholic*

Join Date: May 2003

Location: Germany

Posts: 623

Re: White LED lumen testing

Great data collection!
And the warden_jp2002 data fits quite well to my old measurements with a completely different method (I had also these warden LEDs).

Lumen vs. current and Power

Quote

PeterB

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#9

08-07-2005, 04:15 PM

evan9162
Flashaholic*

Join Date: Apr 2002
Location: Boise, ID
Posts: 2,714

Re: White LED lumen testing

---

jtr,

Sounds cool. I think I may finally do this myself someday. In another thread, I used the method, combined with the typical beam distribution from the luxeon data sheet to come up with a "Lumen coefficient". You would simply take a 0-degree lux measurement of a HD luxeon at 1m, and multiply by the coefficient to get a lumens estimate. I'm hoping to both a) verify that this coefficient is usable and b) see how well the beam distribution in the datasheet holds true.

Quote

evan9162

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#**10**

08-07-2005, 04:38 PM

jtr1962
Flashaholic*

Join Date: Nov 2003
Location: Flushing, NY
Posts: 4,835

Re: White LED lumen testing

I remember that thread, Peter. It looks like you're getting a little less output than I did because the light coming out the back of the LED didn't make it to the fraen lens. Still, it looks like we're reasonably close which makes me feel better. I did a double take after I entered the data for the warden LEDs. I was saying no way can they be this good but I guess they are.

Quote

jtr1962

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#**11**

08-07-2005, 06:52 PM

idleprocess's Avatar
idleprocess
Flashaholic*

Join Date: Feb 2004
Location: dfw.tx.us
Posts: 3,470

Re: White LED lumen testing

Nice!

I've often thought about doing something like that, but lack the math background (and mesurement apparatus) to do something like that.

The calculations in the LEDDB are rather lacking for accurate mcd * beam angle : lumens calculations.

I'll have to look over your spreadsheets. Most manufacturers include radiation patterns, so maybe I can borrow your work for more accurate numbers from spec sheets...

Quote

idleprocess

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#**12**

08-07-2005, 09:52 PM

NewBie
Retired

Join Date: Feb 2004
Location: Oregon- United States of America
Posts: 5,238

Re: White LED lumen testing

A fella should also consider de-rating the lumens due to heat produced in real life. Especially if using as a "calibration" source.

jtr1962- Have you thought about running a luxeon at 20/40/60mA to see where they fall?

Quote

NewBie

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#13

08-08-2005, 02:36 AM

idleprocess's Avatar idleprocess

Flashaholic*

Join Date: Feb 2004

Location: dfw.tx.us

Posts: 3,470

Re: White LED lumen testing

Hm. Looks like I'm going to have to take a different route - but at least I got off my butt and have a somewhat better understanding of optics.

So deviously simple-*(sounding)*!

1 lm == 1 cd / steridian

65.542173315° = 1.0000000000116693 sr *(got tired of monkeying with digits in the beam angle calulator here)*

4Pi steridians (sr) / sphere

Quote

idleprocess

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#14

08-08-2005, 10:16 PM

jtr1962

Flashaholic*

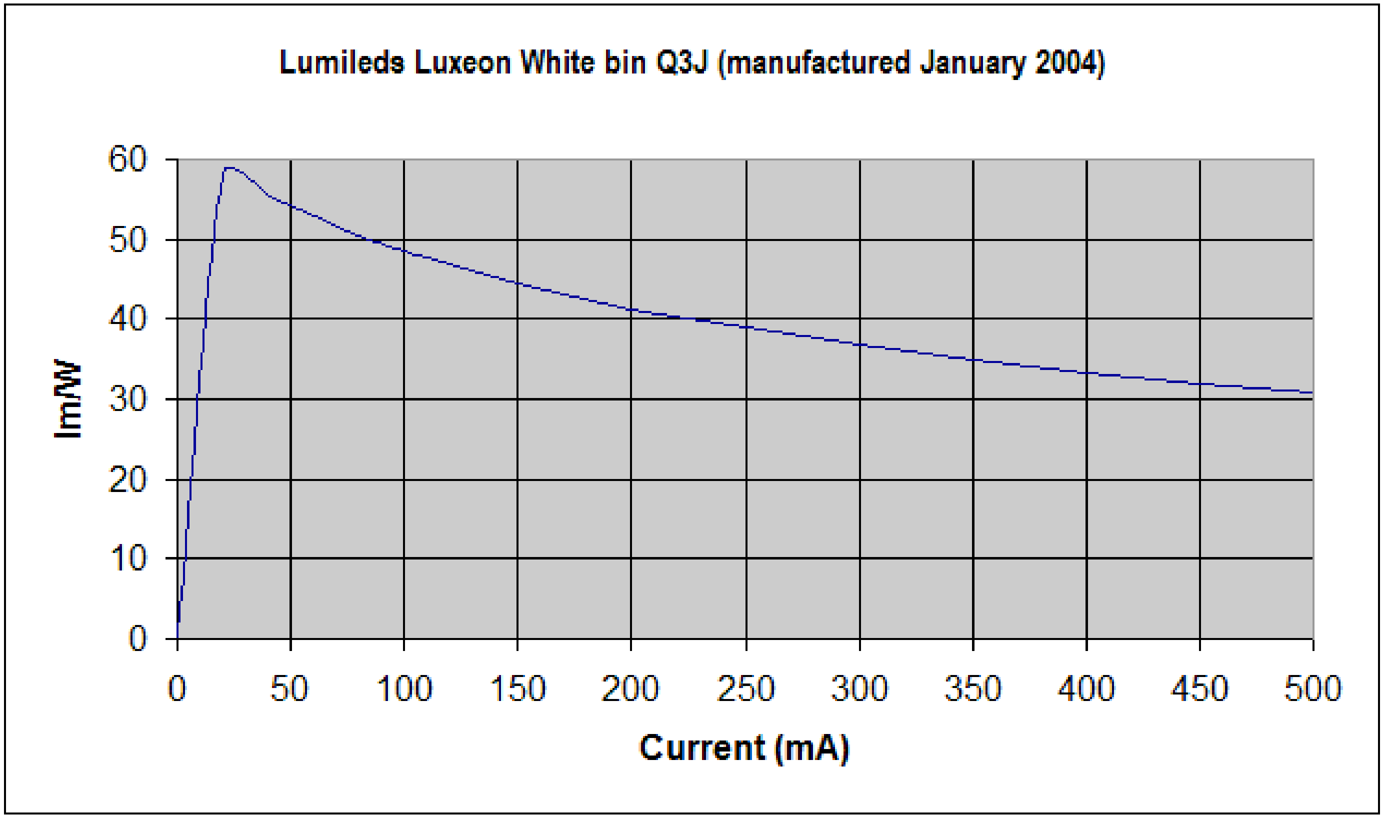
Join Date: Nov 2003

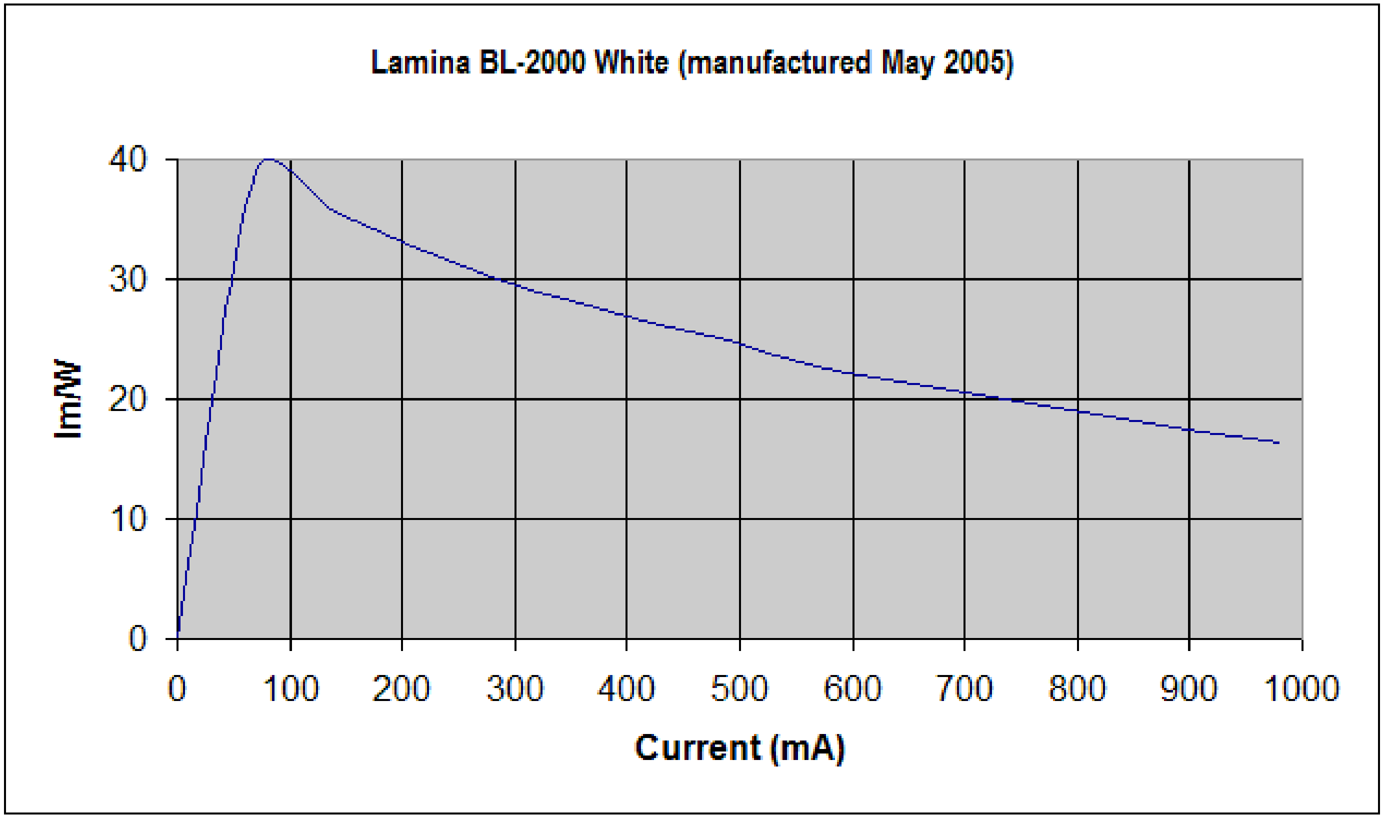
Location: Flushing, NY

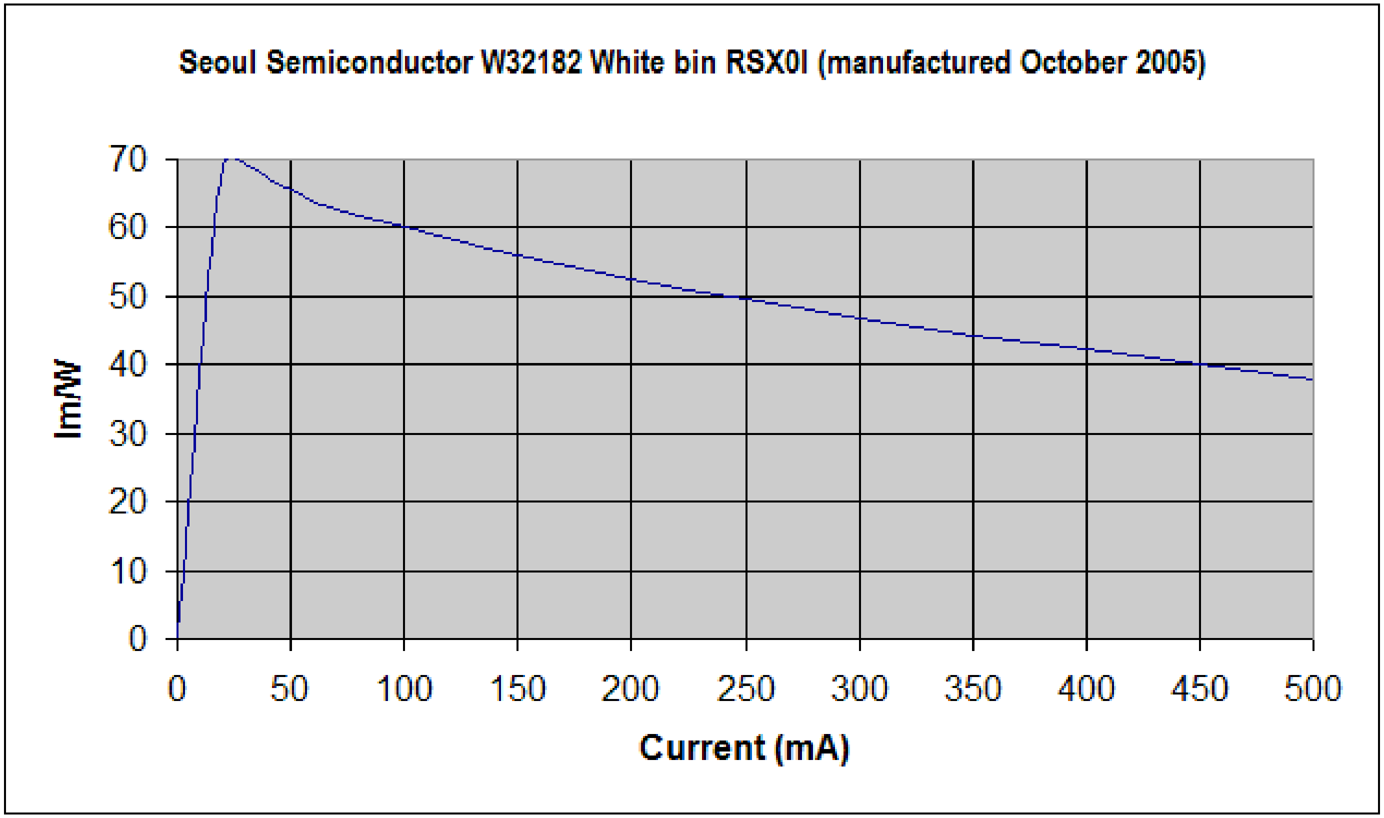
Posts: 4,835

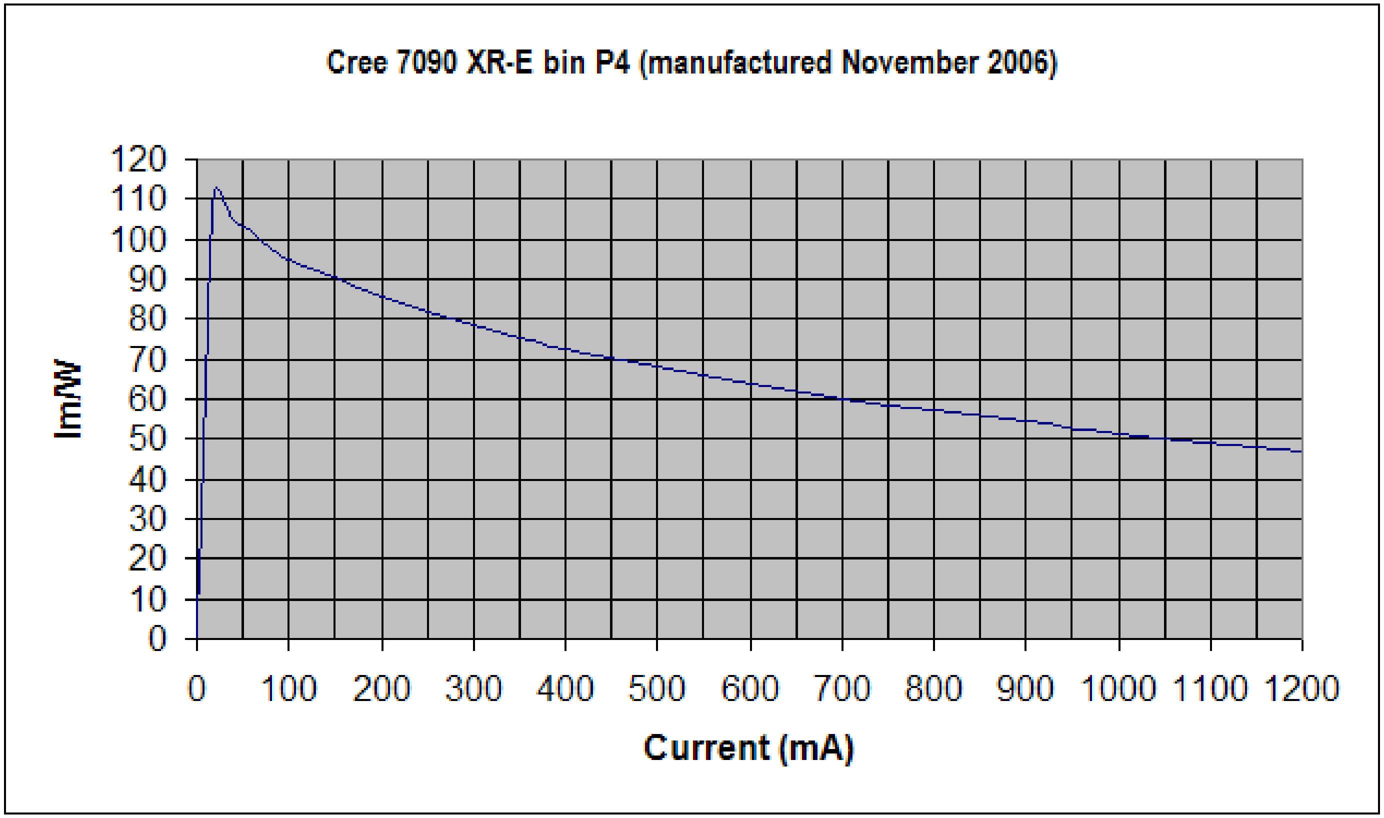
Re: White LED lumen testing

I made a jig for testing power LEDs. Here are my results for a Q3J Luxeon, a Lamina BL-2000, a Seoul Semiconductor W32182 bin RSX0I star, and a Cree 7090 XR-E bin P4:




Lamina BL-2000 White (manufactured May 2005)
lm/W
40
30
20
10
0
0
100
200
300
400
500
600
700
800
900
1000
Current (mA)


Seoul Semiconductor W32182 White bin RSX0I (manufactured October 2005)
lm/W
70
60
50
40
30
20
10
0
0
50
100
150
200
250
300
350
400
450
500
Current (mA)



Here are the relevant spreadsheets.

I have 5 Q bin Luxeons. Four of them seem about equal in brightness and the fifth is about 10% dimmer. Assuming then that the dim one is at the low end of the Q-bin (say 31 lumens), then the other ones should test in the mid 30s. My results give me 37.1 lumens, a little past the middle of the Q-bin. I think this more or less verifies the accuracy of my methods. At worst my results are less than 10% too high.

Last edited by jtr1962; 01-19-2009 at 05:12 AM.

Quote

jtr1962

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#**15**

08-09-2005, 04:19 AM

ViReN
Flashaholic*

Join Date: Apr 2004
Location: CPFReviews.com
Posts: 3,512

Re: White LED lumen testing

Wow .. Amazing Data [img]/ubbthreads/images/graemlins/smile.gif[/img] Thanks for doing the test jtr1962

Any Chance you will test the Nichia NSPW500CS ... C0 / A0 Tint, U Bins...

Also, It would be interesting to see the BS LED's too...

Quote

ViReN

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#**16**

08-09-2005, 08:09 AM

jtr1962
Flashaholic*

Join Date: Nov 2003
Location: Flushing, NY
Posts: 4,835

Re: White LED lumen testing

I'll probably get 5 of the Nichia CS to test from Grumpy's group buy if he has any more. Other than that I don't have any Nichias except possibly two really old ones from around 2001. I purchased them from Hosfelt Electronics but they have the tapered shape typical of Nichias. At the time they were rated at 5600 mcd, 20° viewing angle, which goes to show how old they are. Assuming a similar light distribution pattern to other 20° white LEDs I've tested so far I would imagine they would put out roughly 0.9 to 1.0 lumens at 20 mA, for an overall efficiency in the 15 lm/W area. Maybe I'll run a test on them just to verify my estimates.

If anyone wants to send me LEDs for testing PM me for my address and send a stamped, self-addressed envelope if you want the LEDs returned. For now I'm sticking to testing white LEDs. I've tested a few colored ones, but finding a true hotspot reading at 1 meter is somewhat difficult thanks to the splotchy beam patterns. Also, because of these beam patterns I'm not sure how accurate my methodology would be. Most white LEDs have a fairly even beam, making the results more valid.

Quote

jtr1962

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#**17**

08-09-2005, 03:57 PM

jtr1962

Flashaholic*

Join Date: Nov 2003

Location: Flushing, NY

Posts: 4,835

Re: White LED lumen testing

I added the LCK 12,000 mcd warm white, which arrived today, to my list in the first post and updated the graphs accordingly. You might need to refresh your browser to see the updated graphs.

Quote

jtr1962

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#**18**

08-12-2005, 11:27 AM

jtr1962
Flashaholic*

Join Date: Nov 2003
Location: Flushing, NY
Posts: 4,835

Re: White LED lumen testing

I added an old (c.2001) white LED, probably a Nichia, to the first post and updated the graphs. I also made the comparison charts easier to read by using heavier lines.

Quote

jtr1962

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#**19**

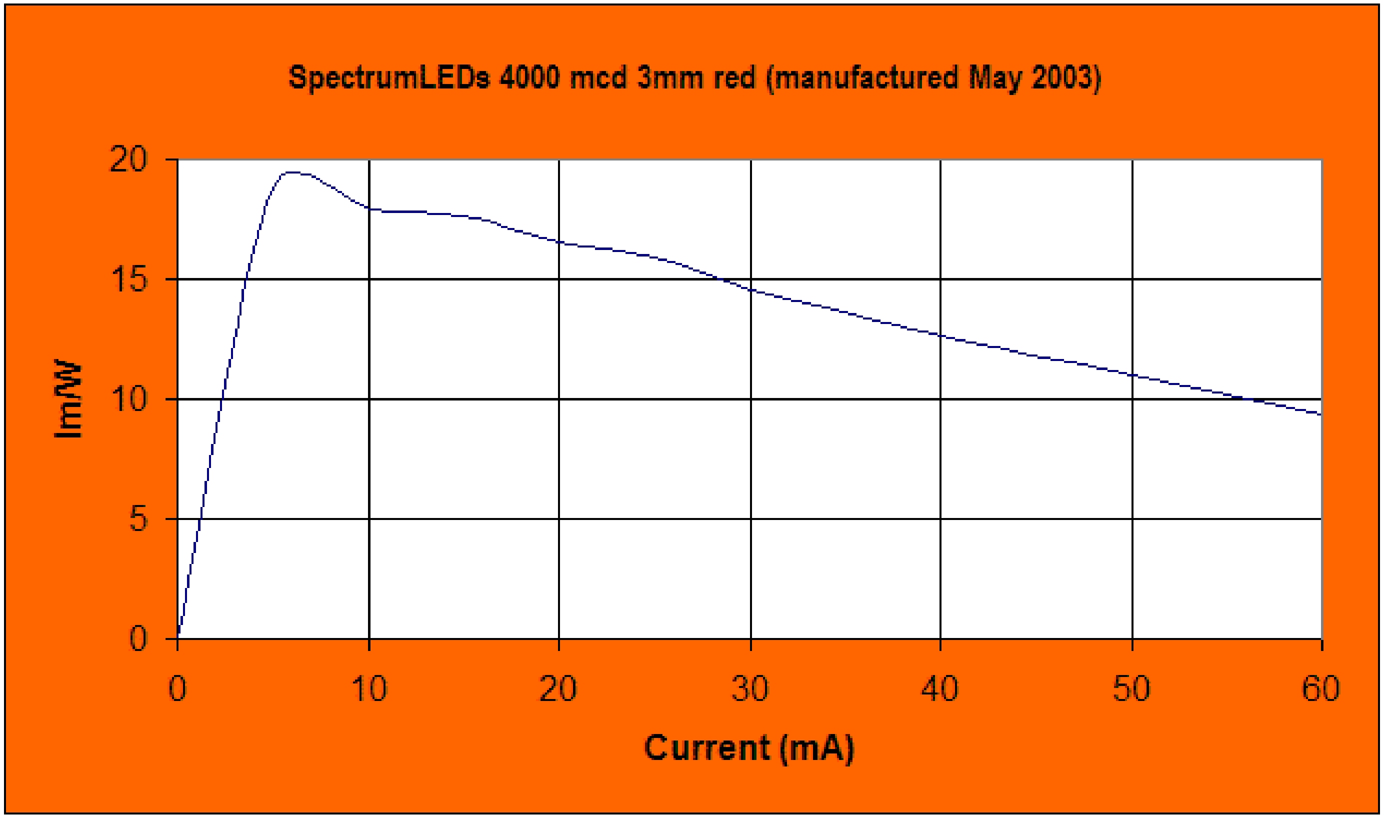
08-12-2005, 08:58 PM

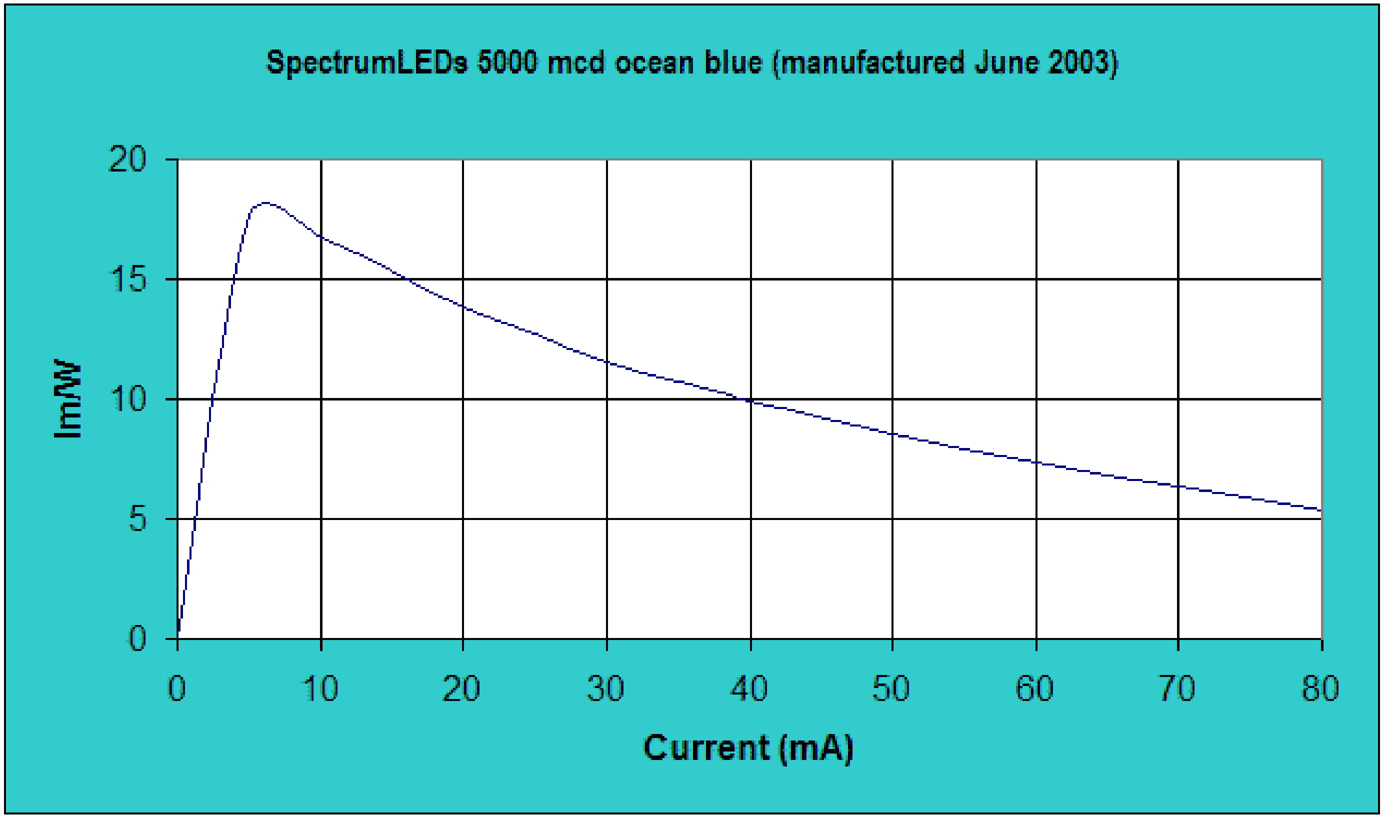
jtr1962
Flashaholic*

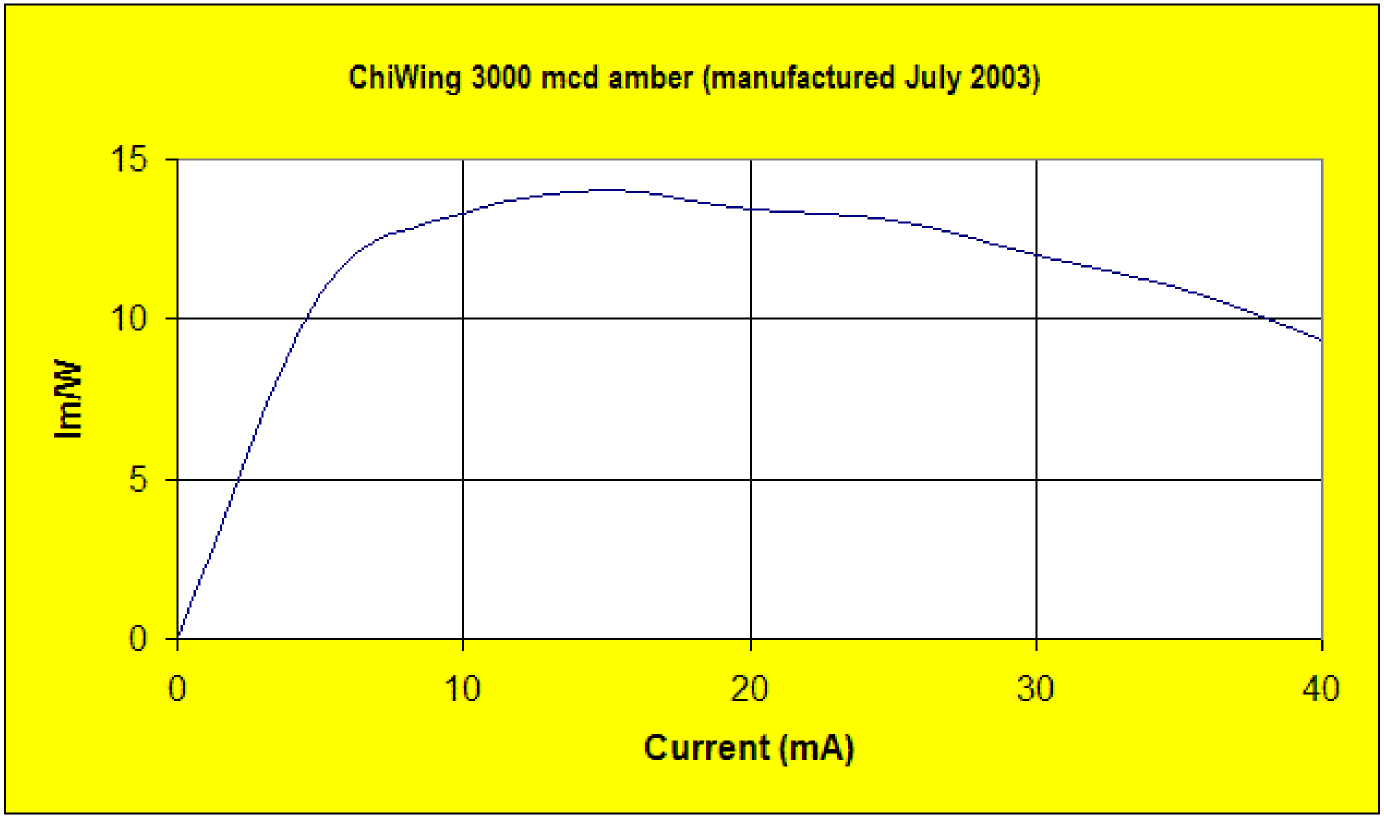
Join Date: Nov 2003
Location: Flushing, NY
Posts: 4,835

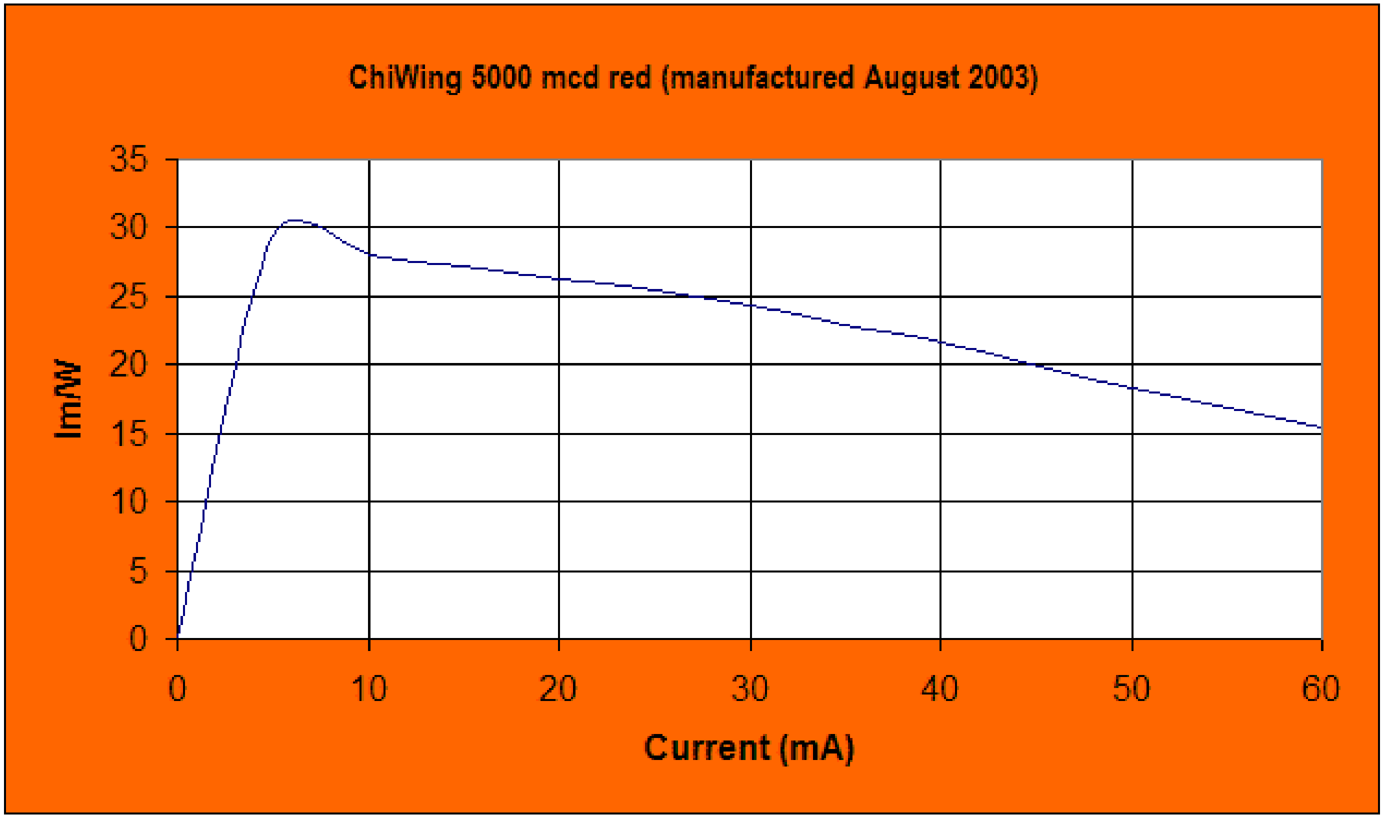
Re: White LED lumen testing

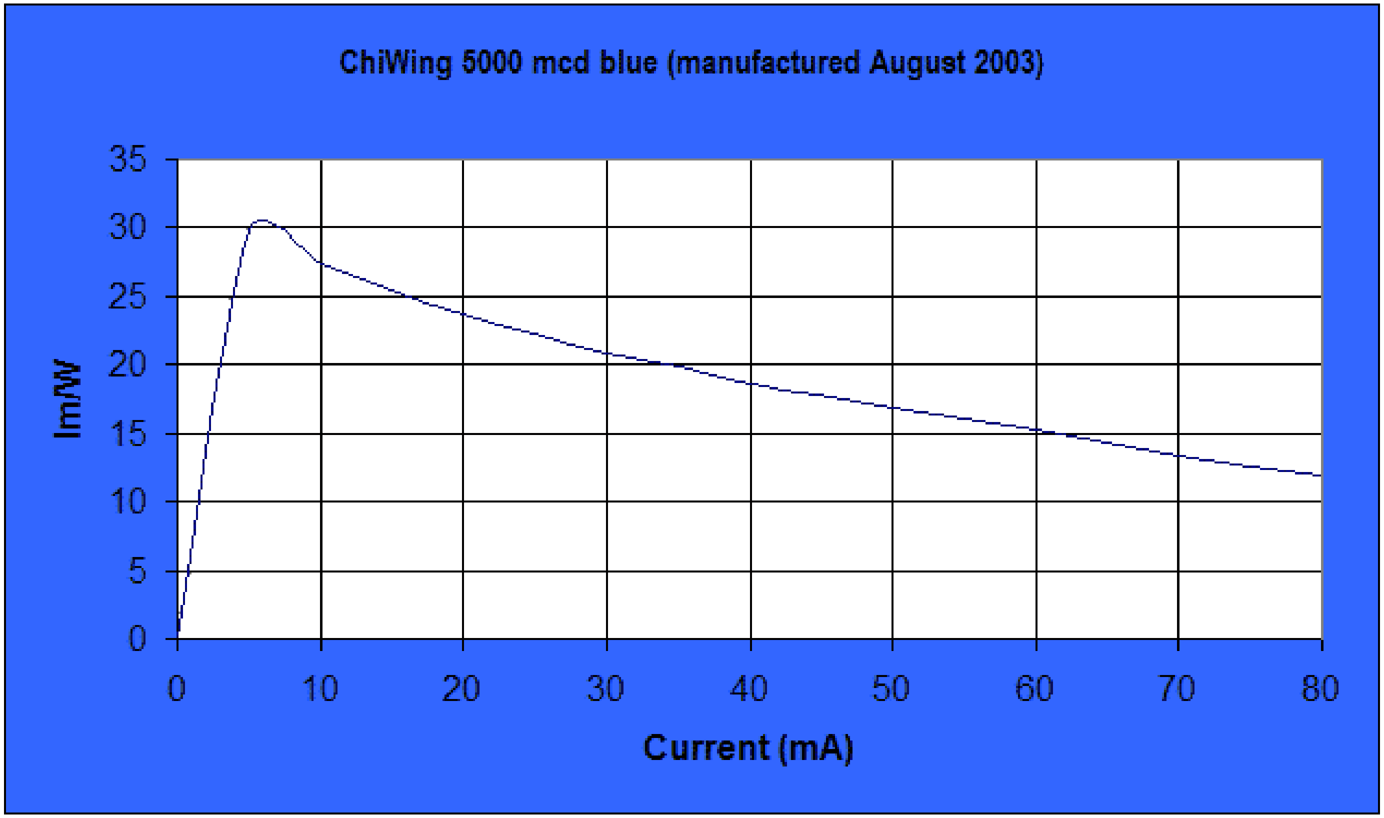
I've finished testing any colored LEDs I have worth testing (the dim indicator LEDs would be pointless). Here are the results in the order in which they were purchased:

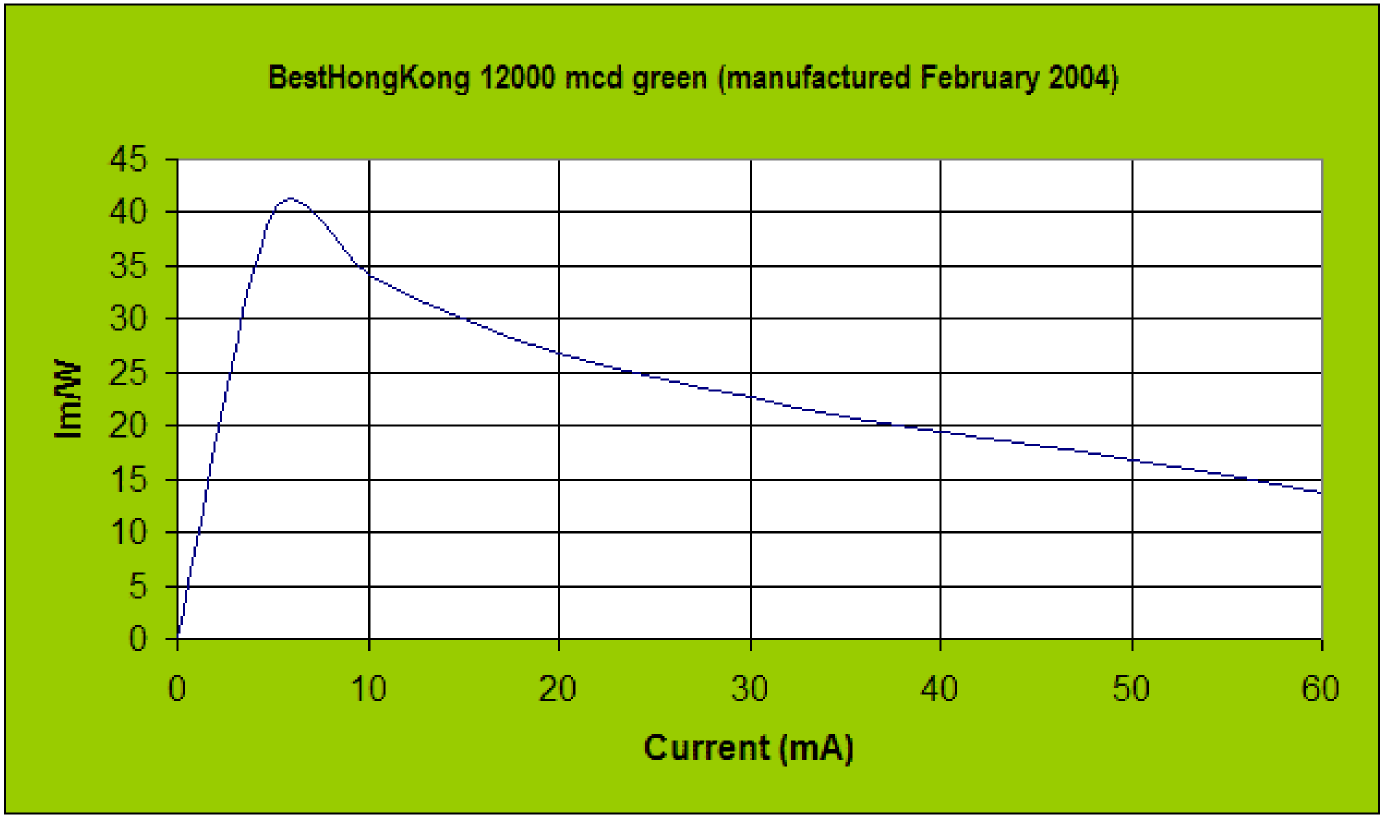


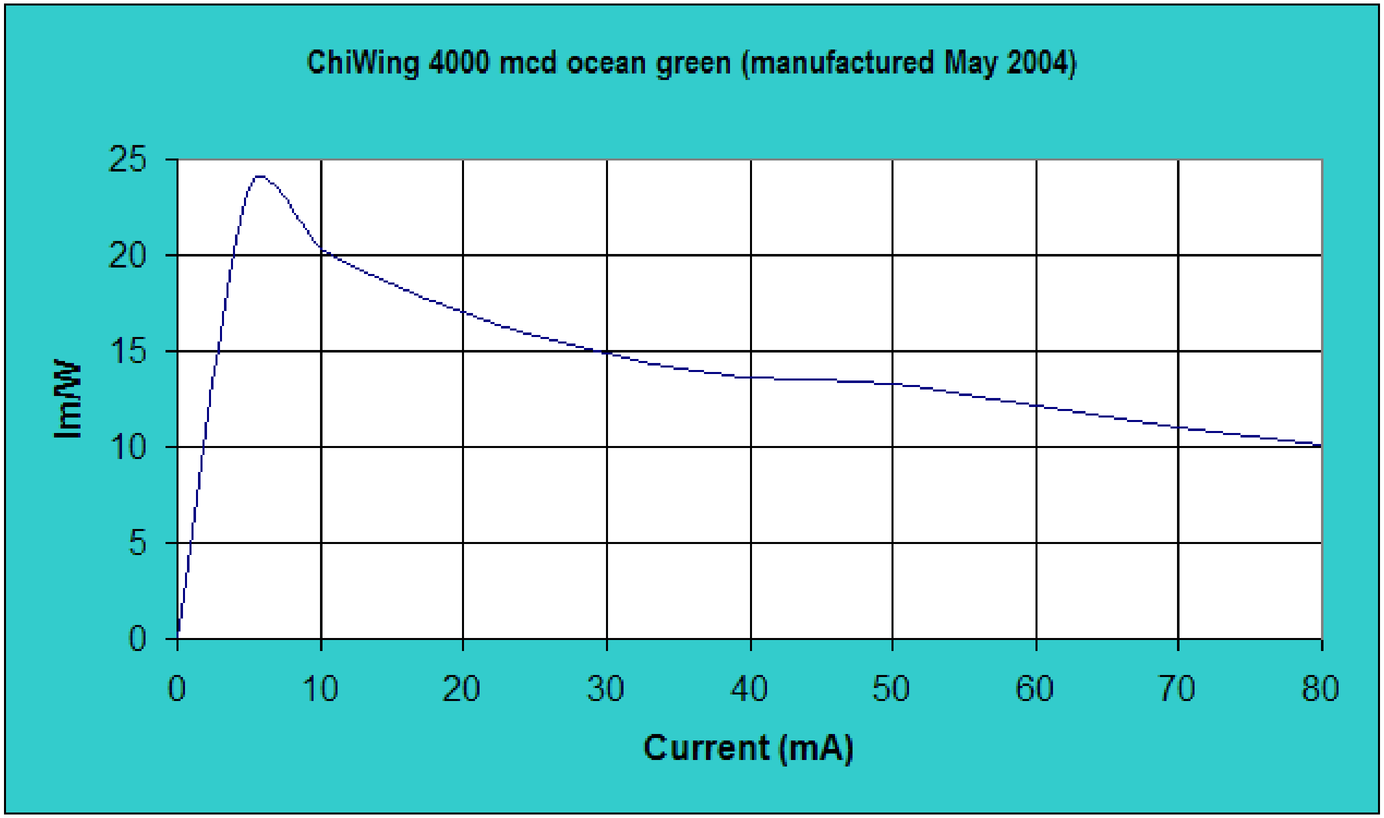

SpectrumLEDs 5000 mcd ocean blue (manufactured June 2003)
lm/W
20
15
10
5
0
0
10
20
30
40
50
60
70
80
Current (mA)

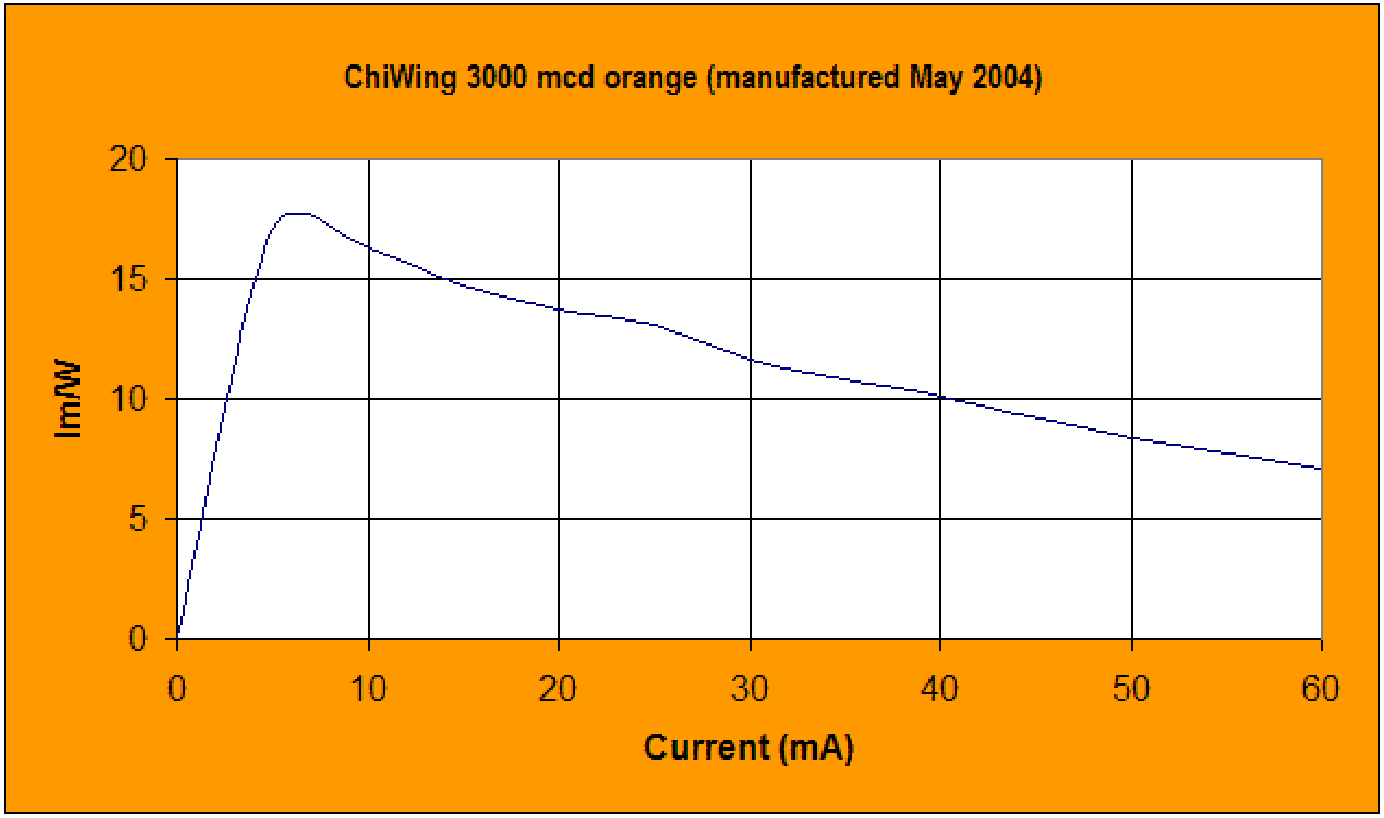

ChiWing 3000 mcd amber (manufactured July 2003)
15
10
5
0
lm/W
0
10
20
30
40
Current (mA)

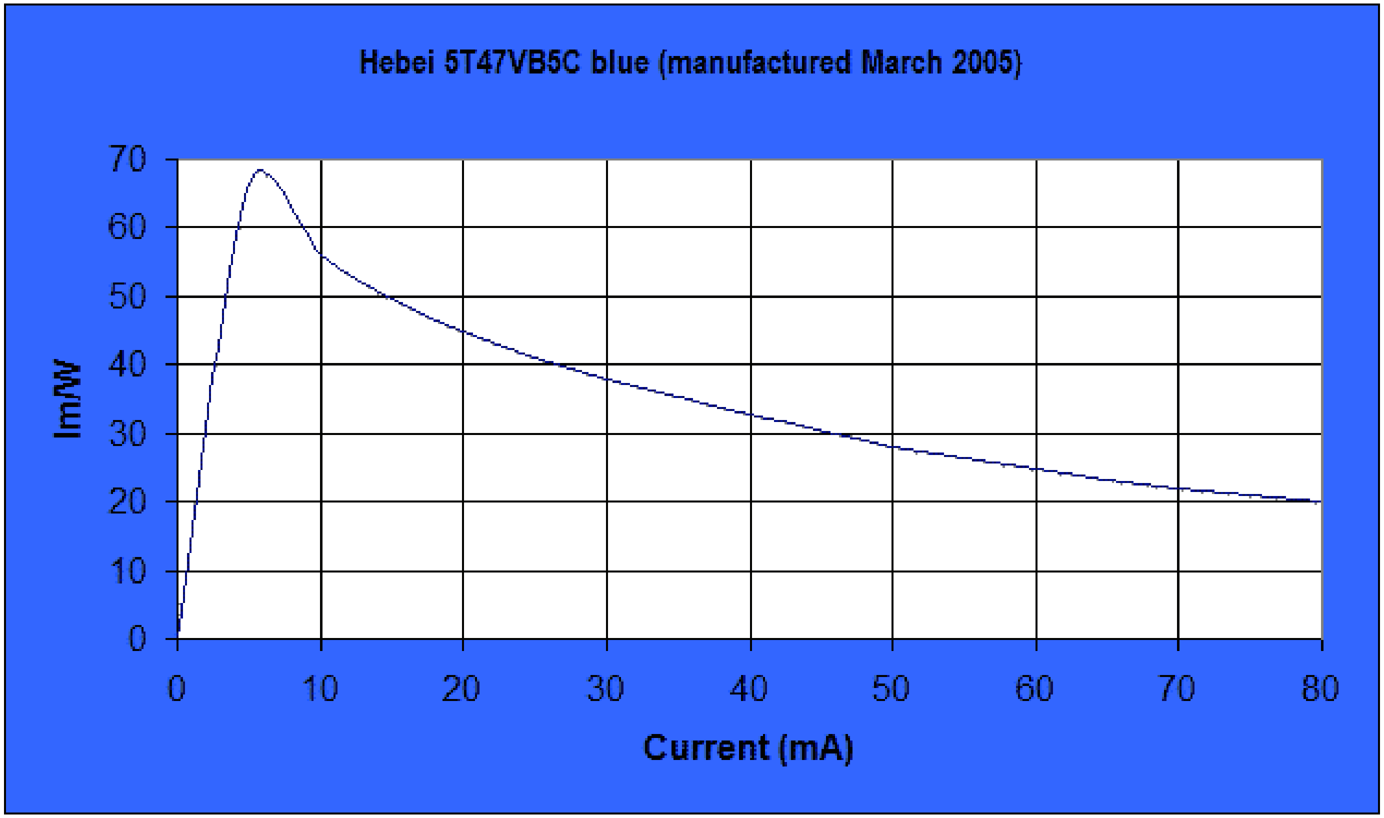

ChiWing 5000 mcd red (manufactured August 2003)
lm/W
0
5
10
15
20
25
30
35
0
10
20
30
40
50
60
Current (mA)

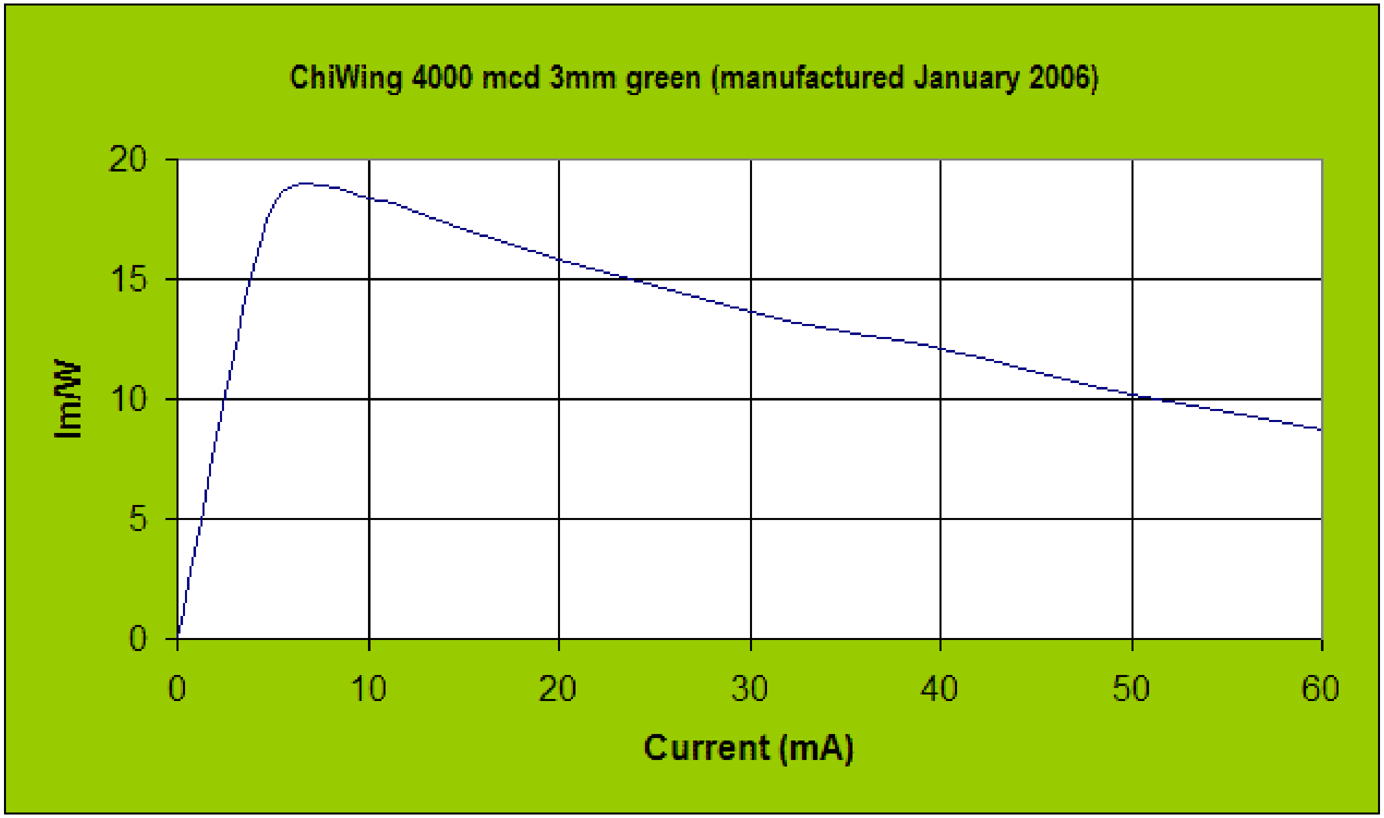

ChiWing 5000 mcd blue (manufactured August 2003)
lm/W
35
30
25
20
15
10
5
0
0
10
20
30
40
50
60
70
80
Current (mA)

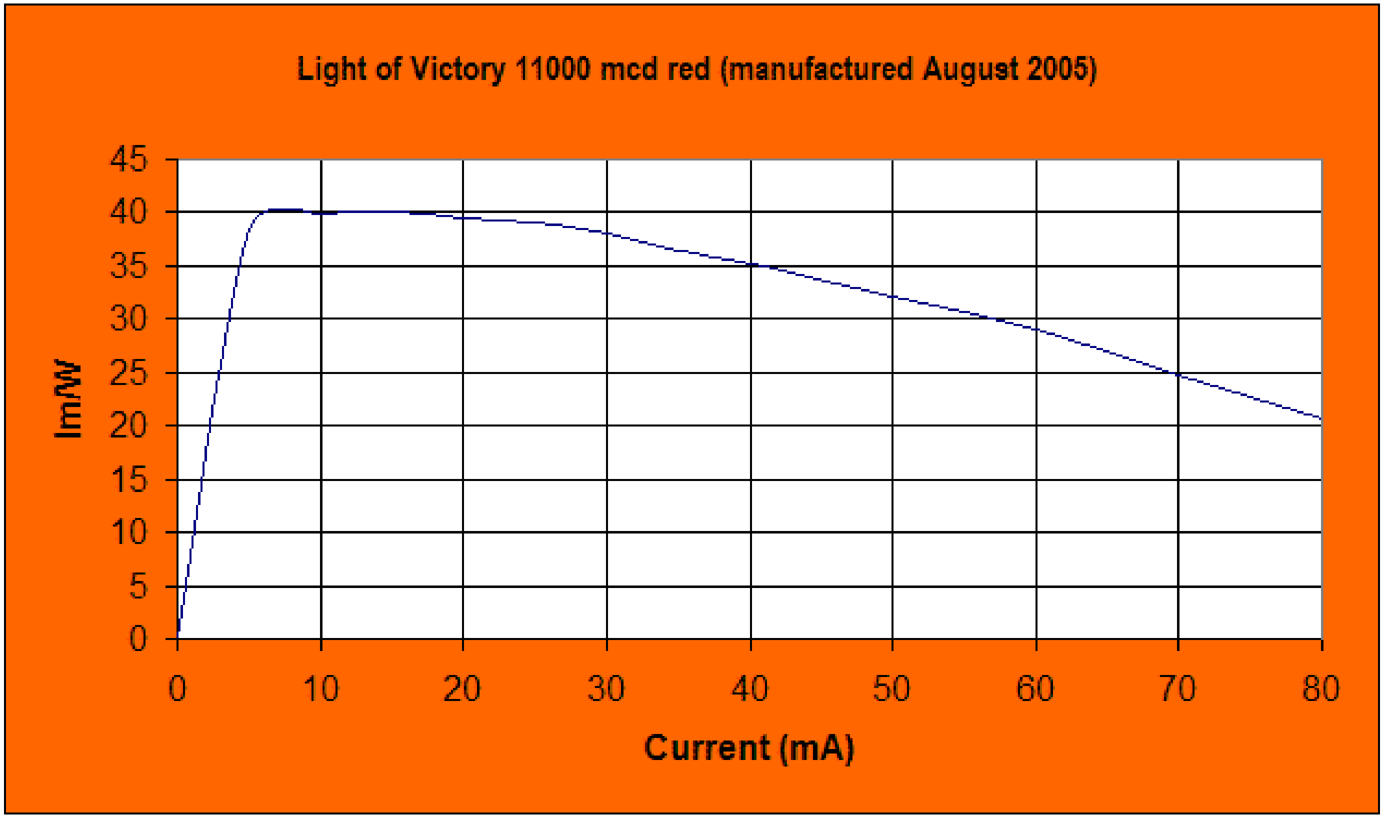

BestHongKong 12000 mcd green (manufactured February 2004)
lm/W
45
40
35
30
25
20
15
10
5
0
0
10
20
30
40
50
60
Current (mA)


ChiWing 4000 mcd ocean green (manufactured May 2004)
lm/W
25
20
15
10
5
0
0
10
20
30
40
50
60
70
80
Current (mA)


ChiWing 3000 mcd orange (manufactured May 2004)
20
15
10
5
0
lm/W
0
10
20
30
40
50
60
Current (mA)


Hebei 5T47VB5C blue (manufactured March 2005)
lm/W
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
Current (mA)


ChiWing 4000 mcd 3mm green (manufactured January 2006)
lm/W
20
15
10
5
0
0
10
20
30
40
50
60
Current (mA)



The blue LEDs are surprisingly efficient in terms of lumens per watt, especially the Hebei blue LED. The likely reason for this is that the dominant wavelength is probably somewhat higher than 470 nm. The rest of the colored LEDs fall more or less where one would expect. Except for blues and reds, colored LED efficiency has not been advancing as fast as white LED efficiency, especially for amber, orange, and yellow green.

The relevant spreadsheets were added to the .zip file linked to in the first post of this thread.

Last edited by jtr1962; 01-12-2007 at 07:50 PM.

Quote

jtr1962

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#**20**

01-20-2006, 12:57 PM

jtr1962
Flashaholic*

Join Date: Nov 2003
Location: Flushing, NY
Posts: 4,835

Re: White LED lumen testing

I added the BestHongKong 40,000 mcd and Jeled 40,000 mcd to the list in the first post and updated the graphs accordingly. You might need to refresh your browser to see the updated graphs. The relevant spreadsheets were added to the .zip file linked to in the first post of this thread.

Quote

jtr1962

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#**21**

01-21-2006, 05:26 AM

ViReN
Flashaholic*

Join Date: Apr 2004
Location: CPFReviews.com
Posts: 3,512

Re: White LED lumen testing

---

jtr1962 .... Great plots in deed... its valuable data when it comes to designing a light considering the Lumen/Watt & total Lumen output for a 5 mm LED

I wonder if you could help me for a project, if you have any Luxeon I (Q/R Bin's H/J Vf) and Luxeon III (S/T Bin's J/K Vf) LED's is it possible for you to have similar charts. i.e. Lumens V/S Current & Vf

i have been looking for this over the forum here and there... but could not find such a chart. i do not have the equipment to do the testing either

your help is highly appreciated.

____
ViReN
www.CPFReviews.com

Last edited by ViReN; 01-21-2006 at 05:30 AM.

Quote

ViReN

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#22

01-21-2006, 12:23 PM

jtr1962

Flashaholic*

Join Date: Nov 2003
Location: Flushing, NY
Posts: 4,835

Re: White LED lumen testing

Quote:

> Originally Posted by **ViReN**
> I wonder if you could help me for a project, if you have any Luxeon I (Q/R Bin's H/J Vf) and Luxeon III (S/T Bin's J/K Vf) LED's is it possible for you to have similar charts. i.e. Lumens V/S Current & Vf

Hi Viren,

Thanks for the compliments, and I hope this data is useful to people. If you look a few posts up you'll see that I did indeed plot a Luxeon Q3J in the same manner as my 5mm LEDs, and included a link for the relevant spreadsheets which have the Vf versus current data. I don't have any Luxeon IIIs on hand to do plots, but I imagine they wouldn't be much different. Maybe now that Future Electronics finally lowered their prices for these to something I consider reasonable I'll pick up a few LIIIs in various colors and play around.

Quote

jtr1962

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#**23**

01-21-2006, 01:02 PM

winny
Flashaholic*

Join Date: Apr 2005
Location: Gothenburg, Sweden
Posts: 1,127

Re: White LED lumen testing

Good job jr1962!

I didn't read it all but as you used the word steradian so I'm quite confident that you know how it works. Very good. Welcome to the higher intelligence club! ;-p

From the picture it looked like you where using the same light meter as I am. I'll give you a warning on them. They are cheap and in my manual it said "the spectral response *almost* corresponds with the CIE curve". When you measure non 2860 K light sources, like LEDs, the error margin is big and comparing LEDs with different shades of white or with incans is, ..., questionable.

Last edited by winny; 04-24-2007 at 07:24 AM.

Quote

winny

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#**24**

01-21-2006, 01:20 PM

jtr1962
Flashaholic*

Join Date: Nov 2003
Location: Flushing, NY
Posts: 4,835

Re: White LED lumen testing

Quote:

> Originally Posted by **winny**
>
> From the picture it looked like you where using the same light meter as I am. I'll give you a warning on them. They are cheap and in my manual it said "the spectral response *almost* corresponds with the CIE curve". When you measure non 2860 K light sources, like LEDs, the error margin is big and comparing LEDs with different shades of white or with incans is well, questionable.

The light meter is a CEM DT-1300. I took part in the light meter tests as described here. For LED-type white light my meter only seems to read a few percent above the averages of everyone elses. It does read quite high for blue LED light which explains my ridiculously high results in tests of blue LEDs (about twice as high as they should be).

Note that I did sanity check my results. The brightest 5mm LEDs nowadays are in the 60 to 70 lm/W range so if I had gotten results much different I would have been suspicious. Also, my Q bin Luxeon came in at 37 lumens, solidly in the middle of the Q bin. Again, if I had gotten results of 45 or 50 lumens, I might have been suspicious. Overall, I'd say for white LEDs my results might be about 5% or so high, if that. I'm more interested in relative measurements anyway so as to tell which LEDs are better. In the future I may adjust my data once the CPF standard LED test lights are professionally checked but for now the relative measurements are a good guide for everyone.

Quote

jtr1962

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#**25**

01-21-2006, 01:30 PM

winny
Flashaholic*

Join Date: Apr 2005
Location: Gothenburg, Sweden
Posts: 1,127

Re: White LED lumen testing

You obviously have thought of everything! Very good.

I hope I didn't offend you, but I just had to warn you as my light meter can be waaay of when it comes to LEDs sometimes. I'll send mine to SilverFox for testing when he get the lamps back.

Anyway, how much did you get out of that MR16 in the background of the picture?

Last edited by winny; 01-21-2006 at 01:33 PM. Reason: added a question

Quote

winny

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Find all posts by winny

#**26**

01-21-2006, 01:37 PM

jtr1962
Flashaholic*

Join Date: Nov 2003
Location: Flushing, NY
Posts: 4,835

Re: White LED lumen testing

Quote:

Originally Posted by **winny**
Anyway, how much did you get out of that MR16 in the background of the picture?

I never tested it but now that you mentioned it I think I will. BTW, it's a standard 50W halogen MR-16 so I figure it should be good for ~1000 lumens.

Quote

jtr1962

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#**27**

02-01-2006, 07:53 AM

jtr1962
Flashaholic*

Join Date: Nov 2003
Location: Flushing, NY
Posts: 4,835

Re: White LED lumen testing

I added the Jeled 50,000 mcd to the list in the first post and updated the graphs accordingly. You might need to refresh your browser to see the updated graphs. The relevant spreadsheets were added to the .zip file linked to in the first post of this thread.

Quote

jtr1962

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Find all posts by jtr1962

#**28**

02-01-2006, 09:26 AM

winny
Flashaholic*

Join Date: Apr 2005
Location: Gothenburg, Sweden
Posts: 1,127

Re: White LED lumen testing

Any progress on the MR16?

Quote

winny

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Visit winny's homepage!

Find all posts by winny

#**29**

02-01-2006, 02:14 PM

jtr1962
Flashaholic*

Join Date: Nov 2003
Location: Flushing, NY
Posts: 4,835

Re: White LED lumen testing

Quote:

Originally Posted by **winny**
Any progress on the MR16?

Unfortunately, that picture was taken before I cleaned the room and now I can't remember where I put the MR16. If/when it turns up I'll be sure to test it and post the results. I did actually look for it for a while when you first mentioned testing it but had no luck.

Quote

jtr1962

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Find all posts by jtr1962

#**30**

02-02-2006, 03:12 AM

Pinter
Flashaholic

Join Date: Oct 2003
Location: Hungary, Europe
Posts: 140

Re: White LED lumen testing

Quote:

> Originally Posted by **jtr1962**
>
> For LED-type white light my meter only seems to read a few percent above the averages of everyone elses. It does read quite high for blue LED light which explains my ridiculously high results in tests of blue LEDs (about twice as high as they should be).

That means that leds with blue hotspot are resulting in higher Lux reading in your test than real white ones?

Quote

Pinter

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Post Reply

Page 1 of 13 **1** 2 3 4 5 6 7 8 11 > Last »

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[IMG] code is **On**
HTML code is **Off**

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All times are GMT -7. The time now is 09:41 AM.

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Thread: White LED lumen testing

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#**303**

06-22-2009, 05:24 AM

jtr1962
Flashaholic*

Join Date: Nov 2003
Location: Flushing, NY
Posts: 4,835

Re: White LED lumen testing

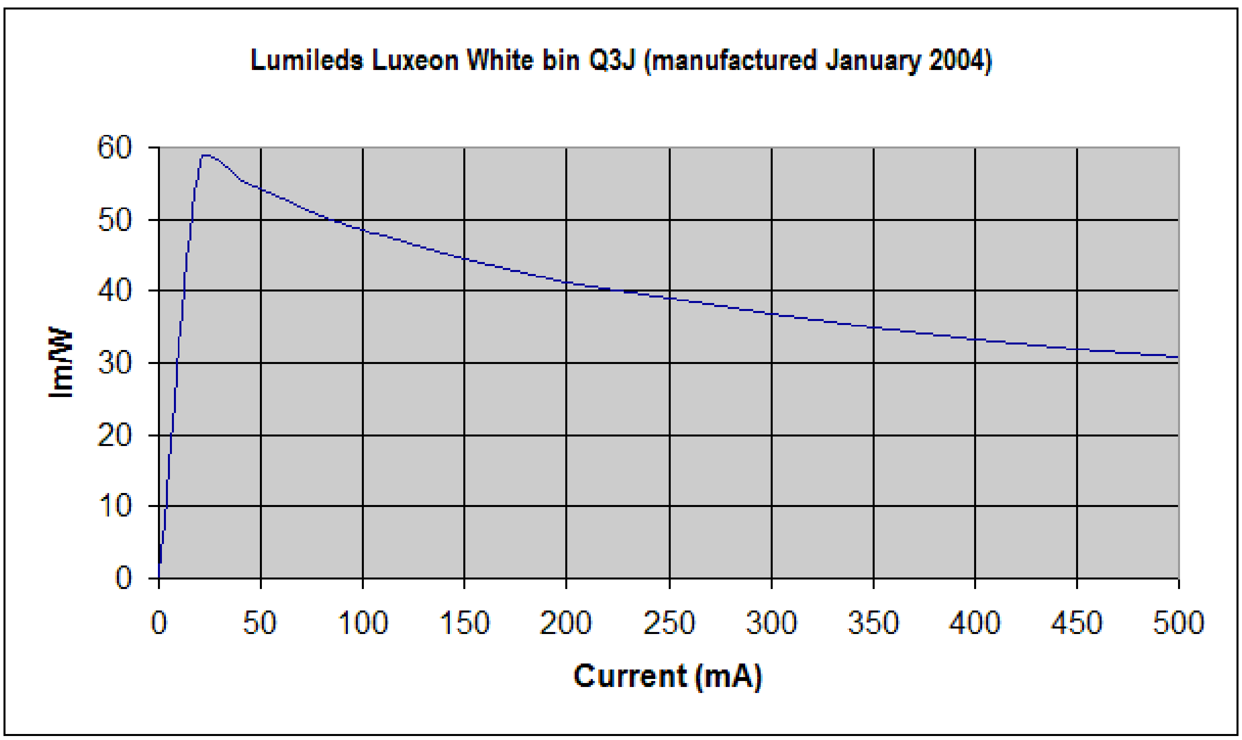
As requested, I collected all of my power LED tests in this post in chronological order and linked to it in the first post (link to original post by clicking the date).

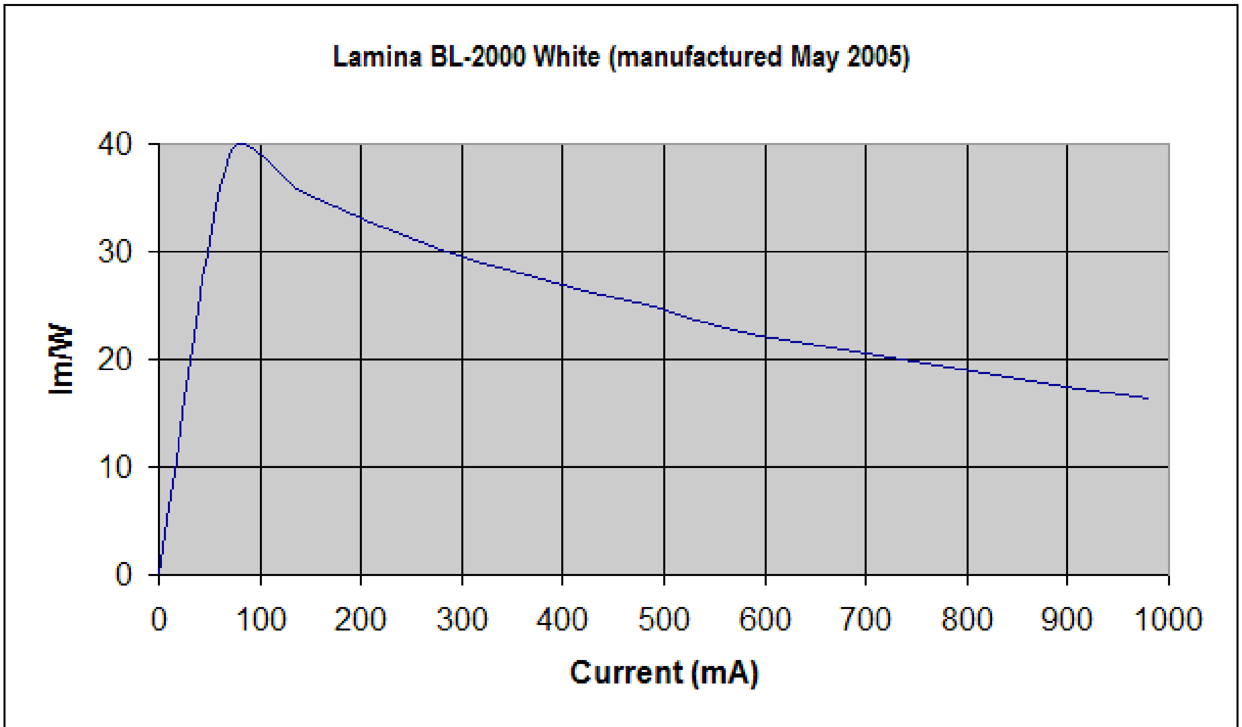
Also, I'm repeating a message from the first post regarding LED recommendations as the volume of PMs I've received asking about which LED to use has gotten to be annoying:

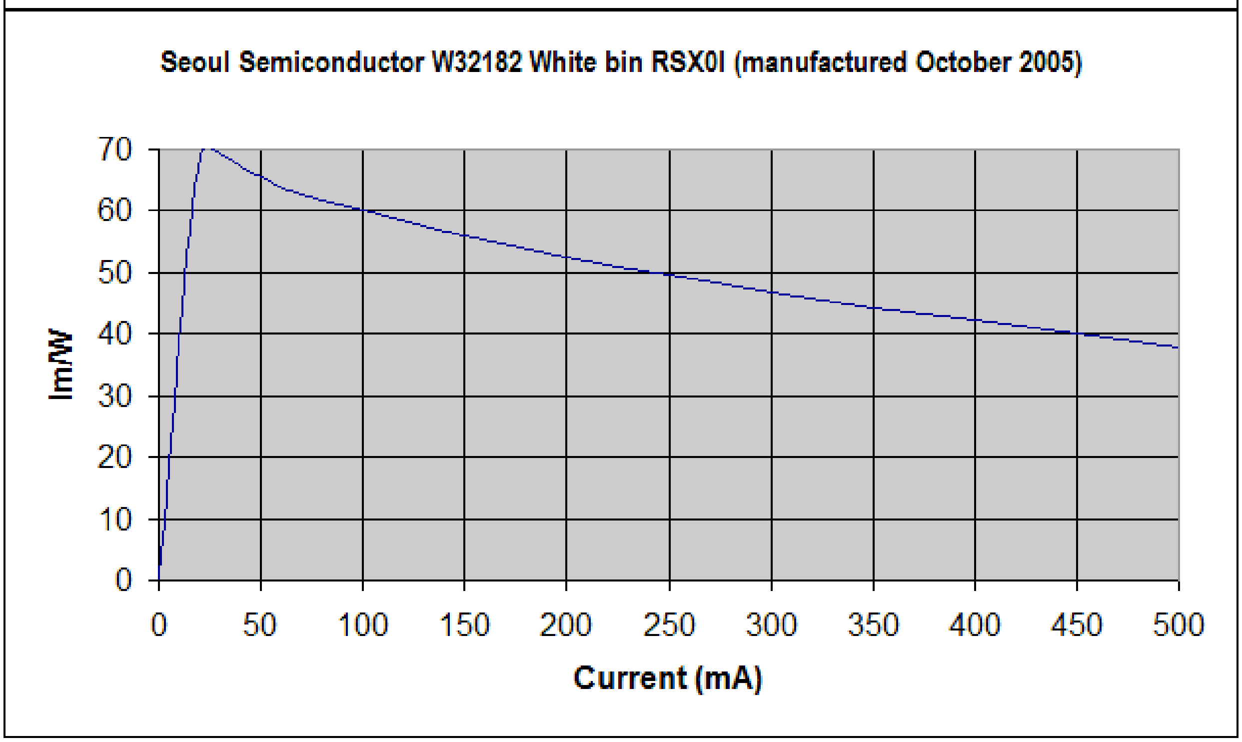
Although I have tested many LEDs in this thread, I am not in a position to recommend specific LEDs for use in flashlights or other devices to people. I feel the need to mention this because I have received quite a few PMs asking me which LED would be good for such and such project. I feel it would be best to start a new thread asking for LED recommendations rather than asking me. I just don't have the time or desire or ability to help people determine which LED to use in any given project.

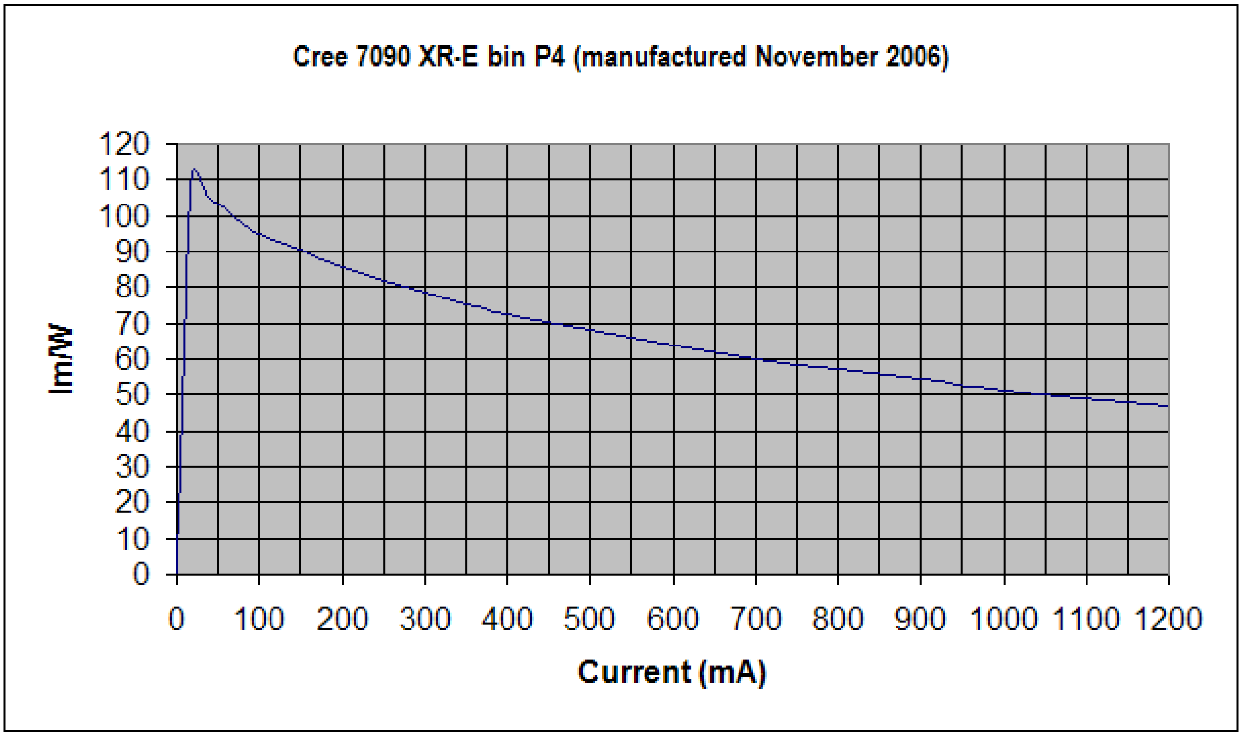
08-09-2005

I made a jig for testing power LEDs. Here are my results for a Q3J Luxeon, a Lamina BL-2000, a Seoul Semiconductor W32182 bin RSX0I star, and a Cree 7090 XR-E bin P4:




Lamina BL-2000 White (manufactured May 2005)
lm/W
40
30
20
10
0
0
100
200
300
400
500
600
700
800
900
1000
Current (mA)


Seoul Semiconductor W32182 White bin RSX0I (manufactured October 2005)
lm/W
70
60
50
40
30
20
10
0
0
50
100
150
200
250
300
350
400
450
500
Current (mA)



Here are the relevant spreadsheets.

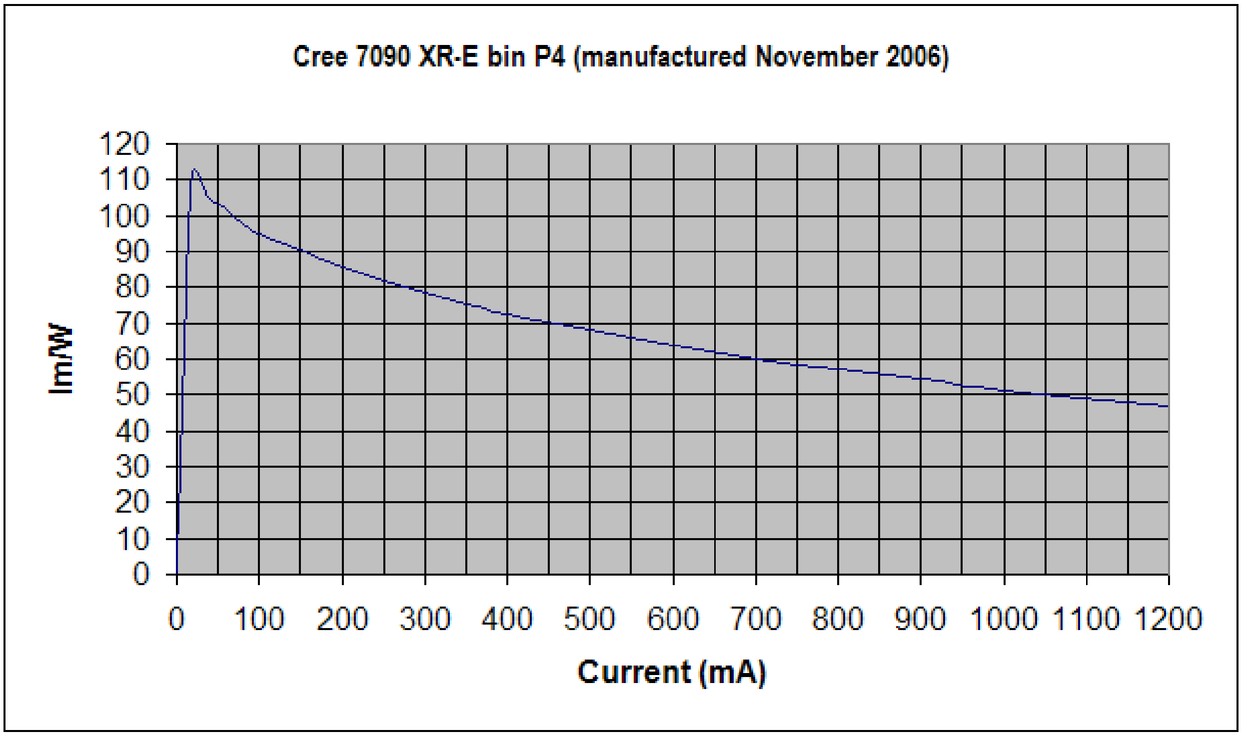
I have 5 Q bin Luxeons. Four of them seem about equal in brightness and the fifth is about 10% dimmer. Assuming then that the dim one is at the low end of the Q-bin (say 31 lumens), then the other ones should test in the mid 30s. My results give me 37.1 lumens, a little past the middle of the Q-bin. I think this more or less verifies the accuracy of my methods. At worst my results are less than 10% too high.

12-03-2006

Cree 7090 XR-E bin P4 (purchased November 2006)

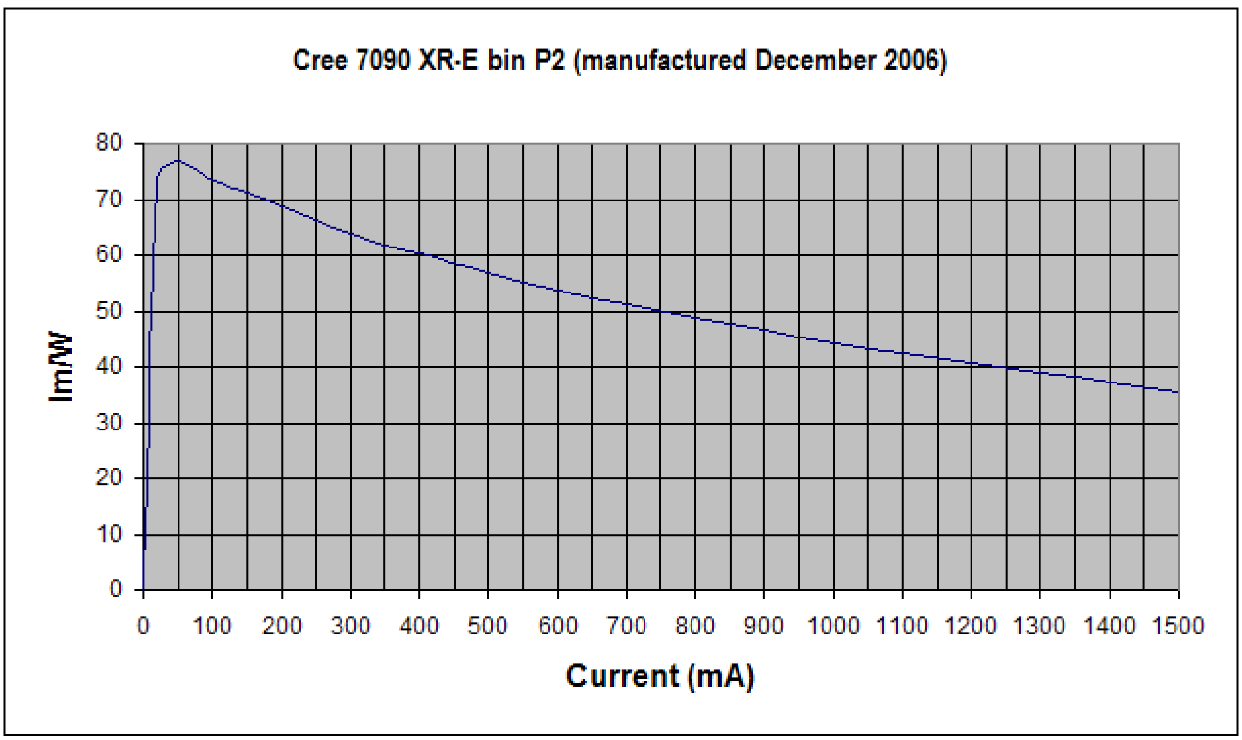
I purchased these from CPF member Erasmus. These are tint bin WH and flux bin P4 (80.6 to 87.4 lumens at 350 mA). The color temp of these seems a close match for my 5000K fluorescents which makes the WH bin perfect for interior lighting although perhaps a bit warm for flashlights. I measured the 50% beam angle at 95.3° which is somewhat wider than the 75° given on the spec sheet. Despite the out of spec beam angle, the overall flux at 350 mA is 85.67 lumens which is within the range of the P4 bin (and also a verification of the accuracy of my methodology). Vf at 350 mA is 3.25V and overall efficiency is a very impressive 75.37 lm/W. Even at 700 mA efficiency remains above 60 lm/W. Luminous flux at 500 mA is about equal to the Lamina Ceramics BL-2000 arrays but the power input is only around 1.7 watts instead of the 4.7 or so watts used by the Lamina array. Although these obviously aren t a 20 mA part if they were they would break previous records by a huge margin, coming in at nearly 112 lm/W. There s really nothing more to say about these than hasn t already been said by me and many others. They represent a huge step forwards in LED technology.

Here is the efficiency versus current chart:

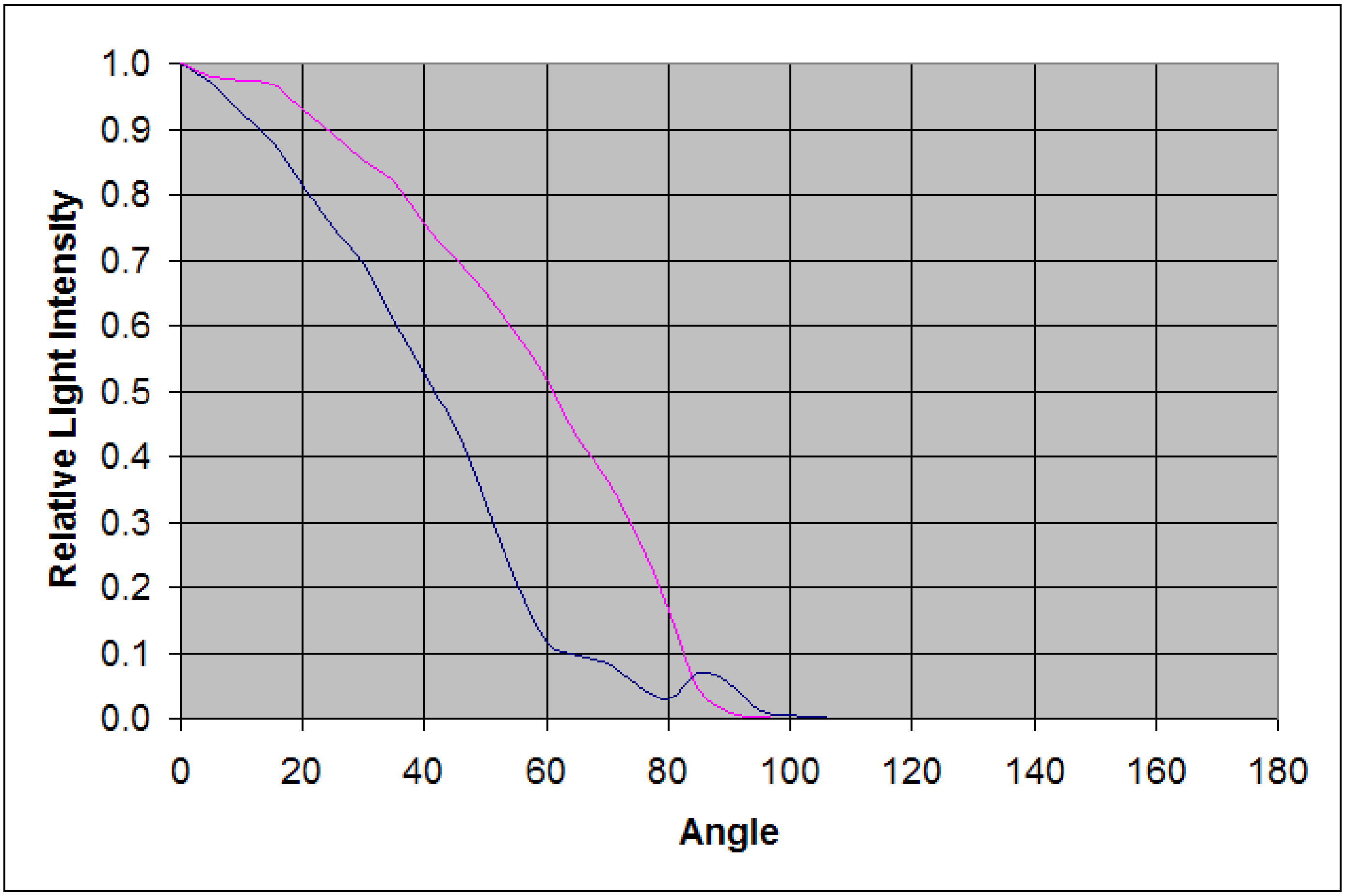


02-04-2007

I finally got around to testing the two Cree XR-E emitters 3rd_shift sent me. The purpose of this test was to determine the difference between an emitter with and without the dome. The unmodified Cree XR-E bin P2 emitter tested as follows:



Output was 70.67 lumens at 350 mA. This is right in the middle of the P2 bin (67.2 to 73.9 lumens). The same bin emitter with the dome removed only had an output of 54.35 lumens at 350 mA. The beam angle was wider as well (122° versus 83.3° for the unmodified emitter). The relative intensity versus angle for the two emitters is shown below (domeless emitter in magenta):

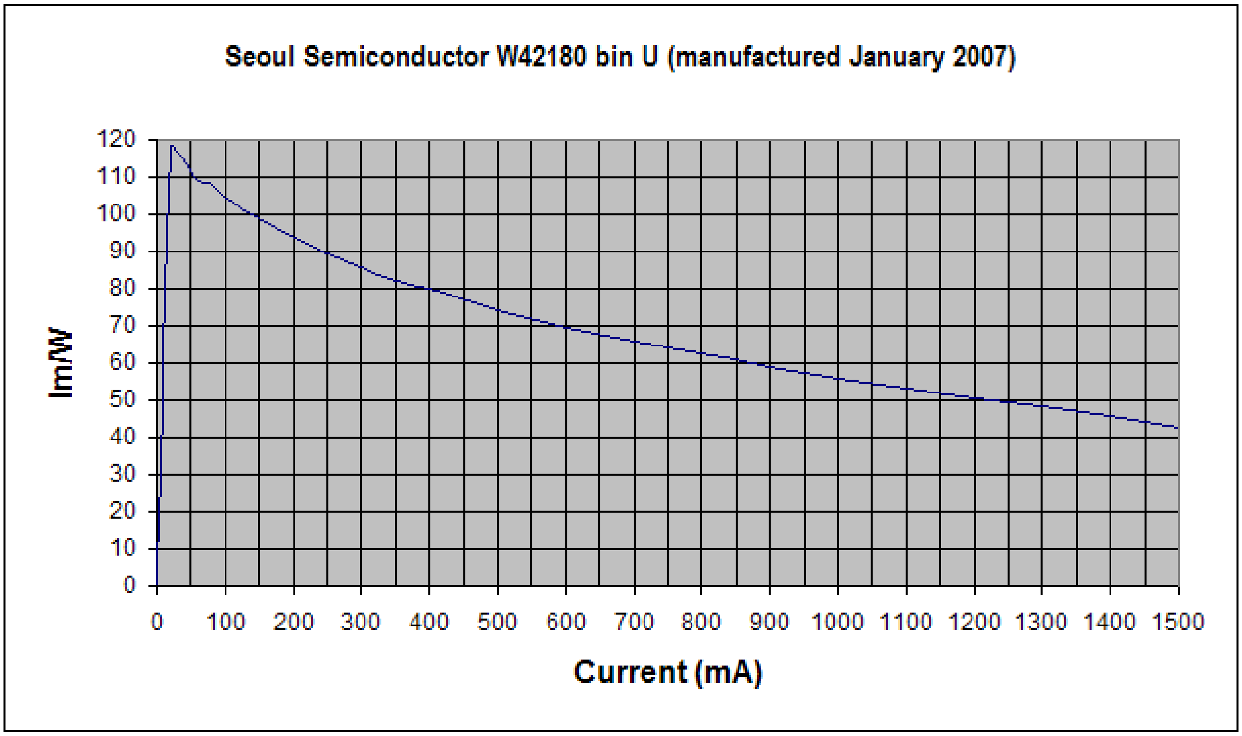


Apparently the silicon encapsulant combined with the dome helps to extract a considerable amount of light from the die. The output of the domeless emitter is 24% less than the stock emitter.

02-04-2007

Seoul Semiconductor W42180 bin U (tested February 2007)

I purchased a U bin Seoul Semiconductor emitter from milkyspit recently. The results of the test are shown below:



I believe the results speak for themselves. The efficiency at 350 mA is a very impressive 82.1 lm/W and the output is 96 lumens. This is a new record for power LEDs and also matches my best results for single die 5mm LEDs. Beam angle is close to 130° which means these have a light distribution similar to a Luxeon emitter. Since the emitter is rated for 1000 mA I felt comfortable going to 1500 mA, at which point output more or less leveled off. The output scales with current almost identically to the Cree XR-E bin P4 which I tested in December but this is no surprise since both emitters use the same die. Note that the U bin has a range of 91 to 118.5 lumens so these are at the low end (which I expected). I anticipate that the Cree XR-E Q3 bins will offer similar results. Shown below is a chart of Vf, power, and lumens at various currents.

current	Vf	Pin	lumens
0	0.00	0.00	0.00
20	2.74	0.05	6.47
40	2.84	0.11	12.95
60	2.91	0.17	19.06
80	2.96	0.24	25.53
100	3.01	0.30	31.29
150	3.10	0.47	46.03
200	3.18	0.64	59.70
250	3.24	0.81	72.65
300	3.29	0.99	84.87
350	3.34	1.17	96.02
400	3.39	1.36	108.25
500	3.46	1.73	128.75
600	3.53	2.12	147.45
700	3.58	2.51	164.35
800	3.63	2.90	181.26
900	3.68	3.31	195.64
1000	3.72	3.72	208.23
1100	3.76	4.14	220.46
1200	3.79	4.55	230.53
1300	3.82	4.97	239.16
1400	3.85	5.39	246.35
1500	3.88	5.82	249.59

09-04-2007

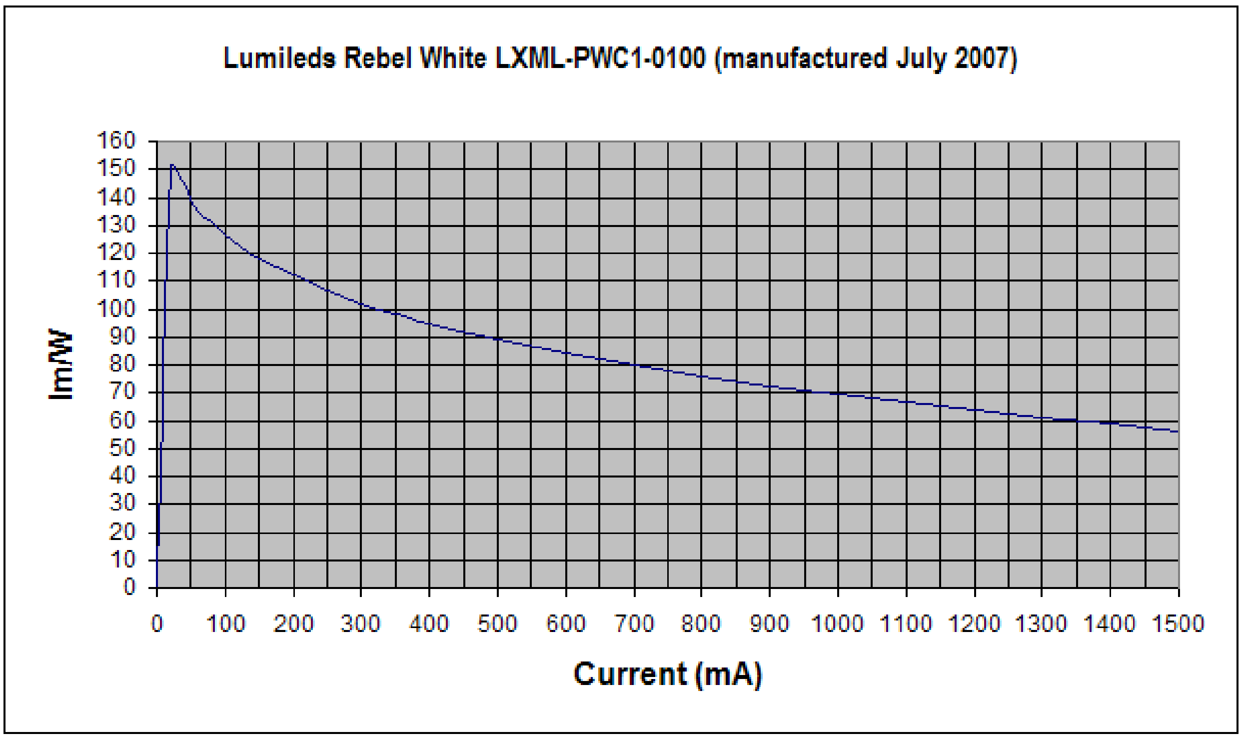
Lumileds Rebel White LXML-PWC1-0100 (acquired July 2007)

Note: Earlier results multiplied by correction factor of 1.116 and post edited accordingly (See post #138 for explanation).

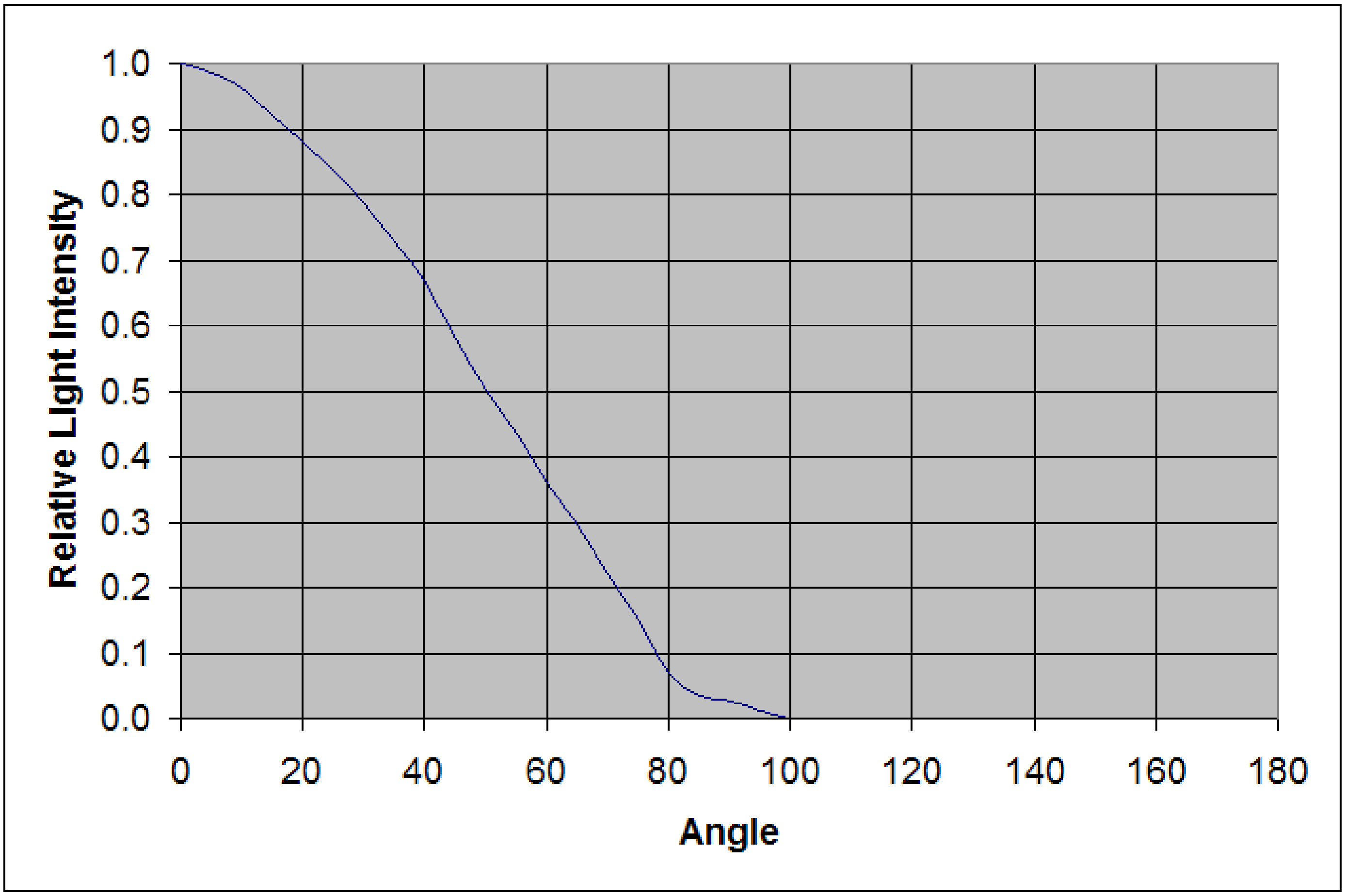
I purchased a pair of these from Future Electronics for evaluation. I only tested one of the two samples. Color bin was not specified, but these are similar in color to the WH Crees, so I'd guess that they are V0s. I soldered the Rebel to a small length of brass bar with two holes drilled in the ends. I screwed the bar to my heat sinked power LED test jig with some thermal grease at the interface for better heat transfer. Beam angle measured 100.1°, a bit narrower than Luxeon IIIs, and the beam pattern is close to, but not exactly, lambertian. In the course of testing I learned how important it is to keep the lens of these LEDs clean. My initial test results gave roughly 91 lumens at 350 mA. I tried cleaning the lens with alcohol and then rerunning the tests. The final results were 96.7 lumens at 350 mA, but I later determined that I needed to apply the correction factor for my light meter. This revised the results to 107.9 lumens which is within spec. At 700 mA the Rebel put out 183.1 lumens, just about dead on the specified 180 lumens. Output continued to increase with current, reaching over 290 lumens at 1500 mA, which is as high as my current source goes. Moreover, the output curve wasn't entirely flattened out, even at 1500 mA. I would guess that output would continue to increase to 2 amps, albeit not very much over the output at 1.5 amps. Vf was extremely low and didn't rise very fast with current. It was 3.14V at 350 mA but only 3.43V at 1500 mA. Efficiency at 350 mA was 98.2 lm/W, a new record for power LEDs, and tantalizingly close to the magic 100 lm/W. Interestingly, with the apparent stagnation in small LED efficiency since early 2006, power LEDs are now actually more efficient than indicator-type LEDs. Moreover, efficiency at 1000 mA, the maximum specified operating current, was still a very decent 69.4 lm/W, about on par with CFLs, and stayed above 56 lm/W even at 1500 mA. Maximum efficiency was reached at 20 mA, and it was an incredible 150.7 lm/W. This translates into a conversion efficiency of over 45%. Efficiency remained above 100 lm/W until around 325 mA. Overall the Rebels have broken all previous records, but I suspect their time on top will be short-lived as I have yet to acquire the Cree XR-E Q5s for testing.

Original post:

I purchased a pair of these from Future Electronics for evaluation. I only tested one of the two samples. Color bin was not specified, but these are similar in color to the WH Crees, so I'd guess that they are V0s. I soldered the Rebel to a small length of brass bar with two holes drilled in the ends. I screwed the bar to my heat sinked power LED test jig with some thermal grease at the interface for better heat transfer. Beam angle measured 100.1°, a bit narrower than Luxeon IIIs, and the beam pattern is close to, but not exactly, lambertian. In the course of testing I learned how important it is to keep the lens of these LEDs clean. My initial test results gave roughly 91 lumens at 350 mA. I tried cleaning the lens with alcohol and then rerunning the tests. The final results were 96.7 lumens at 350 mA. Since this is less than Lumiled's tolerance for lumen measurement this is still within spec. More importantly, at 700 mA the Rebel put out 179.63 lumens, just about dead on the specified 180 lumens. Output continued to increase with current, reaching over 260 lumens at 1500 mA, which is as high as my current source goes. Moreover, the output curve wasn't entirely flattened out, even at 1500 mA. I would guess that output would continue to increase to 2 amps, albeit not very much over the output at 1.5 amps. Vf was extremely low and didn't rise very fast with current. It was 3.14V at 350 mA but only 3.43V at 1500 mA. Efficiency at 350 mA was 88.0 lm/W, a new record for power LEDs. Interestingly, with the apparent stagnation in small LED efficiency since early 2006, power LEDs are now actually more efficient than indicator-type LEDs. Moreover, efficiency at 1000 mA, the maximum specified operating current, was still a very decent 62.2 lm/W, about on par with CFLs, and stayed above 50 lm/W even at 1500 mA. Maximum efficiency was reached at 20 mA, and it was an incredible 135 lm/W. This translates into a conversion efficiency of over 40%. Efficiency remained above 100 lm/W until 200 mA. Overall the Rebels have broken all previous records, but I suspect their time on top will be short-lived as I have yet to acquire the Cree XR-E Q5s for testing.



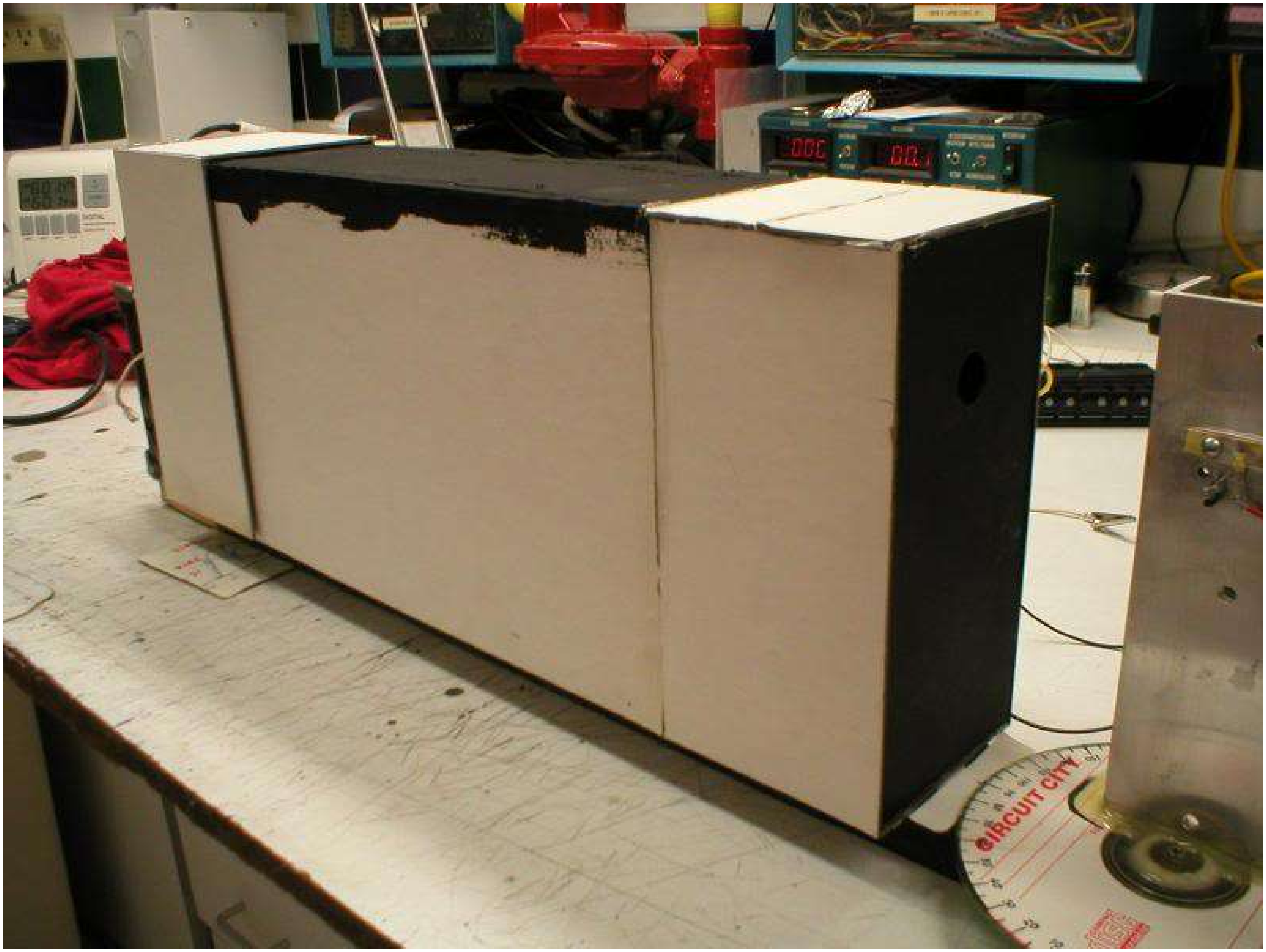
current	Vf	Pin	lumens
0	0.00	0.00	0.00
20	2.74	0.05	8.26
40	2.81	0.11	16.23
60	2.86	0.17	23.06
80	2.90	0.23	30.47
100	2.93	0.29	37.02
150	2.99	0.45	52.96
200	3.04	0.61	68.06
250	3.07	0.77	81.72
300	3.11	0.93	95.11
350	3.14	1.10	107.92
400	3.16	1.26	119.88
500	3.20	1.60	142.09
600	3.24	1.94	163.45
700	3.27	2.29	183.10
800	3.30	2.64	200.47
900	3.33	3.00	217.27
1000	3.35	3.35	232.64
1100	3.37	3.71	246.88
1200	3.39	4.07	260.26
1300	3.41	4.43	271.37
1400	3.42	4.79	281.33
1500	3.43	5.15	290.45



10-01-2007

Relevant description of change in methodology:

I changed my setup somewhat immediately before the tests of the Rebel 100 and the Hebei LEDs. I set up a series of baffles and totally enclosed them to block out any ambient light:

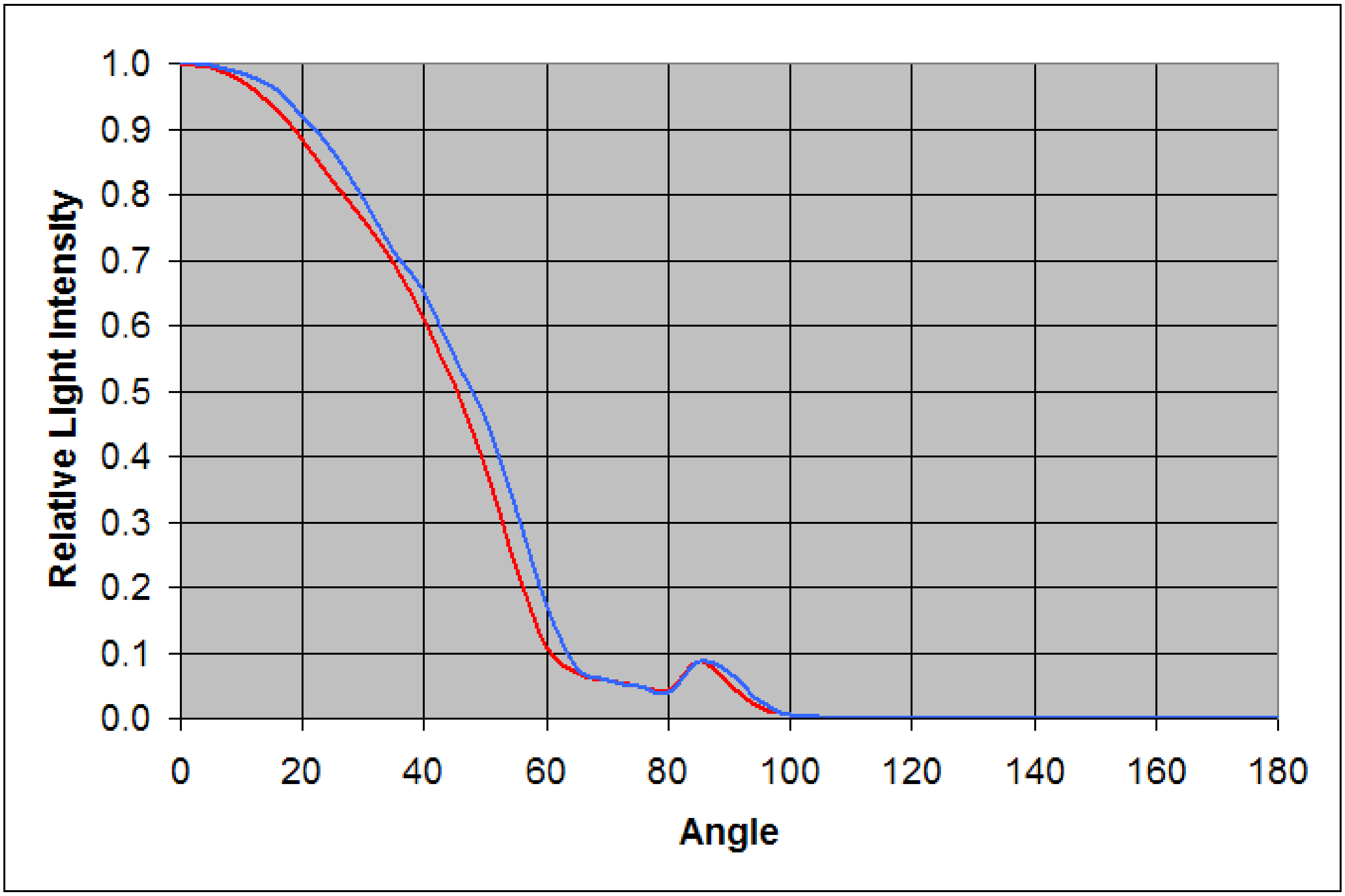


I even put a removeable cover to block ambient light near the light meter:

The purpose of these modifications was to eliminate guestimating the background light which needed to be subtracted from the light meter reading. For 5mm LEDs this was at most about 0.5 lux, but for power LEDs it was considerably more. Prior to this, I would block out the direct portion of the beam with a piece of cardboard, note the reading, then subtract it from the unblocked reading. This method always bothered me because it introduced another variable. While the background reading was fairly steady, it did vary enough depending upon the placement of the cardboard to cause concern. Hence my use of the term guestimating at the start of this paragraph. The modified setup introduces consistency. When I block off the small hole where light enters from the LED, the reading is at most 0.1 lux, even in a undarkened room. I still do my testing in a darkened room, but with the new setup I don't have to!

Now this is all good and well except that when I tested the Rebel 100 I was getting somewhat less than the minimum of 100 lumens (96.7 lumens @ 350 mA to be exact). However, according to the results of the CPF light meter testing which I had participated in my light meter was reading low for white LED light. The correction factor was 1.116. I applied the correction factor to my Rebel 100 results in post #127 and the numbers are more in line with what I should have gotten.

The only question remaining was whether or not I could reliably compare my earlier results with my new ones. To answer this question I decided to retest the P4 bin Cree XR-E which I had tested last November. The original results were 85.67 lumens at 350 mA. The *uncorrected* results using the modified tester were 80.24 lumens at the same 350 mA. This was about 6.4% low. The corrected result was 89.55 lumens, within 4.5% of my original results. I also ended up with a somewhat narrower beam angle (new results in red, old in blue):



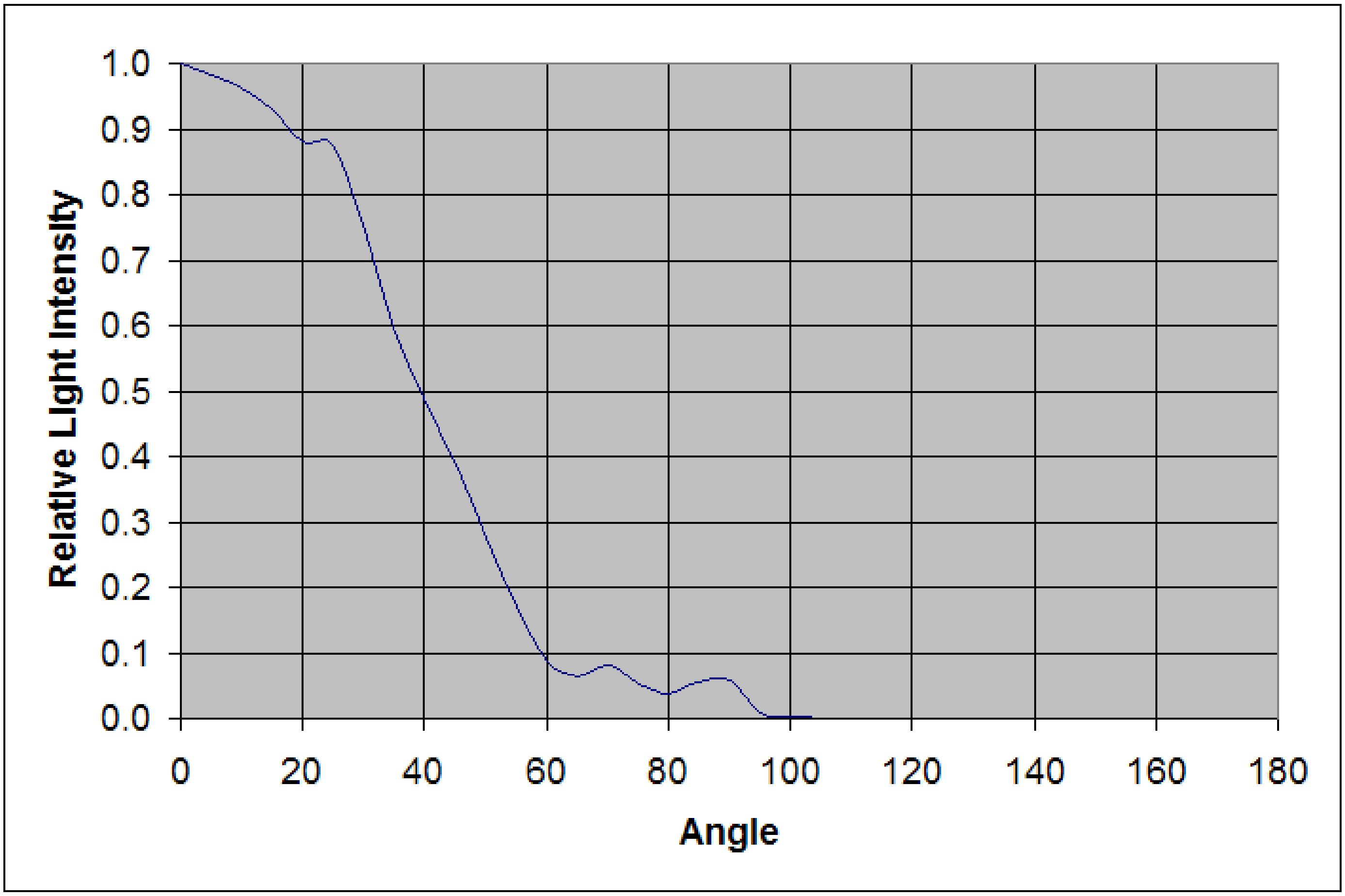
It seems then that although I did not apply any correction factors to my earlier results the inherent methodology resulted in slightly wider beam angles which more or less compensated for the lower absolute lux readings. Remember that all of my earlier power LED test results pretty much fell within the ballpark of where they were supposed to for a given bin. The only problem is that LEDs obviously come in different tints, and I suspect I would need different correction factors depending upon the tint. Based on the fact that my light meter was nearly dead-on with incandescent light, the correction factor would increase with increasing color temperature. However, since guestimating correction factors would make this testing more art than science, I'll stick to using the official correction factor of 1.116. The fact that my corrected result for the P4 Cree is a little high probably has to do with that LED being a warmer (WH) tint bin.

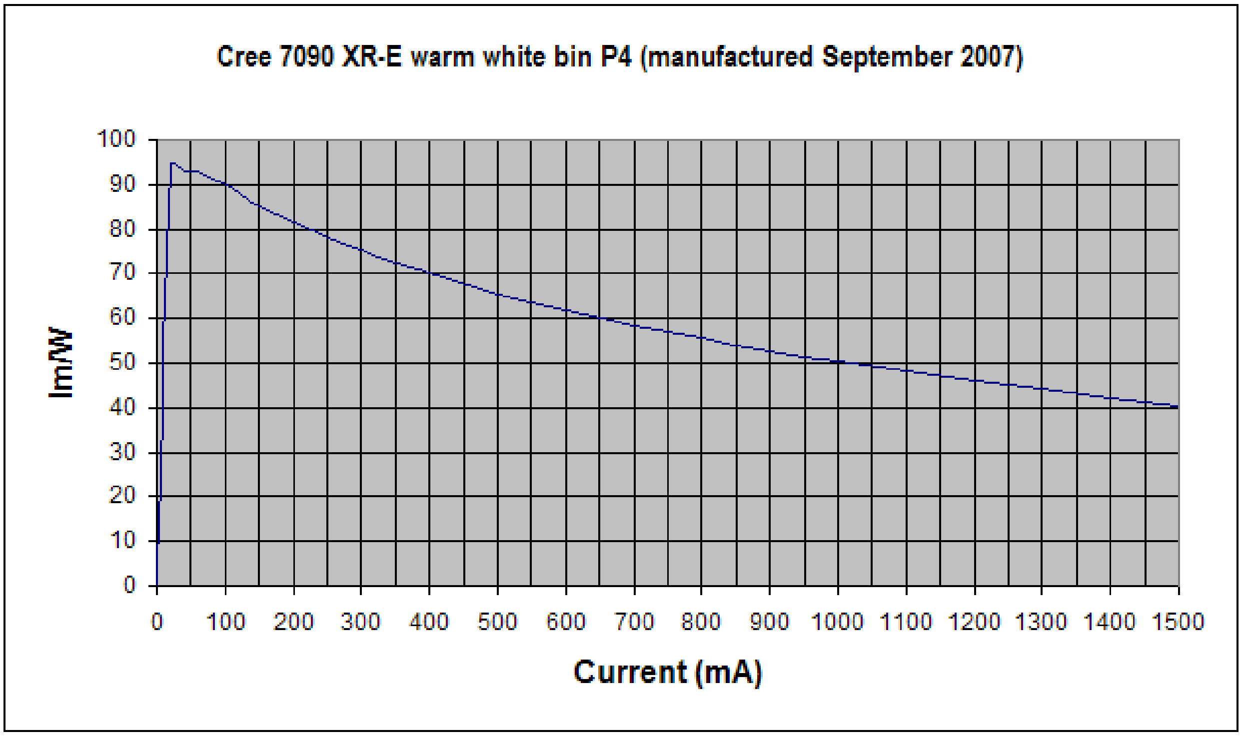
10-01-2007

Cree 7090 XR-E Warm White bin P4 (acquired September 2007)

I ordered some Q5 Cree XR-Es from CPF member **Erasmus**. Along with the Q5s Erasmus sent me a Cree XR-E warm white bin P4 for testing. The P4 bin is specified at 80.6 to 87.4 lumens at 350 mA. The color temperature looked like roughly 3300K, so I would say the tint bin was 7A. Since the color temperature was in the incandescent range, I didn't need to apply a correction factor. The output of 83.0 lumens at 350 mA is solidly within the P4 flux bin.

Results are shown below:


Relative Light Intensity
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0 20 40 60 80 100 120 140 160 180
Angle


Cree 7090 XR-E warm white bin P4 (manufactured September 2007)
lm/W
100
90
80
70
60
50
40
30
20
10
0
0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500
Current (mA)

current	Vf	Pin	lumens
0	0.00	0.00	0.00
20	2.77	0.06	5.22
40	2.85	0.11	10.62
60	2.91	0.17	16.20
80	2.96	0.24	21.61
100	3.00	0.30	27.01
150	3.08	0.46	39.25
200	3.14	0.63	51.31
250	3.19	0.80	62.29
300	3.23	0.97	72.92
350	3.27	1.14	83.00
400	3.31	1.32	92.72
500	3.37	1.69	110.19
600	3.42	2.05	126.75
700	3.47	2.43	141.87
800	3.52	2.82	156.46
900	3.56	3.20	169.06
1000	3.60	3.60	181.12
1100	3.63	3.99	192.64
1200	3.66	4.39	202.73
1300	3.69	4.80	211.55
1400	3.73	5.22	220.19
1500	3.76	5.64	227.39

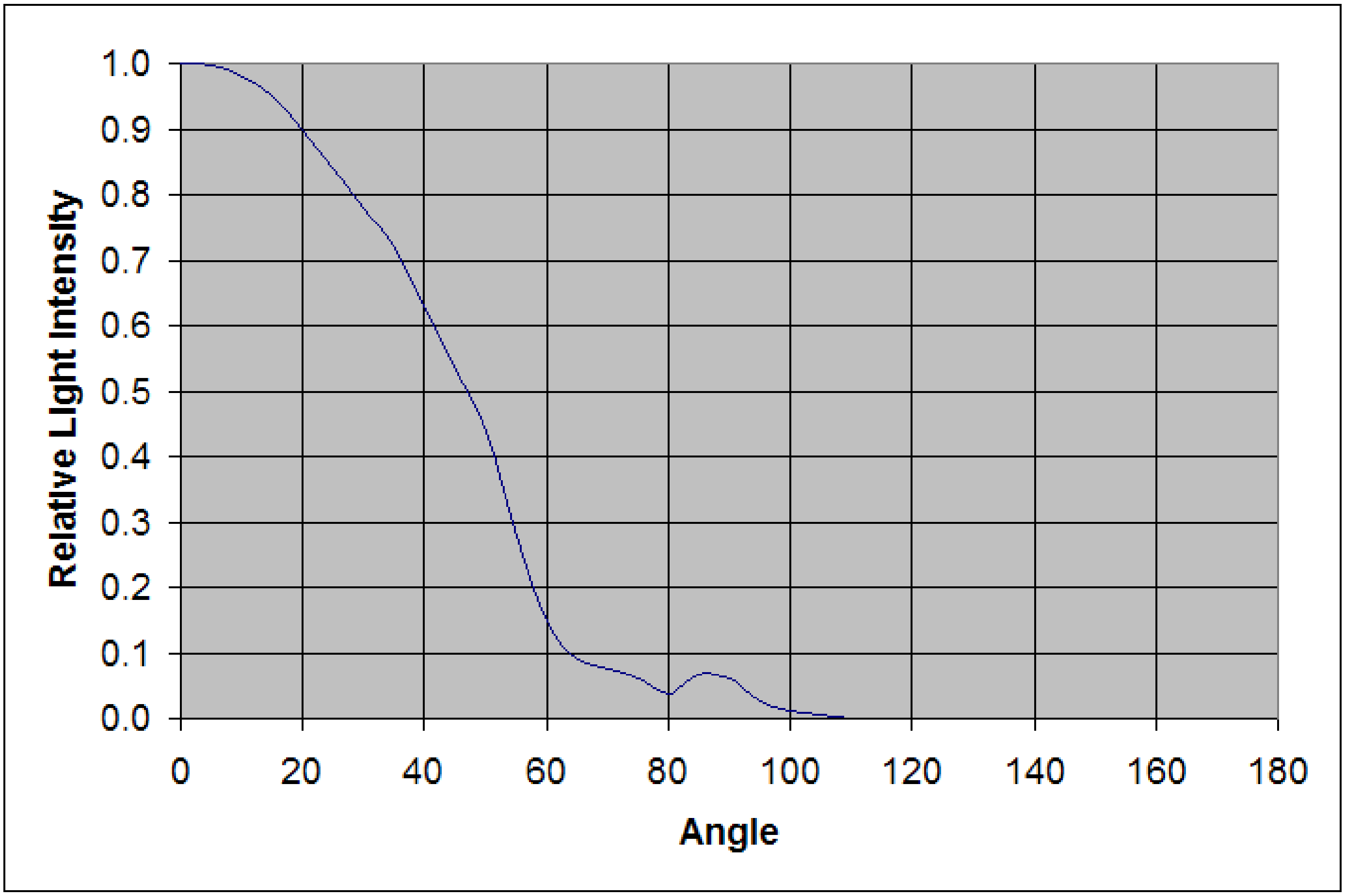
10-01-2007

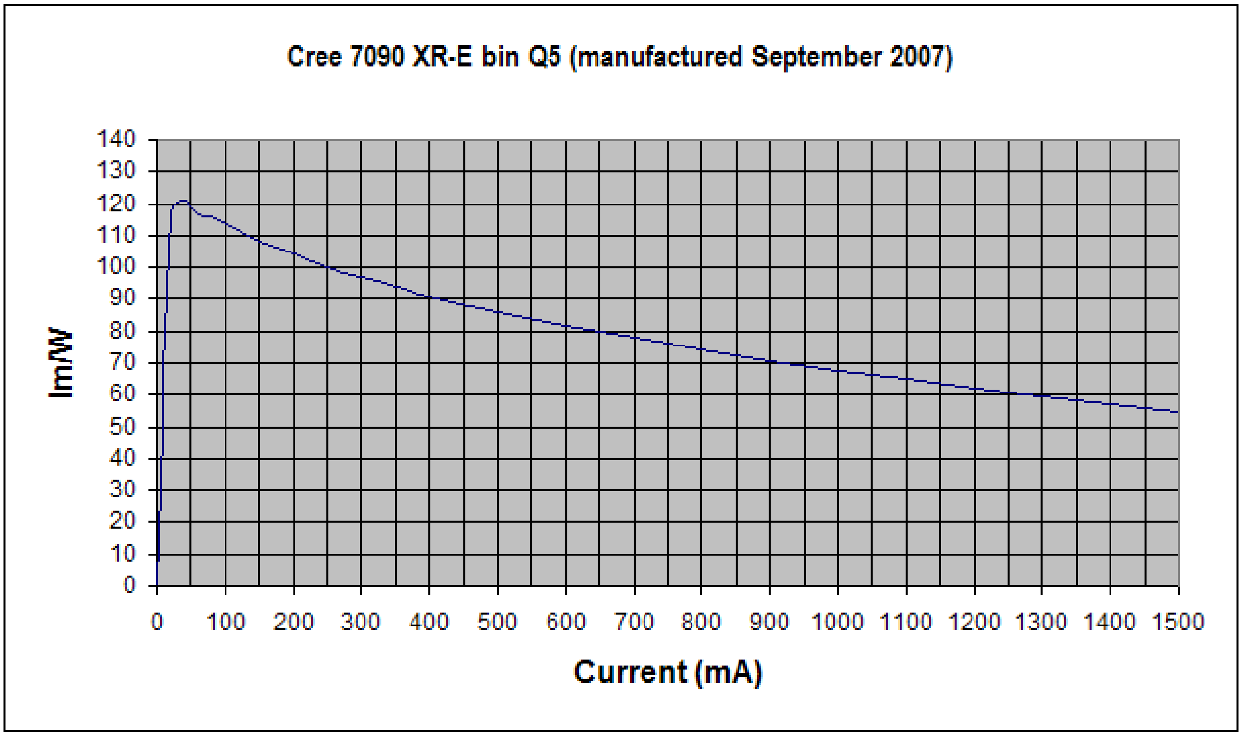
Cree 7090 XR-E bin Q5 (acquired September 2007)

I ordered 10 Q5 Cree XR-Es, bin WG, from CPF member **Erasmus**. The Q5 bin is specified at 107 to 114 lumens at 350 mA. The color temperature of the WG bin is roughly 6000K. The results are a little low (105 lumens at 350 mA), but remember that this is a cooler bin. My correction factor is probably a little too low for such a cool tint, and this is what accounts for the discrepancy. In any case, the difference between the actual measurement and the manufacturer's specification is less than 2%, and my setup is far from 100% accurate anyway. Even if this difference is real, it is well outside what would be noticeable with the eye.

Vf is 3.20V @ 350 mA, efficiency is a very impressive 93.7 lm/W. Note that this is a little less than the corrected results for the Rebel 100 (98.2 lm/W @ 350 mA). However, the Rebel's higher efficiency is nearly all due to its lower Vf (3.14V @ 350 mA), and the fact that it is a warmer tint (and hence reads a little higher on my light meter). Also note that despite the slightly lower output at 350 mA the Cree bests the Rebel in terms of raw output at higher currents (298.5 versus 290.5 lumens at 1500 mA). The Rebel 100 still has a slight edge in efficiency at 1500 mA (56.5 versus 54.7 lm/W) due to its Vf increasing less with current than the Cree Q5. I took the Cree all the way to 2000 mA and it managed 334 lumens.

Results below:


Relative Light Intensity
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
Angle

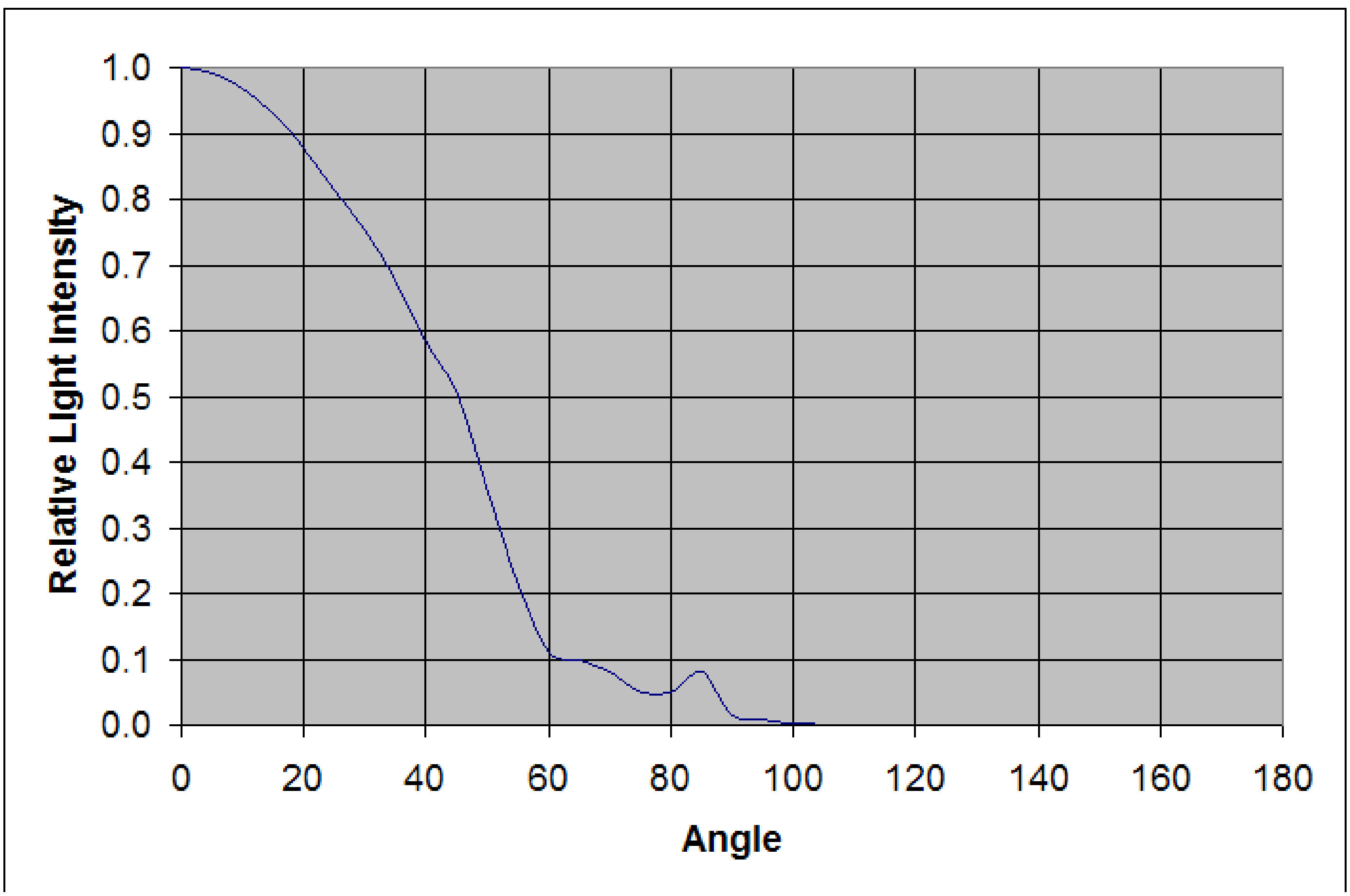

Cree 7090 XR-E bin Q5 (manufactured September 2007)
lm/W
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
Current (mA)

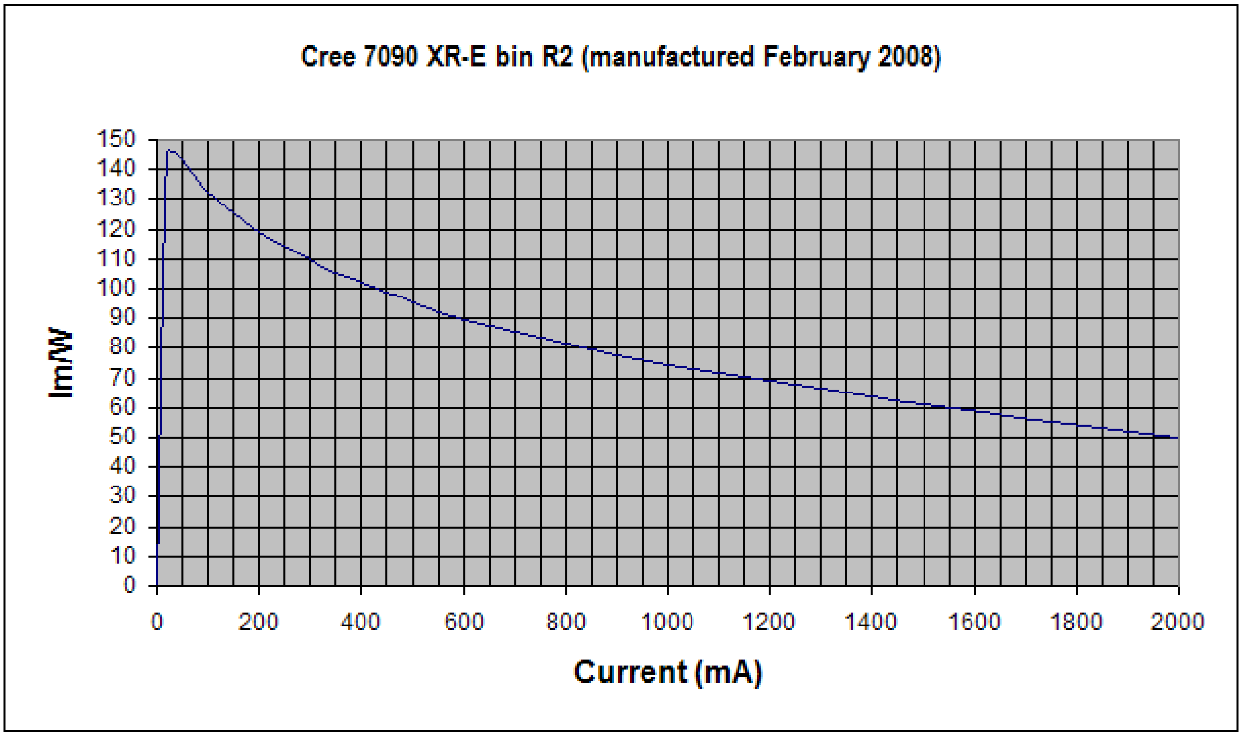
current	Vf	Pin	lumens
0	0.00	0.00	0.00
20	2.74	0.05	6.44
40	2.81	0.11	13.60
60	2.86	0.17	20.04
80	2.90	0.23	26.96
100	2.94	0.29	33.40
150	3.01	0.45	48.91
200	3.07	0.61	63.94
250	3.12	0.78	78.25
300	3.16	0.95	92.09
350	3.20	1.12	104.97
400	3.24	1.30	117.61
500	3.30	1.65	141.95
600	3.35	2.01	164.37
700	3.40	2.38	184.89
800	3.44	2.75	204.21
900	3.47	3.12	220.67
1000	3.50	3.50	237.37
1100	3.53	3.88	251.69
1200	3.56	4.27	265.05
1300	3.59	4.67	276.97
1400	3.62	5.07	288.43
1500	3.64	5.46	298.45

03-27-2008

Cree 7090 XR-E bin R2 (acquired March 2008)

I borrowed an R2 Cree XR-E, bin WG, from CPF member **nein166** for testing. The R2 bin is specified at 114 to 122 lumens at 350 mA. The color temperature of the WG bin is roughly 6000K. The results are as show below:





current	Vf	Pin	lumens
0	0.00	0.00	0.00
20	2.78	0.06	8.12
40	2.87	0.11	16.67
60	2.94	0.18	24.79
80	2.98	0.24	32.46
100	3.03	0.30	40.14
150	3.11	0.47	58.56
200	3.17	0.63	75.67
250	3.22	0.81	92.12
300	3.27	0.98	107.48
350	3.31	1.16	121.96
400	3.35	1.34	136.21
500	3.41	1.71	162.53
600	3.47	2.08	186.88
700	3.51	2.46	210.57
800	3.56	2.85	231.85
900	3.60	3.24	251.81
1000	3.63	3.63	270.89
1100	3.67	4.04	288.66
1200	3.70	4.44	305.33
1300	3.73	4.85	320.68
1400	3.76	5.26	335.38
1500	3.78	5.67	346.78
1750	3.85	6.74	373.32
2000	3.91	7.82	390.87

These results are nothing short of amazing! The output at 350 mA is nearly 122 lumens, well above any previous results for power LEDs at that current. Despite the middle of the road Vf of 3.31V, efficiency at 350 mA is still 105.3 lm/W. It remains above 100 lm/W past 400 mA. Even at 1000 mA, efficiency is nearly 75 lm/W. Things get even more interesting at low currents. Under 50 mA, efficiency hovers around 145 lm/W. This represents a wall-plug, or power-to-light conversion efficiency, of around 45%.

Output scales with current in pretty much the same manner as other XR-Es I've tested. At 1000 mA output is over 270 lumens. It approaches 400 lumens at 2000 mA. Cree has continued to raise the bar for LED performance. While we won't see as dramatic improvements as in the past, Cree has continued to squeeze every last ounce of perfomance from its XR-E line of LEDs. I expect we'll have R4 bins and beyond by this time next year.

07-06-2008

This was a test of a Cree XR-E R2 **saabluster** sent me mounted on a heat pipe attached to a copper plate:

I finally finished the testing. First order of business after drilling the holes and attaching the LED to my heat sink was to determine the nominal output the usual way. My results were 122.97 lumens at 350 mA, slightly above spec actually, but then again the margin of error for my testing is probably a few percent either way. Vf was a somewhat high 3.37V. Efficiency was 104.3 lm/W.

Next order of business was to begin increasing current until either the LED blew, or it didn't get any brighter. For this round of tests I used passive cooling. The heat pipe and copper plate spread the heat to the heat sink, which in turn dissipated it. The results were a little better than my usual setup. Apparently the heat pipe, or perhaps the combination of heat pipe and copper plate, did *something*. At 2 amps the output was 3.35 times the output at 350 mA, compared to 3.21 for the stock setup. The heatpipe provided a small (about 4%) advantage here. As I increased the current past 2 amps I was crossing my fingers for the LED to hold together. Finally at 2.5 amps the output stopped increasing. At 2.6 amps it was a little lower. Peak output was passive cooling was **436.7 lumens**. Vf at 2.5 amps was 4.22V, and total power input was 10.55 watts.

Obviously in the case of passive cooling you'll eventually reach a point of diminishing returns. However, it's a good indication of what a reasonably-sized flashlight body can do if you pump enough current into the LED. The next order of business was the ultimate output which the LED was capable of. To that end I set a large fan to actively cool the heat sink. Throughout the tests the temperature of the copper plate the LED was mounted on remained very close to room temperature. Once the temperature rise of the heat sink was factored out of the equation, I was able to get increasing output past 2.5 amps. The peak output was reached at 2.7 amps. At 2.8 amps it was a little less. The results at 2.7 amps were **453.9 lumens**, Vf was 4.32V, and a power input was 11.664 watts. This is the absolute maximum which this Cree R2 emitter can give under ideal cooling conditions.

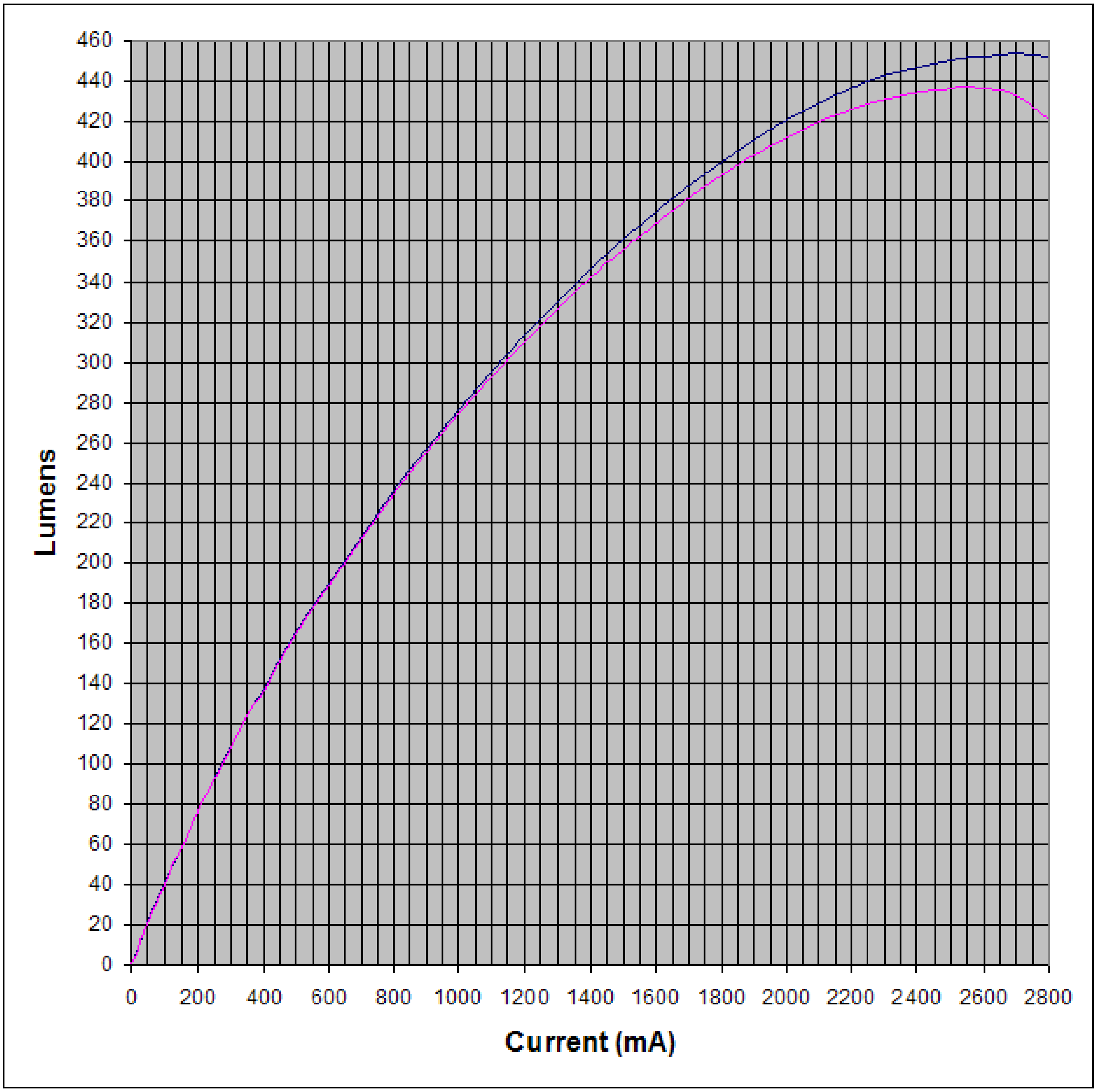
Wanting to continue this "insanity", I bolted the copper plate and LED to the cold plate of one of my thermoelectric assemblies. By the time ice was starting to form on the plate, the LED was giving me **502 lumens** at 2.5 amps. Even though below ambient cooling was required, the 500 lumen barrier for a single emitter was finally broken. Even better, the emitter is none the worse for all the abuse it's been through. It didn't have to die in the name of science.

Here are some charts of the final results:

Lumen output using fan-cooled heatsink

current	Vf	Pin	lumens
0	0.00	0.00	0.00
20	2.81	0.06	8.50
40	2.91	0.12	16.99
60	2.98	0.18	25.04
80	3.03	0.24	33.09
100	3.08	0.31	40.69
150	3.17	0.48	59.03
200	3.24	0.65	76.47
250	3.30	0.83	92.79
300	3.35	1.01	108.44
350	3.40	1.19	123.20
400	3.44	1.38	137.73
500	3.52	1.76	165.01
600	3.58	2.15	190.05
700	3.64	2.55	213.75
800	3.69	2.95	236.56
900	3.74	3.37	257.35
1000	3.79	3.79	276.35
1100	3.83	4.21	295.81
1200	3.87	4.64	313.92
1300	3.91	5.08	330.24
1400	3.94	5.52	346.56
1500	3.97	5.96	360.87
1750	4.05	7.09	393.74
2000	4.12	8.24	420.57
2250	4.19	9.43	439.57
2500	4.26	10.65	450.30
2600	4.29	11.15	452.54
2700	4.32	11.66	453.88
2800	4.35	12.18	452.54

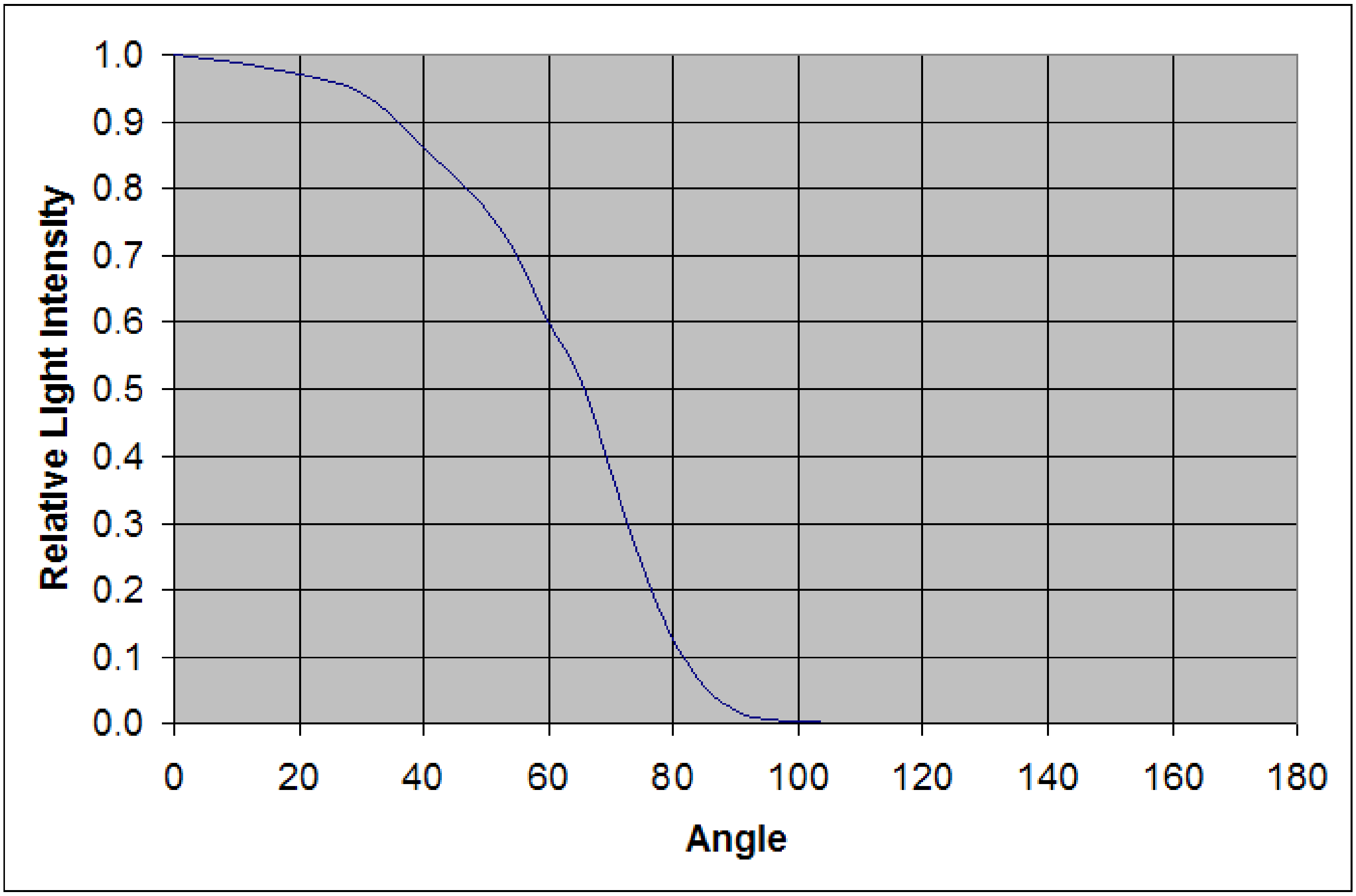
Comparison of passive versus fan-cooled output

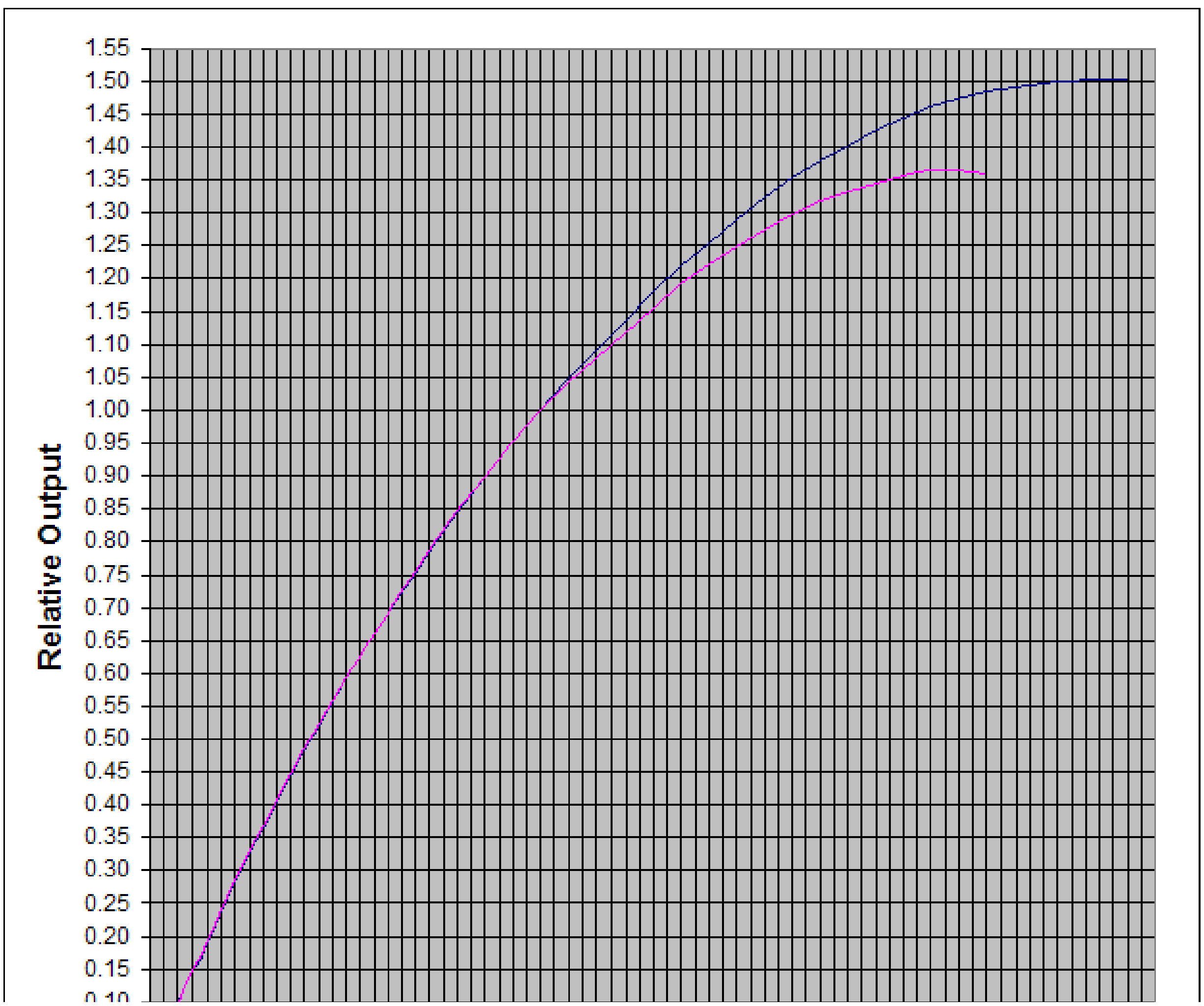


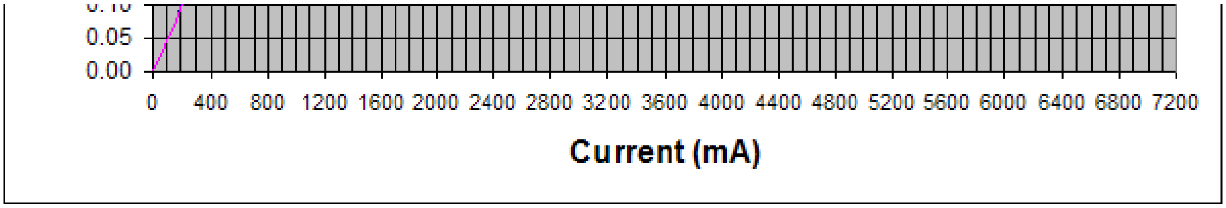
10-20-2008

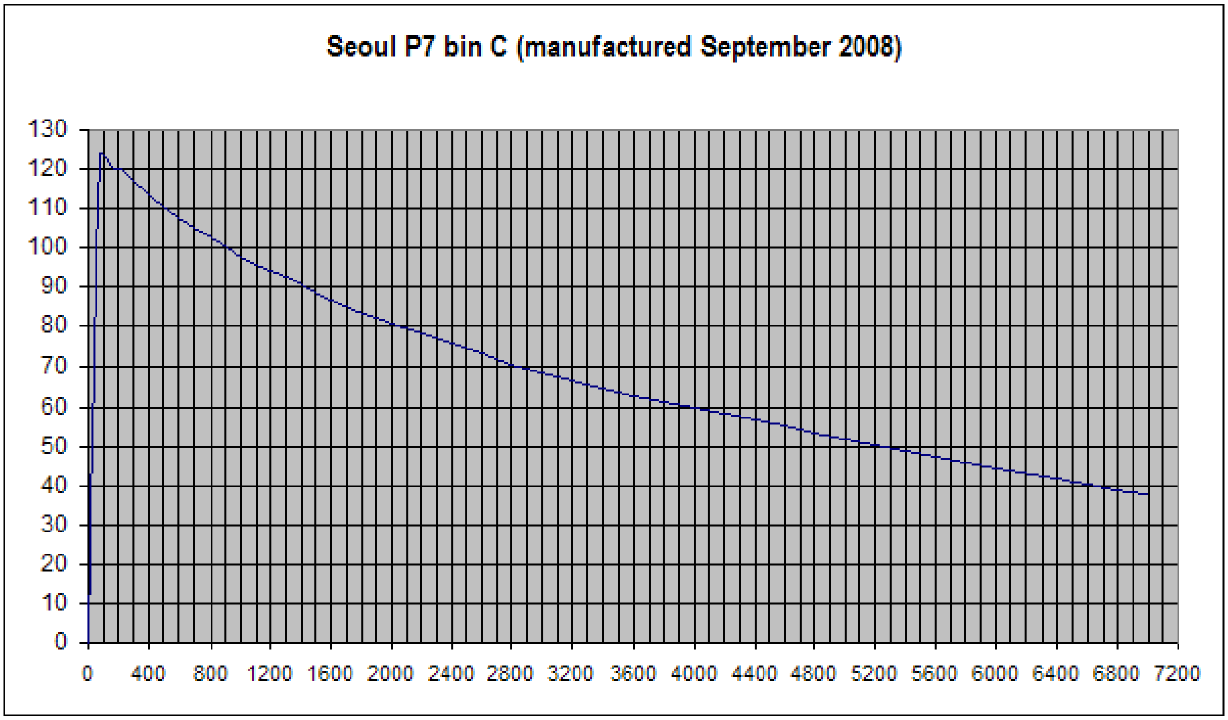
Seoul Semiconductor P7 Bin C (tested October 2008)

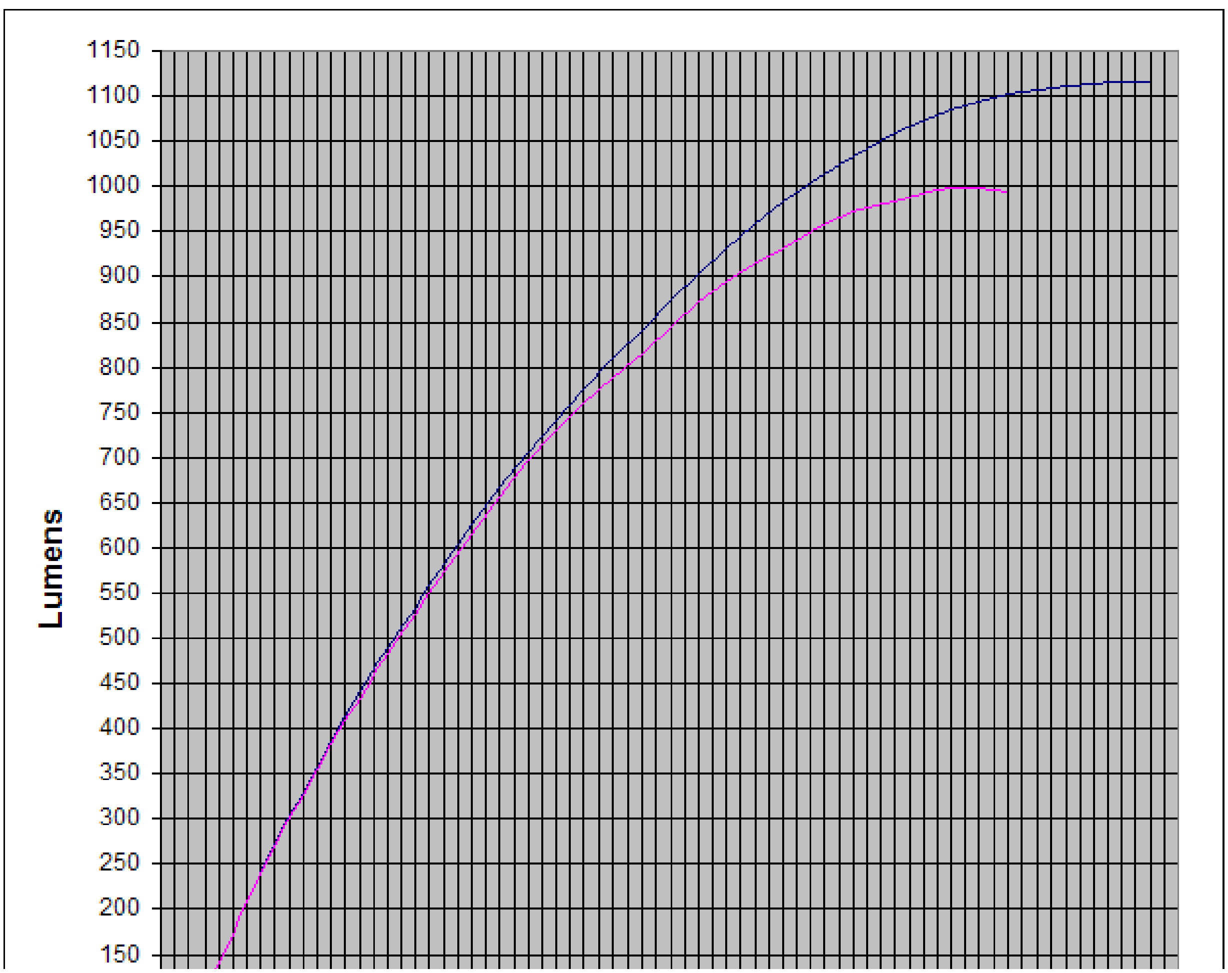
I obtained a Seoul P7 of the highest brightness bin this week. The C bin is rated at between 740 and 900 lumens. For this test I epoxied the P7 to a 60mm heat sink. I tested the output with and without a fan cooling the heat sink. Here are the results:

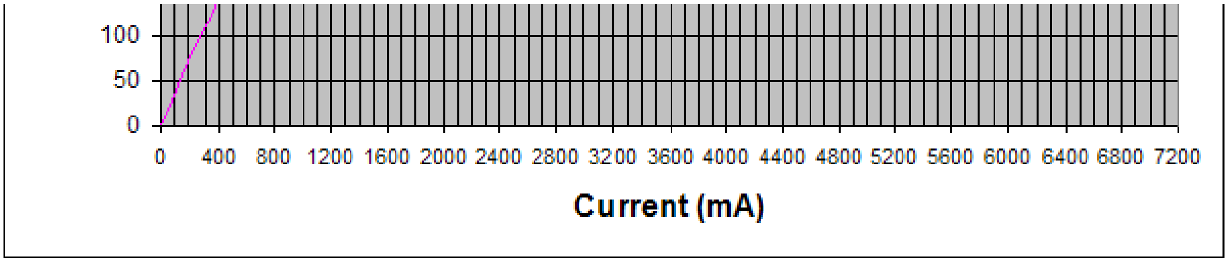

Relative Light Intensity
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
Angle


Relative Output
1.55
1.50
1.45
1.40
1.35
1.30
1.25
1.20
1.15
1.10
1.05
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15


0.05
0.00
0 400 800 1200 1600 2000 2400 2800 3200 3600 4000 4400 4800 5200 5600 6000 6400 6800 7200
Current (mA)


Seoul P7 bin C (manufactured September 2008)
130 120 110 100 90 80 70 60 50 40 30 20 10 0
0 400 800 1200 1600 2000 2400 2800 3200 3600 4000 4400 4800 5200 5600 6000 6400 6800 7200


Lumens
1150 1100 1050 1000 950 900 850 800 750 700 650 600 550 500 450 400 350 300 250 200 150



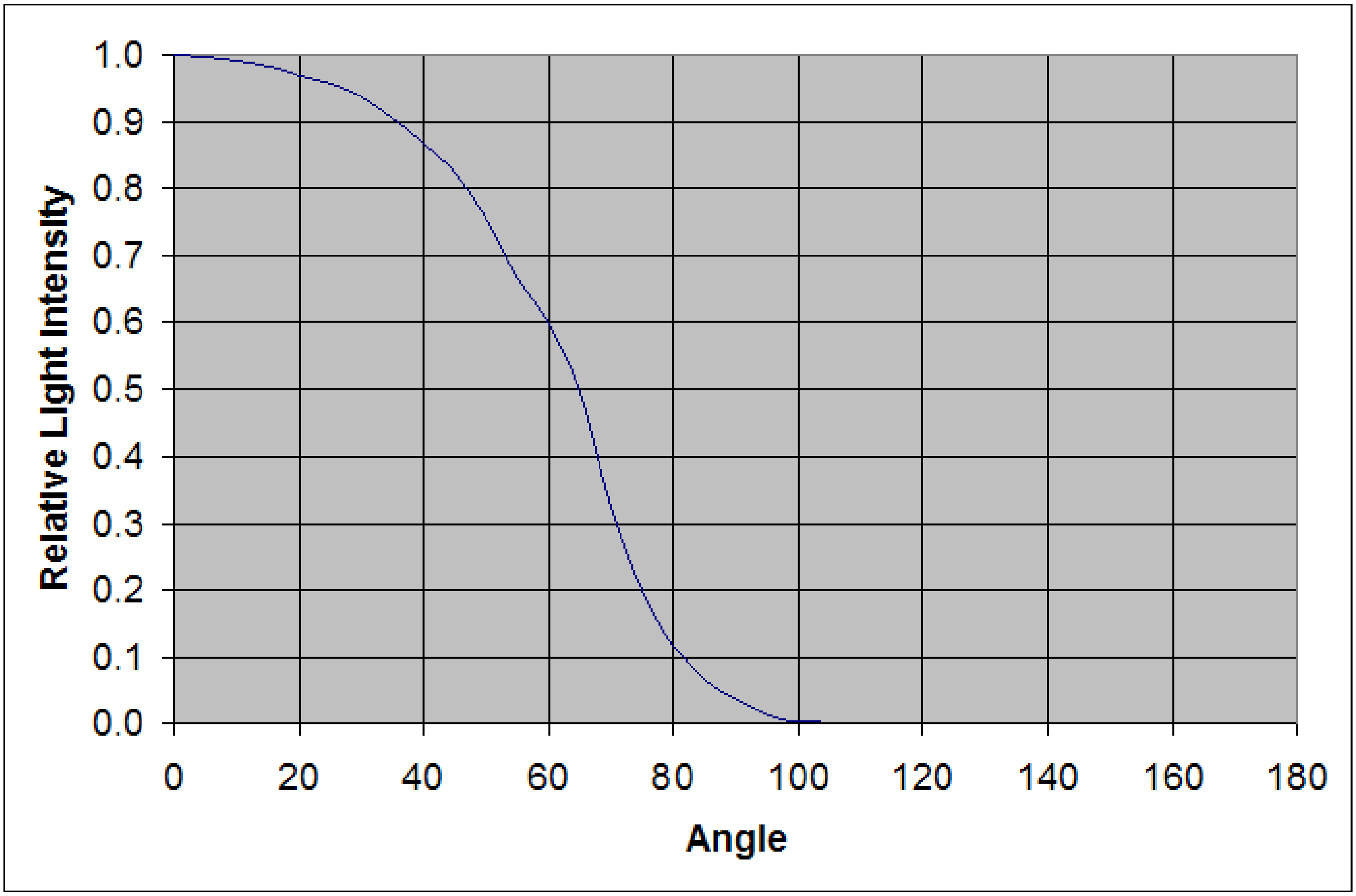
current	Vf	Pin	lumens
0	0.00	0.00	0.00
80	2.83	0.23	27.95
160	2.94	0.47	56.69
240	3.01	0.72	86.19
320	3.07	0.98	114.15
400	3.11	1.24	141.32
600	3.21	1.93	206.94
800	3.30	2.64	270.61
1000	3.36	3.36	328.85
1200	3.42	4.10	385.54
1400	3.48	4.87	440.67
1600	3.52	5.63	489.20
2000	3.61	7.22	581.61
2400	3.68	8.83	667.02
2800	3.75	10.50	741.95
3200	3.80	12.16	811.34
3600	3.86	13.90	874.89
4000	3.91	15.64	931.00
4400	3.95	17.38	983.33
4800	4.00	19.20	1024.45
5200	4.05	21.06	1058.11
5600	4.09	22.90	1084.28
6000	4.13	24.78	1102.99
6400	4.17	26.69	1110.45
6800	4.21	28.63	1114.17
7000	4.23	29.61	1114.17

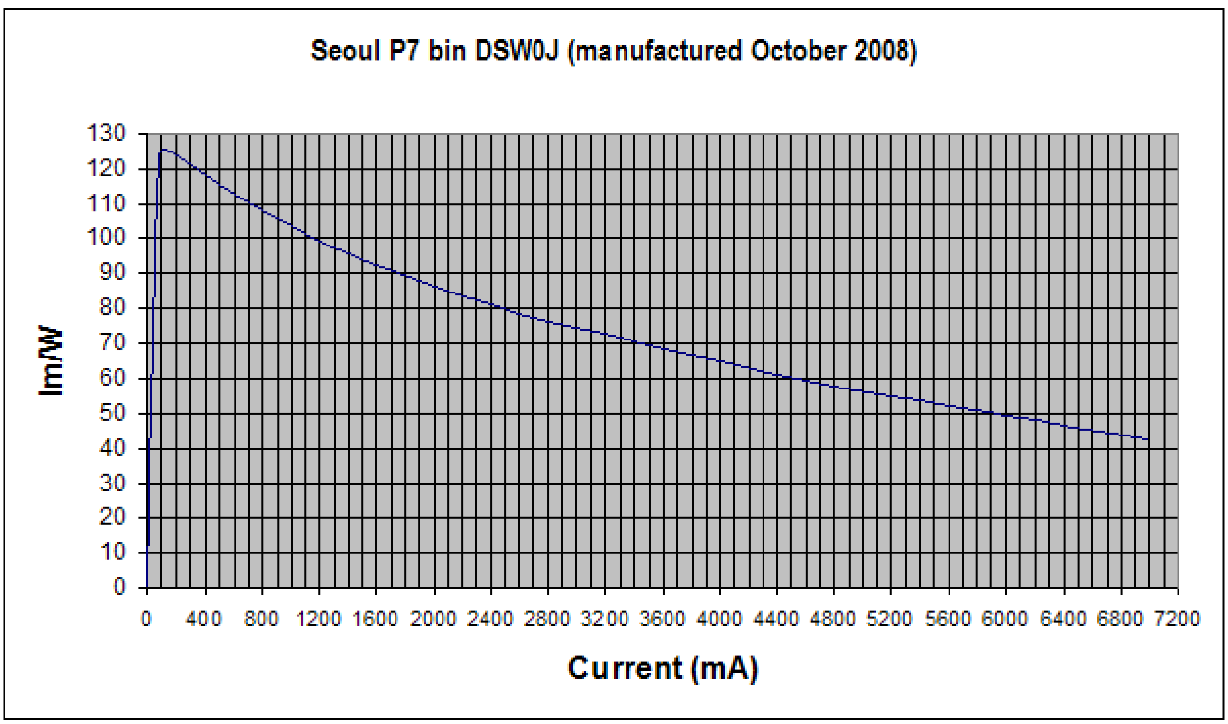
At the nominal current of 2800 mA the fan makes only a small difference. Output is 731 lumens without the fan, and 742 lumens with fan cooling. This is barely but still within ratings. Efficiency at nominal current is 70.7 lm/W, good but certainly not in the same league as the latest single-die Cree or Seoul LEDs running at a comparable current of 700 mA. However, that's to be expected since the thermal path per die for the P7 isn't as good as for the Seoul P4 or Cree XR-E. If you underdrive the P7 then you can get significantly greater efficiency. For example, at 1000 mA the efficiency is 97.9 lm/W, way better than even an R2 bin XR-E at that current, and output is 329 lumens, about 20% greater than the Cree at that current. At 350 mA the P7 can manage 115 lm/W and 125 lumens, both figures somewhat greater than the best single die LEDs. Efficiency peaks in the 125 lm/W area at currents under 100 mA. Output versus current actually remains linear to well under 10 mA, but with the slight drop in Vf you're only gaining a few percent efficiency compared to 100 mA.

The results when cranking up the current are interesting. Without the fan cooling the heat sink, the output levels off at 6 amps and 998 lumens. With the fan I was able to go to 7 amps and 1114 lumens, although the increase in output was flat from 6.8 to 7.0 amps. The increase from 6.5 to 6.8 amps barely registered on my light meter. Therefore, even with very good forced-air cooling there is no point taking the P7 past about 6.5 amps, and only then if you want to squeeze out every last lumen. In fact, if you consider that the eye can't detect brightness differences of 10%, then the absolute maximum current of the P7 should be no more than around 4.5 amps, even less with the heat sinking typically available in flashlight bodies. At 4.5 amps you will get about 1000 lumens with very good cooling. Note however that 1000 lumens is only 35% more than what the P7 will give you at its nominal current of 2.8 amps. The lumen increases from overdriving the P7 just aren't as dramatic as with single die LEDs. In a typical situation with less than stellar heat-sinking I doubt it even pays to go above the nominal 2.8 amp current.

01-13-2009

Gryloc sent me a pair of DSW0J Seoul Semiconductor P7s and one each of U2SW0H and U2SV0H P4s. One of the P7s appeared defective (it didn't light up until driven at around 1 amp, and output was reduced compared to the good one). Here are the results of the good P7:

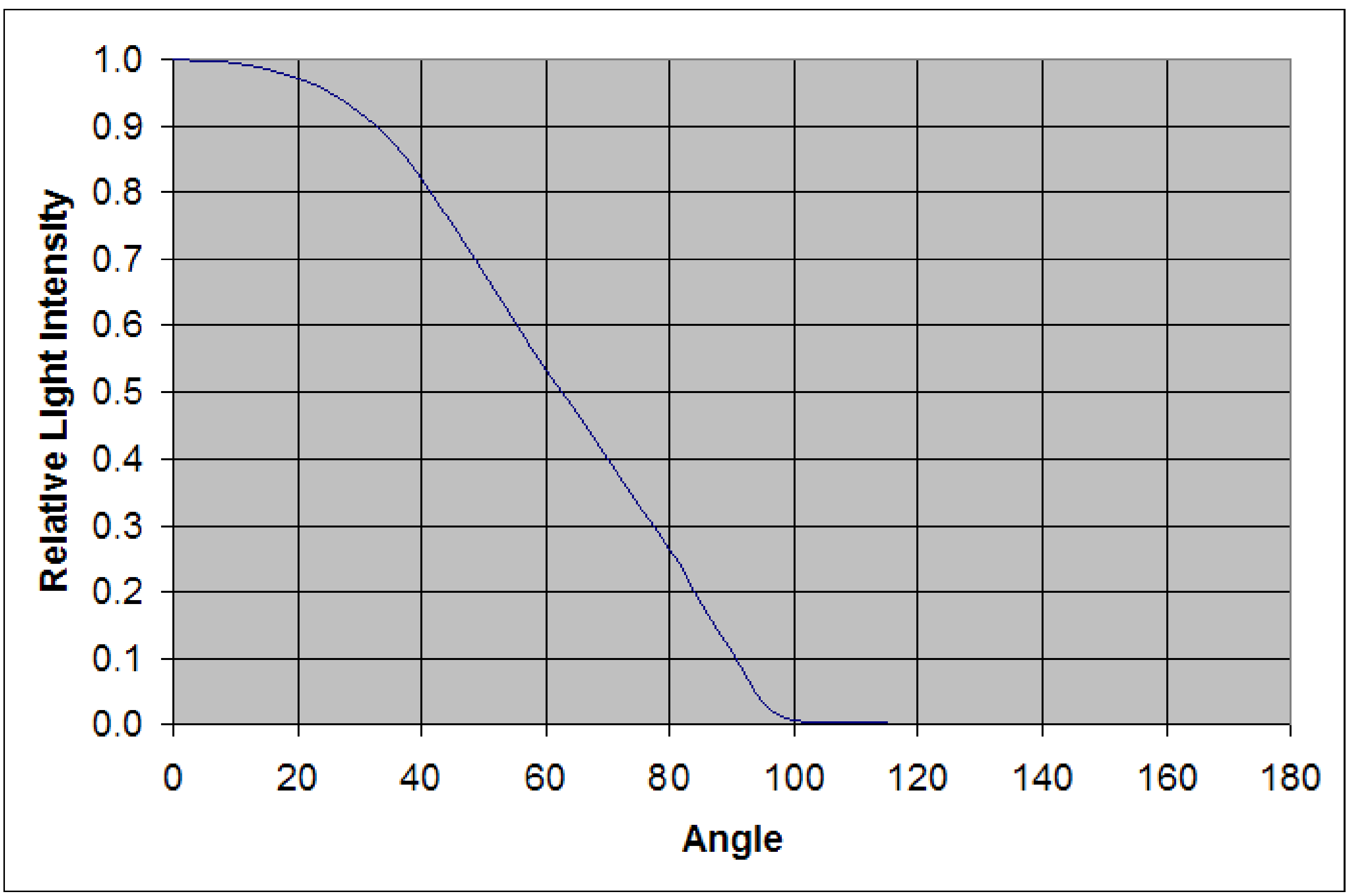

Relative Light Intensity
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
Angle

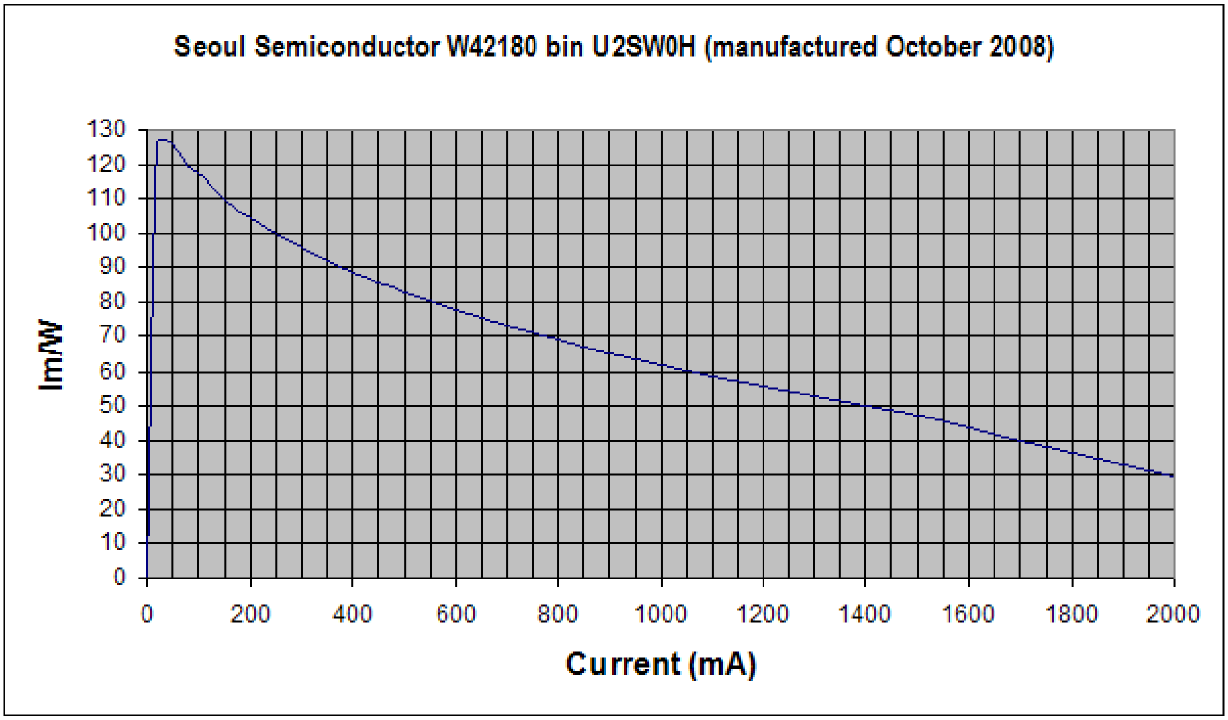

Seoul P7 bin DSW0J (manufactured October 2008)
lm/W
130
120
110
100
90
80
70
60
50
40
30
20
10
0
0
400
800
1200
1600
2000
2400
2800
3200
3600
4000
4400
4800
5200
5600
6000
6400
6800
7200
Current (mA)

current	Vf	Pin	lumens
0	0.00	0.00	0.00
80	2.75	0.22	27.42
160	2.84	0.45	56.75
240	2.91	0.70	86.08
320	2.96	0.95	114.65
400	3.01	1.20	142.45
600	3.10	1.86	209.87
800	3.18	2.54	274.62
1000	3.24	3.24	335.56
1200	3.30	3.96	393.07
1400	3.34	4.68	447.54
1600	3.39	5.42	500.48
2000	3.47	6.94	599.51
2400	3.53	8.47	685.59
2800	3.59	10.05	765.30
3200	3.64	11.65	842.56
3600	3.69	13.28	905.11
4000	3.73	14.92	963.98
4400	3.77	16.59	1019.17
4800	3.81	18.29	1063.32
5200	3.84	19.97	1103.79
5600	3.88	21.73	1133.23
6000	3.92	23.52	1158.98
7000	4.00	28.00	1195.78

Output at 2800 mA is only a little lower than the speced value of 800 to 900 lumens. Note that I was able to reach nearly 1200 lumens at 7 amps. Unlike the last P7 test, this time around I always had a fan cooling the heat sink in order to maximize output.

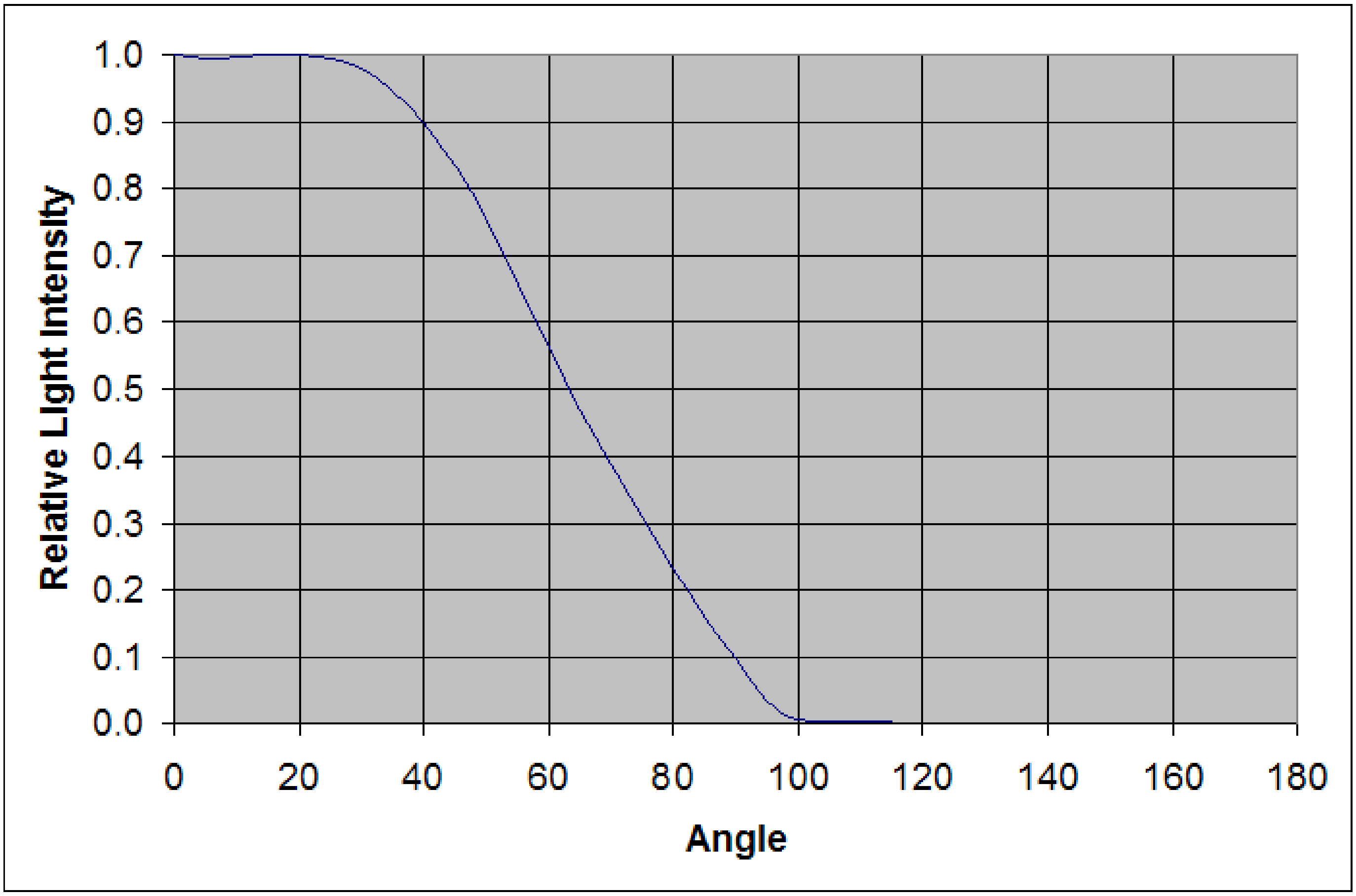
Here are the results of the U2SW0H:

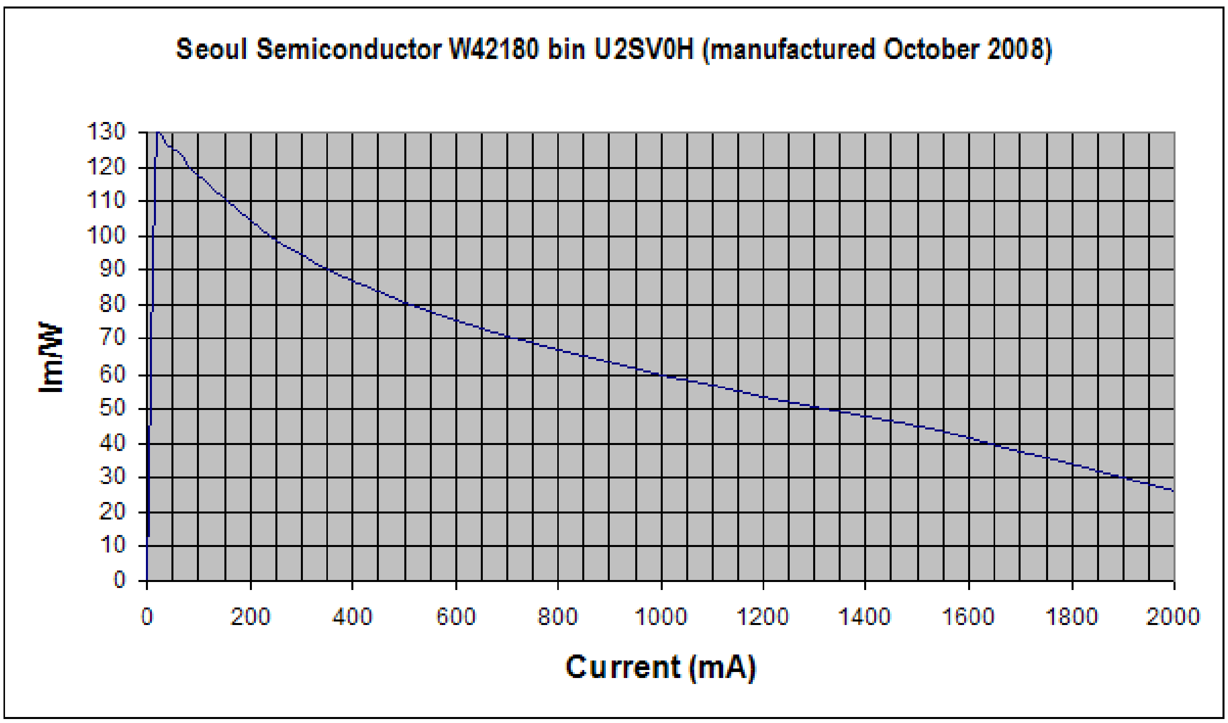




current	Vf	Pin	lumens
0	0.00	0.00	0.00
20	2.67	0.05	6.76
40	2.74	0.11	13.91
60	2.79	0.17	20.67
80	2.84	0.23	27.03
100	2.88	0.29	33.78
150	2.95	0.44	48.49
200	3.01	0.60	62.80
250	3.07	0.77	76.71
300	3.11	0.93	89.43
350	3.16	1.11	101.35
400	3.20	1.28	112.88
500	3.26	1.63	134.34
600	3.32	1.99	154.21
700	3.38	2.37	172.10
800	3.43	2.74	188.79
900	3.48	3.13	203.90
1000	3.52	3.52	217.81
1100	3.56	3.92	230.13
1200	3.60	4.32	241.26
1300	3.63	4.72	250.80
1400	3.67	5.14	258.75
1500	3.70	5.55	263.52
1750	3.78	6.62	251.20
2000	3.84	7.68	226.95

Here are the results of the U2SV0H:


Relative Light Intensity
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
Angle


Seoul Semiconductor W42180 bin U2SV0H (manufactured October 2008)
lm/W
130
120
110
100
90
80
70
60
50
40
30
20
10
0
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Current (mA)

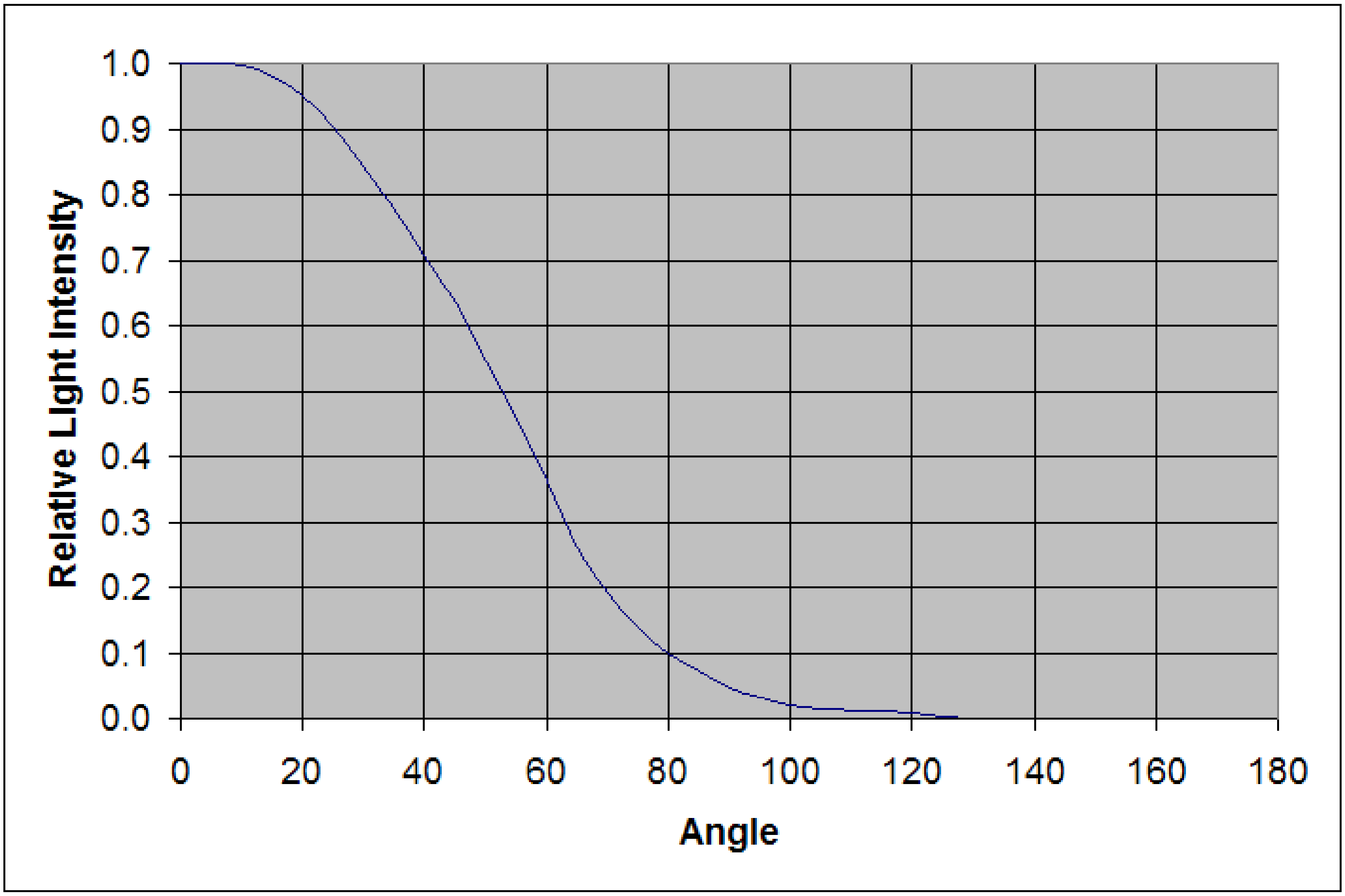
current	Vf	Pin	lumens
0	0.00	0.00	0.00
20	2.70	0.05	7.01
40	2.77	0.11	14.02
60	2.82	0.17	21.04
80	2.87	0.23	27.63
100	2.91	0.29	34.23
150	2.99	0.45	49.50
200	3.05	0.61	63.52
250	3.11	0.78	76.72
300	3.15	0.95	89.50
350	3.20	1.12	101.05
400	3.24	1.30	112.60
500	3.31	1.66	133.23
600	3.37	2.02	151.79
700	3.43	2.40	169.93
800	3.48	2.78	185.20
900	3.54	3.19	201.28
1000	3.58	3.58	214.07
1100	3.62	3.98	226.03
1200	3.67	4.40	236.34
1300	3.71	4.82	244.59
1400	3.74	5.24	252.01
1500	3.78	5.67	256.96
1750	3.86	6.76	243.76
2000	3.97	7.94	209.94

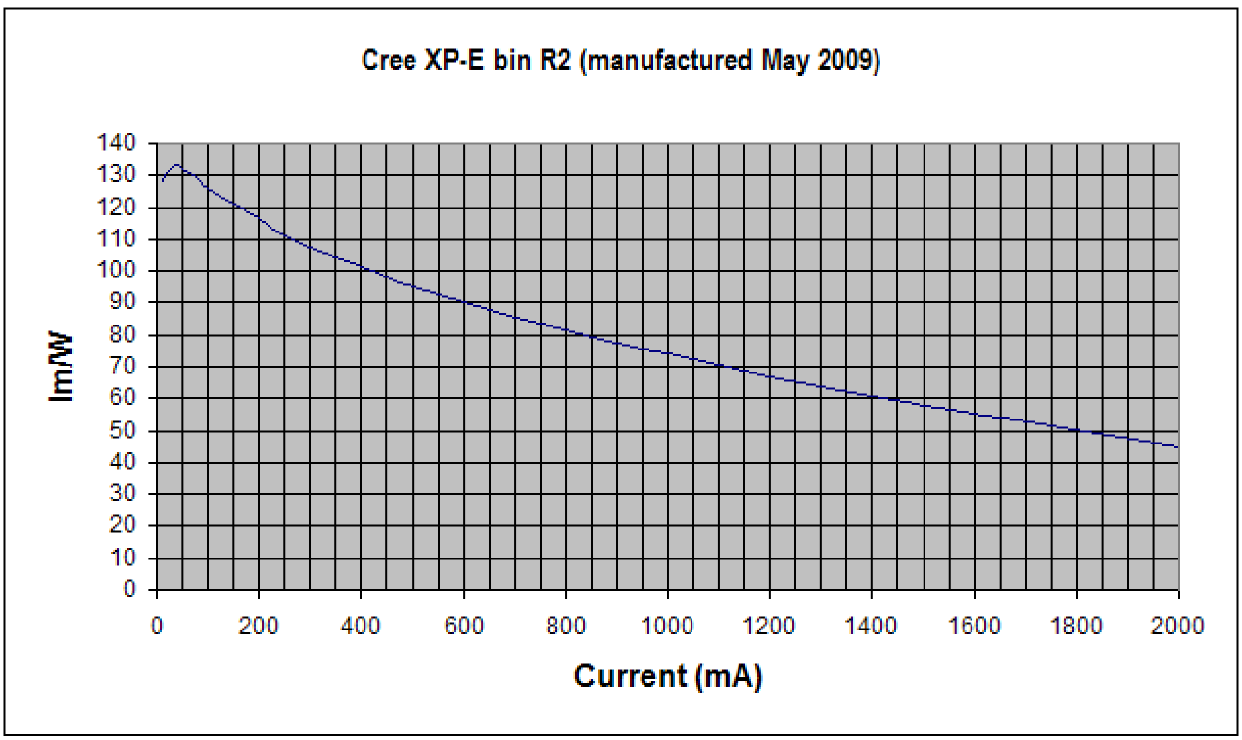
The U2 bin is speced for 100 to 118.5 lumens. Both samples met this spec, although on the low side. Although not quite in the same league as Cree's best XR-E bins, these are close enough that most couldn't tell the difference by eye. Note that the efficiency of these really falls off above 1500 mA, and not much past 1500 mA the output levels off. At 2000 mA the output is quite a bit less, and the LEDs also turn an angry blue color. Hence, I only drove them a few seconds at that level.

07-21-2009

Cree 7090 XP-E bin R2 (acquired May 2009)

I borrowed an R2 Cree XP-E, from CPF member **nein166** for testing. The R2 bin is specified at 114 to 122 lumens at 350 mA. The color temperature of this sample was roughly 6500K. The results are as show below:


Relative Light Intensity
Angle
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180


Cree XP-E bin R2 (manufactured May 2009)
lm/W
Current (mA)
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
0
200
400
600
800
1000
1200
1400
1600
1800
2000

current	Vf	Pin	lumens
10	2.63	0.03	3.37
20	2.69	0.05	7.05
40	2.76	0.11	14.71
60	2.81	0.17	22.06
80	2.85	0.23	29.42
100	2.89	0.29	36.47
150	2.96	0.44	53.63
200	3.01	0.60	70.18
250	3.06	0.77	85.19
300	3.10	0.93	99.90
350	3.13	1.10	114.61
400	3.16	1.26	127.79
500	3.22	1.61	153.22
600	3.26	1.96	176.82
700	3.30	2.31	197.65
800	3.34	2.67	217.57
900	3.37	3.03	235.35
1000	3.40	3.40	252.20
1100	3.43	3.77	266.91
1200	3.46	4.15	277.02
1300	3.49	4.54	288.97
1400	3.51	4.91	298.17
1500	3.53	5.30	305.83
1750	3.59	6.28	322.38
2000	3.64	7.28	326.97

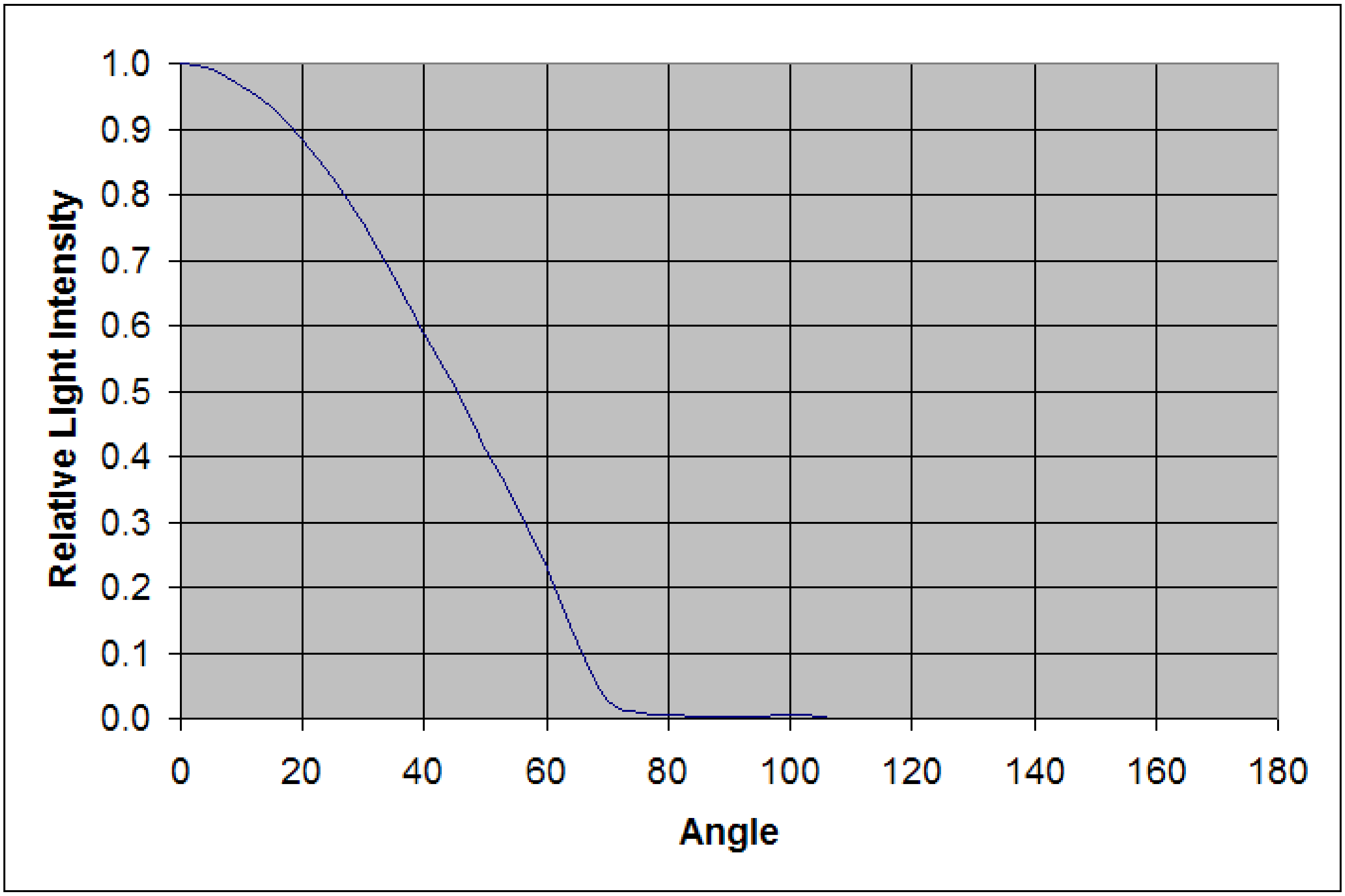
These results are excellent! The output at 350 mA is nearly 114.6 lumens, meeting spec. Vf is a very low 3.13V and efficiency at 350 mA is 104.6 lm/W. It remains above 100 lm/W past 400 mA. At 1000 mA, efficiency is nearly 75 lm/W. Efficiency at very low currents peaks at around 133 lm/W around 40 mA. This isn't quite as good as the R2 XR-E samples I've testing. Also note that I've added a new test point at 10 mA for power LEDs so that the inflection point where efficiency drops shows up more clearly in my graphs. More interesting than the results at low current is the high current performance. Despite the tiny package, the XP-E does quite well at higher currents. At 1000 mA output is 252 lumens. At 2000 mA it reaches 330 lumens. While these figures aren't quite as good as the XR-E's ~270 and ~400 lumens, respectively, they are more than I expected given the XP-E's package size and thermal path. I'll also note that my mounting method was less than optimal. I attached the LED with Arctic Alumina thermal epoxy. Had it been soldered to the heat sink, I think my results would have been somewhat higher.

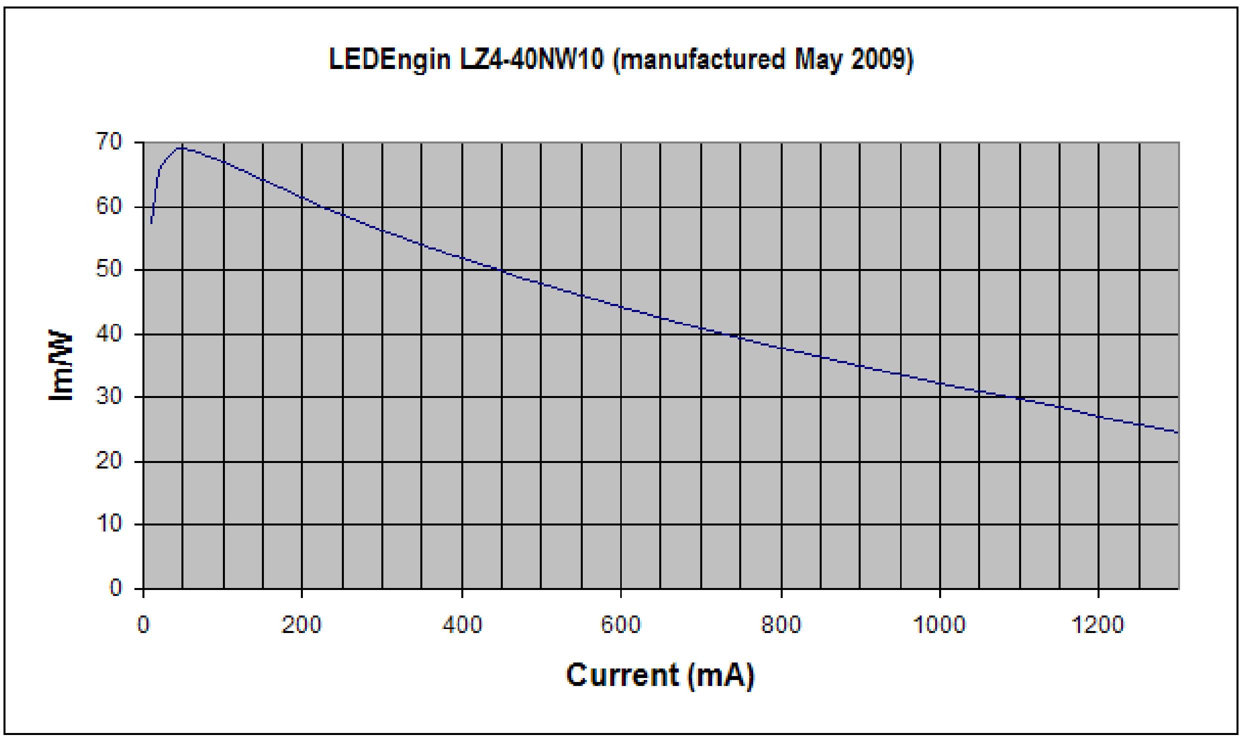
07-21-2009

CPF member **HarryN** arranged for several LEDs to be sent to me for testing. One was the LEDEngin LZ4-40NW10 10 watt neutral white star. The others were the K2 TFFC cool white -220 and the K2 neutral white -180. Here are the results:

LEDEngin LZ4-40NW10 10 watt neutral white (acquired July 2009)

The 10 watt LEDEngin is a 4-die series connnected LED designed for the general lighting market. The dome is about the same size as that of the SSC P7 and is translucent rather than clear. The output is speced at 400 lumens at 700 mA. Here are the test results:


Relative Light Intensity
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
Angle

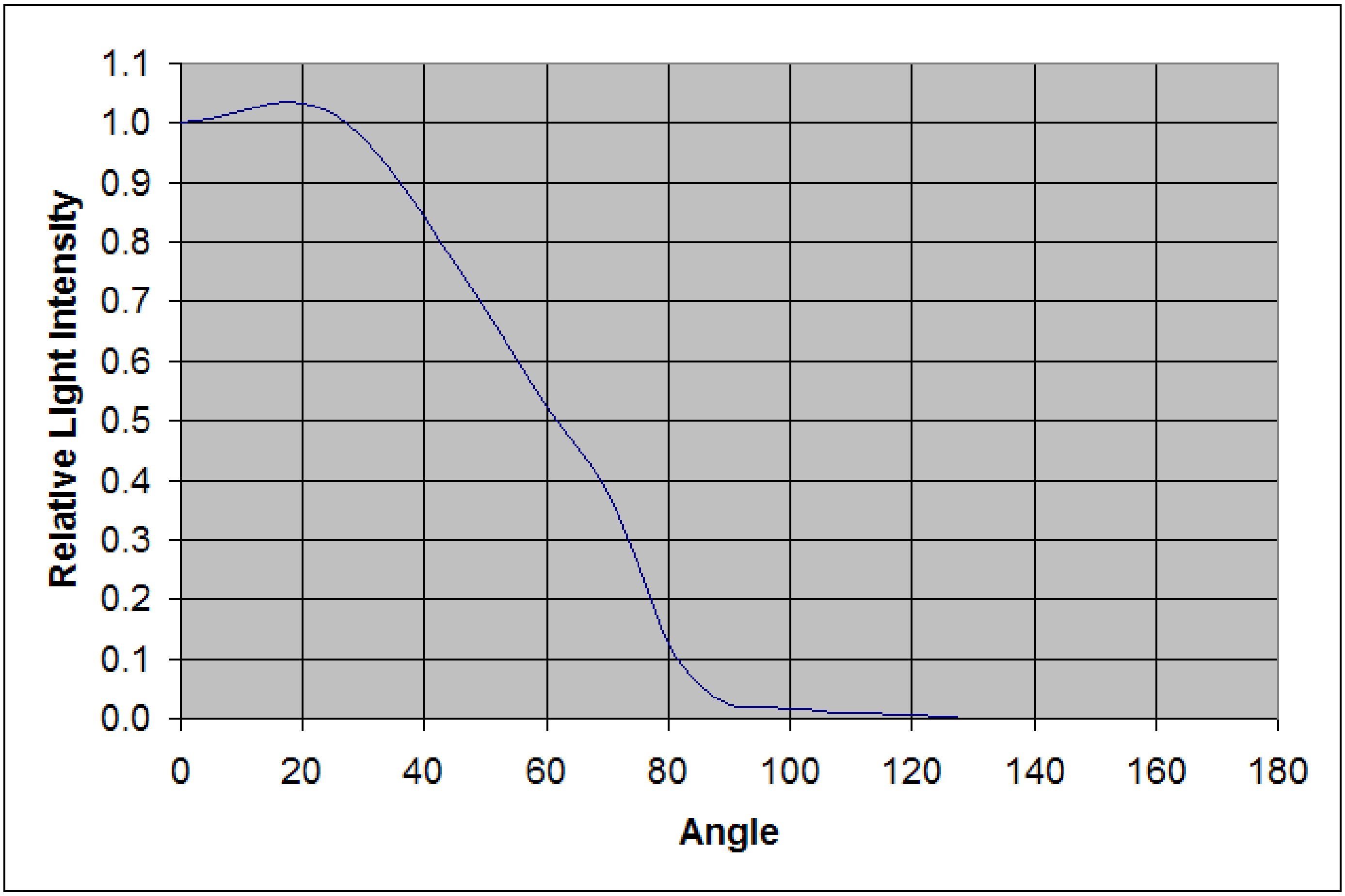

LEDEngin LZ4-40NW10 (manufactured May 2009)
lm/W
70
60
50
40
30
20
10
0
0
200
400
600
800
1000
1200
Current (mA)

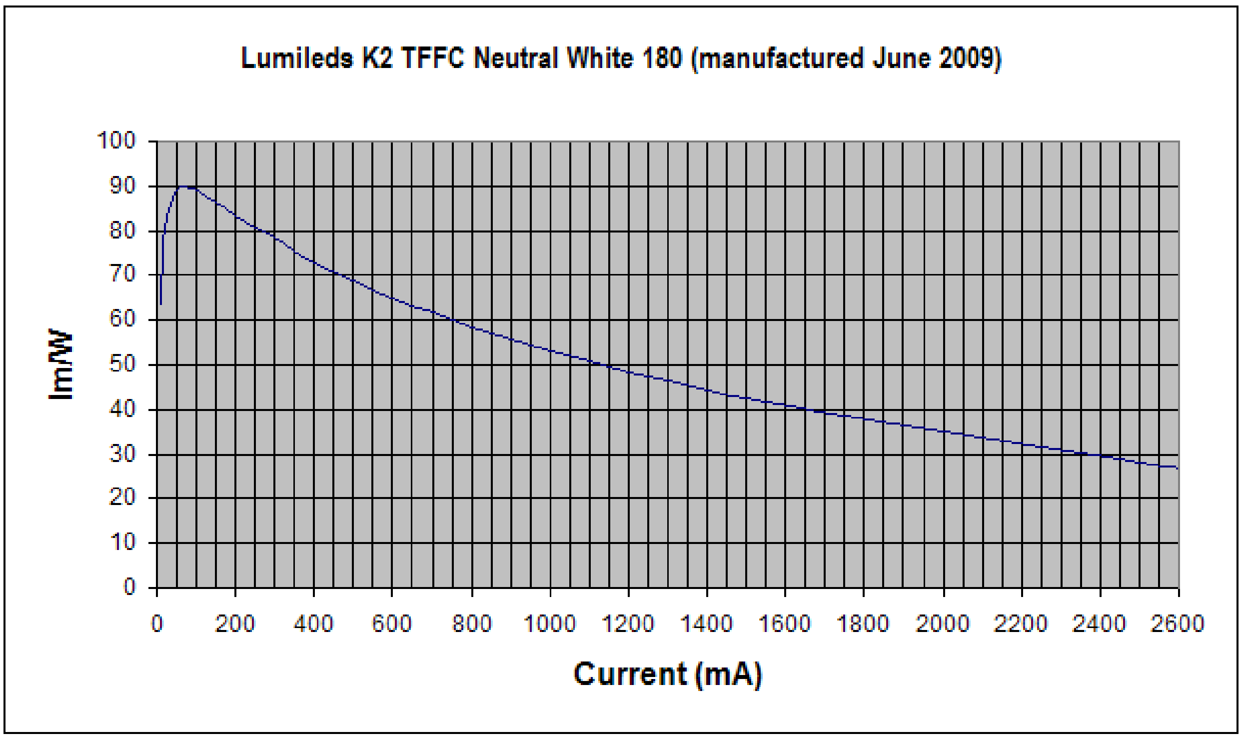
current	Vf	Pin	lumens
10	10.43	0.10	5.98
20	10.66	0.21	13.96
40	10.96	0.44	30.14
60	11.18	0.67	46.10
80	11.37	0.91	61.84
100	11.53	1.15	77.13
150	11.86	1.78	113.93
200	12.14	2.43	148.73
250	12.38	3.10	181.75
300	12.60	3.78	212.56
350	12.80	4.48	242.04
400	12.99	5.20	268.86
500	13.34	6.67	318.95
600	13.67	8.20	362.62
700	13.96	9.77	399.85
800	14.25	11.40	430.88
900	14.53	13.08	456.37
1000	14.82	14.82	475.66
1100	15.11	16.62	492.72
1200	15.40	18.48	501.37
1300	15.69	20.40	501.37

Color temperature looks to be around 4000K and beam angle is 90°, somewhat narrower than on most power LEDs but still fairly wide. Output at 700 mA meets spec almost exactly at 399.9 lumens. Vf is 13.96 V, or 3.49 volts per die, power input is 9.77 watts, and efficiency is only 40.9 lm/W. Keep in mind however that warm and neutral white LEDs generally don't perform as well as their cool white counterparts. Output doesn't scale much with current, leveling off at a bit over 500 lumens at 1300 mA. Overall the LEDEngin appears to be well made. It would be nice to see this product made with higher performing dice.

Lumileds K2 TFFC neutral white -180 (acquired July 2009)

This is the highest available bin of Lumiled's neutral white K2 presently available. The spec sheet does list a 200 lumen bin, but Future so far doesn't carry it. The 180 lumen spec is at a drive current of 1000 mA. Here are the results:


Relative Light Intensity
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
Angle

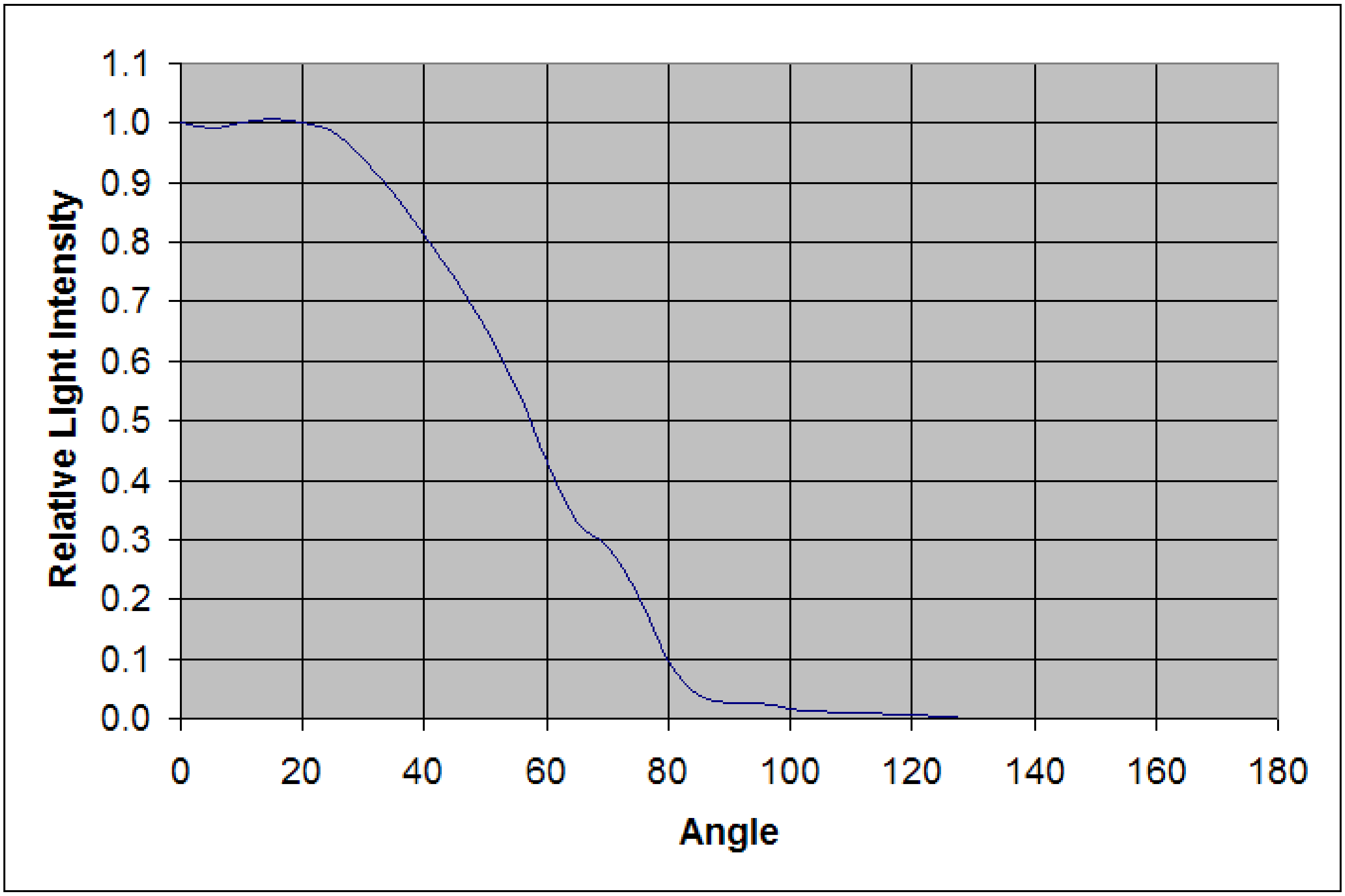

Lumileds K2 TFFC Neutral White 180 (manufactured June 2009)
lm/W
100
90
80
70
60
50
40
30
20
10
0
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
Current (mA)

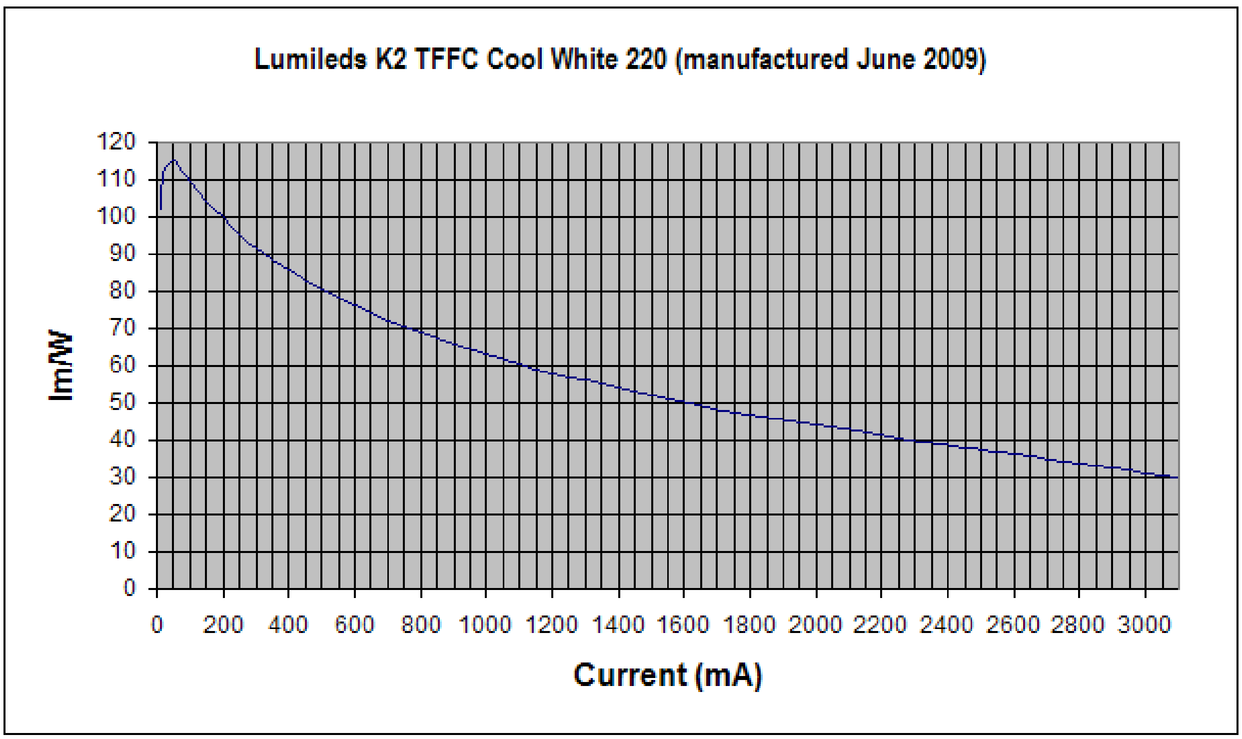
current	Vf	Pin	lumens
10	2.68	0.03	1.71
20	2.75	0.06	4.44
40	2.84	0.11	9.91
60	2.91	0.17	15.72
80	2.96	0.24	21.18
100	3.00	0.30	26.65
150	3.08	0.46	39.98
200	3.15	0.63	52.62
250	3.20	0.80	64.58
300	3.25	0.98	76.53
350	3.29	1.15	86.78
400	3.33	1.33	96.69
500	3.40	1.70	116.85
600	3.45	2.07	134.28
700	3.50	2.45	151.36
800	3.55	2.84	165.71
900	3.59	3.23	180.06
1000	3.63	3.63	192.70
1100	3.67	4.04	205.00
1200	3.71	4.45	215.25
1300	3.74	4.86	225.50
1400	3.77	5.28	234.73
1500	3.80	5.70	243.61
1750	3.86	6.76	261.72
2000	3.93	7.86	274.36
2250	3.98	8.96	282.22
2500	4.03	10.08	284.61
2600	4.05	10.53	283.59

Color temperature looks to be in the high 3000s. As can be seen, the K2 TFFC neutral white 180 exceeds the spec at 1000 mA with nearly 193 lumens. Lumileds also specifies typical figures of 85, 150, and 250 lumens at 350 mA, 700 mA, and 1500 mA, respectively. The test results at these respective currents were 86.8, 151.4, and 243.6 lumens, all either exceeding or very close to specification. Vf at 350 mA is 3.29 volts, and only rises to 4.03 volts at 2500 mA. This brings me to the area where I was most impressed with the K2. Its output scaled very well with current. While the scaling with current up to about 1500 mA was about the same as similar products from Cree, above 1500 mA was where the K2 shined (pun intended). Cree XR-Es typically level off in output once current gets slightly above 2000 mA. The K2 neutral white increased in output up to 2600 mA. It may have done even better if I had soldered it to the heat sink instead of using Arctic Alumina thermal epoxy. Peak output at 2600 mA was close to 285 lumens. Granted, this is only 14% more than the 1500 mA output, but it nevertheless indicates superior ability to deal with the thermal effects of higher current.

Lumileds K2 TFFC cool white -220 (acquired July 2009)

This is the highest available bin of Lumiled's cool white K2 presently available. The 220 lumen spec is at a drive current of 1000 mA. Here are the results:

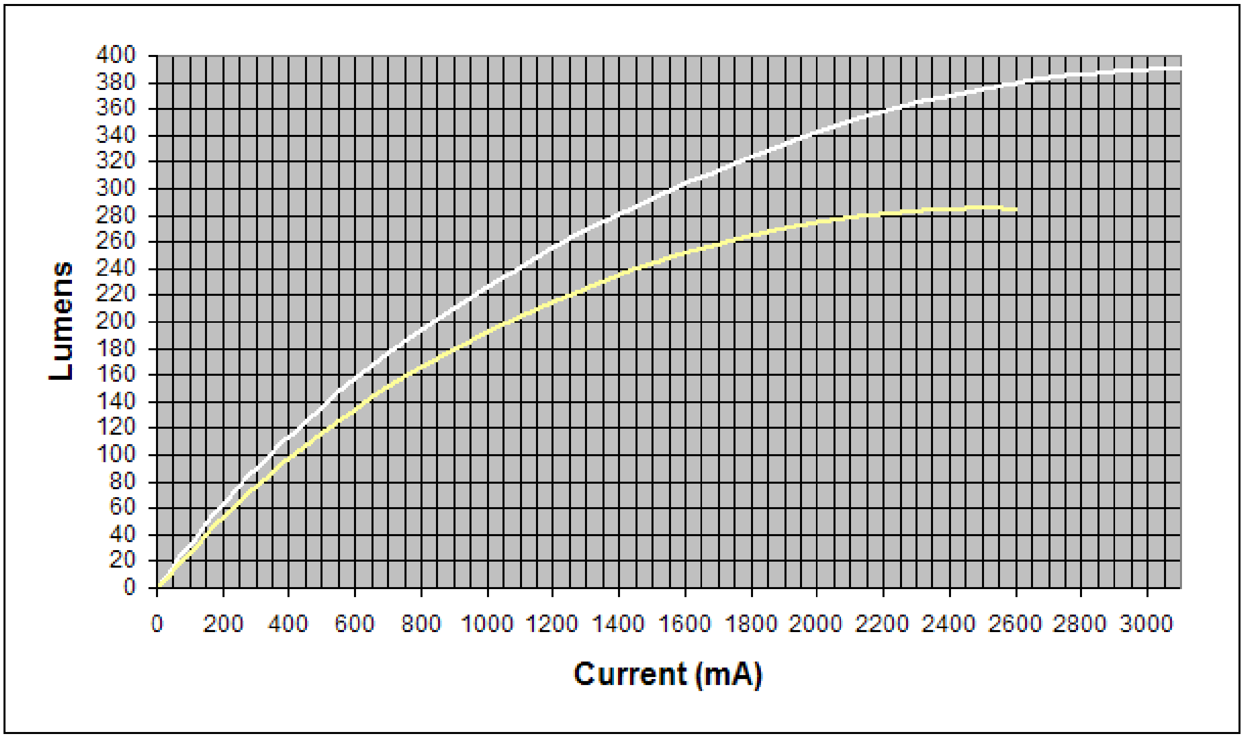

1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Relative Light Intensity
0
20
40
60
80
100
120
140
160
180
Angle


Lumileds K2 TFFC Cool White 220 (manufactured June 2009)
120
110
100
90
80
70
60
50
40
30
20
10
0
lm/W
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
Current (mA)

current	Vf	Pin	lumens
10	2.72	0.03	2.78
20	2.79	0.06	6.25
40	2.87	0.11	13.20
60	2.93	0.18	20.14
80	2.98	0.24	26.74
100	3.02	0.30	33.00
150	3.09	0.46	48.28
200	3.15	0.63	62.87
250	3.20	0.80	76.41
300	3.24	0.97	89.26
350	3.28	1.15	101.77
400	3.31	1.32	113.57
500	3.37	1.69	135.80
600	3.42	2.05	156.64
700	3.47	2.43	175.75
800	3.51	2.81	193.46
900	3.55	3.20	210.13
1000	3.59	3.59	227.15
1100	3.63	3.99	241.39
1200	3.66	4.39	255.28
1300	3.69	4.80	269.17
1400	3.72	5.21	281.33
1500	3.75	5.63	292.79
1750	3.83	6.70	318.84
2000	3.89	7.78	342.46
2250	3.96	8.91	361.22
2500	4.03	10.08	375.46
2600	4.05	10.53	379.97
2700	4.07	10.99	383.79
2800	4.10	11.48	385.88
2900	4.12	11.95	387.61
3000	4.15	12.45	389.00
3100	4.18	12.96	390.04

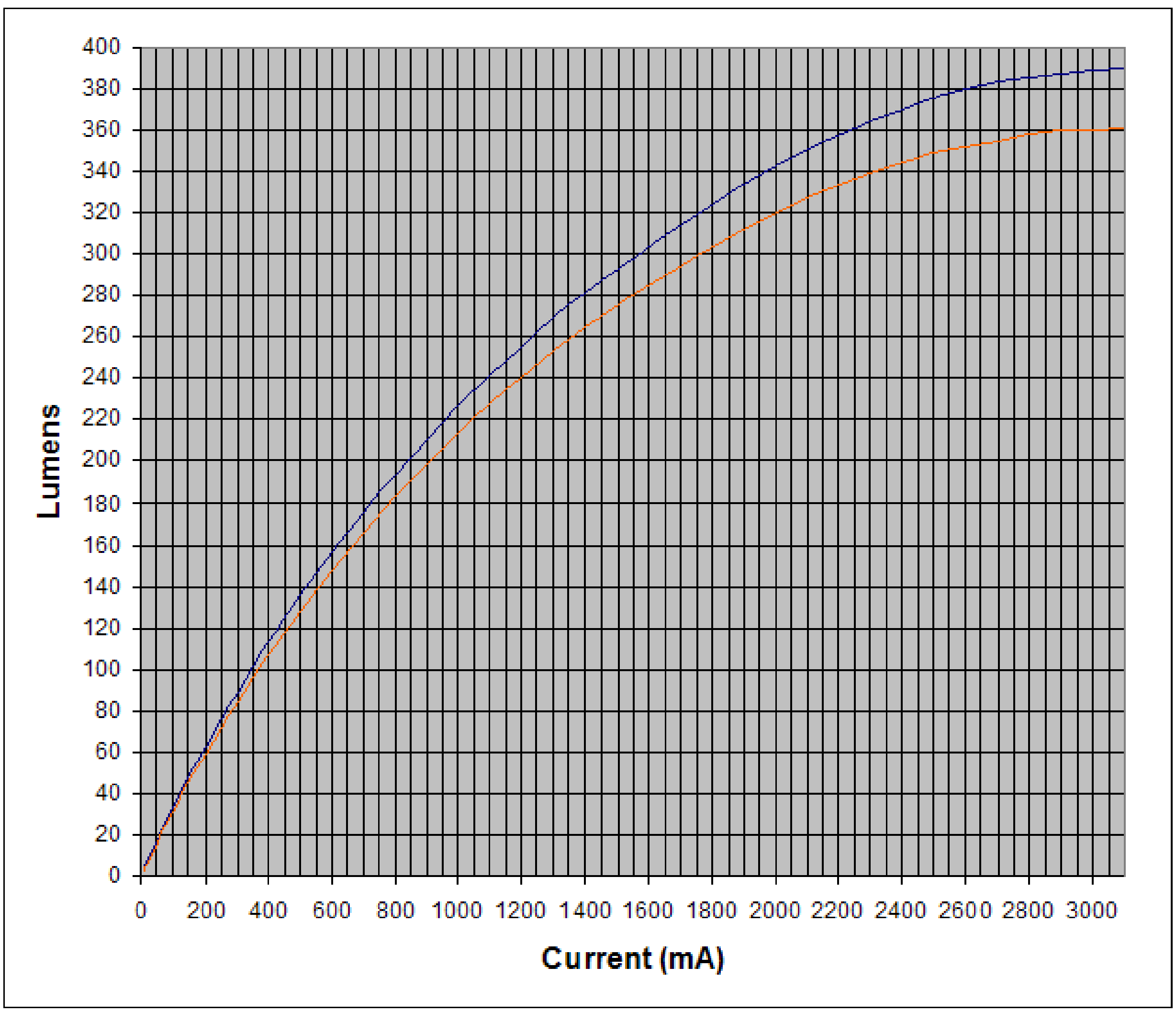
Color temperature is around 6000K and appears snow white, with no discernable tint. The K2 TFFC cool white 220 exceeds the spec at 1000 mA with over 227 lumens. Lumileds specifies typical figures of 105, 185, and 300 lumens at 350 mA, 700 mA, and 1500 mA, respectively. The test results at these respective currents were 101.8, 175.8, and 292.8 lumens, all less than but still within a few percent of specification. Vf at 350 mA is 3.28 volts, and only rises to 4.18 volts at 3100 mA. This again brings me to how well the output scales with current. The K2 cool white kept right on rising in output all the way to 3100 mA! It may have done even better if I had soldered it to the heat sink instead of using Arctic Alumina thermal epoxy. Peak output at 3100 mA was 390 lumens. This was over 33% more than the 1500 mA output. Good things are definitely occurring with the K2 TFFC's thermal management. Also interesting to note was that 350 mA efficiency was 88.6 lm/W. If Lumileds comes out with a -250 bin, then it should equal the Cree R2 at lower currents, and have dramatically better output at higher ones. Also noteworthy is that I accidentally spiked the current to about 3.6 amps with no ill effects on the emitter. The K2s are evidently quite robust.

Here is a chart of lumens versus current for the two K2s:

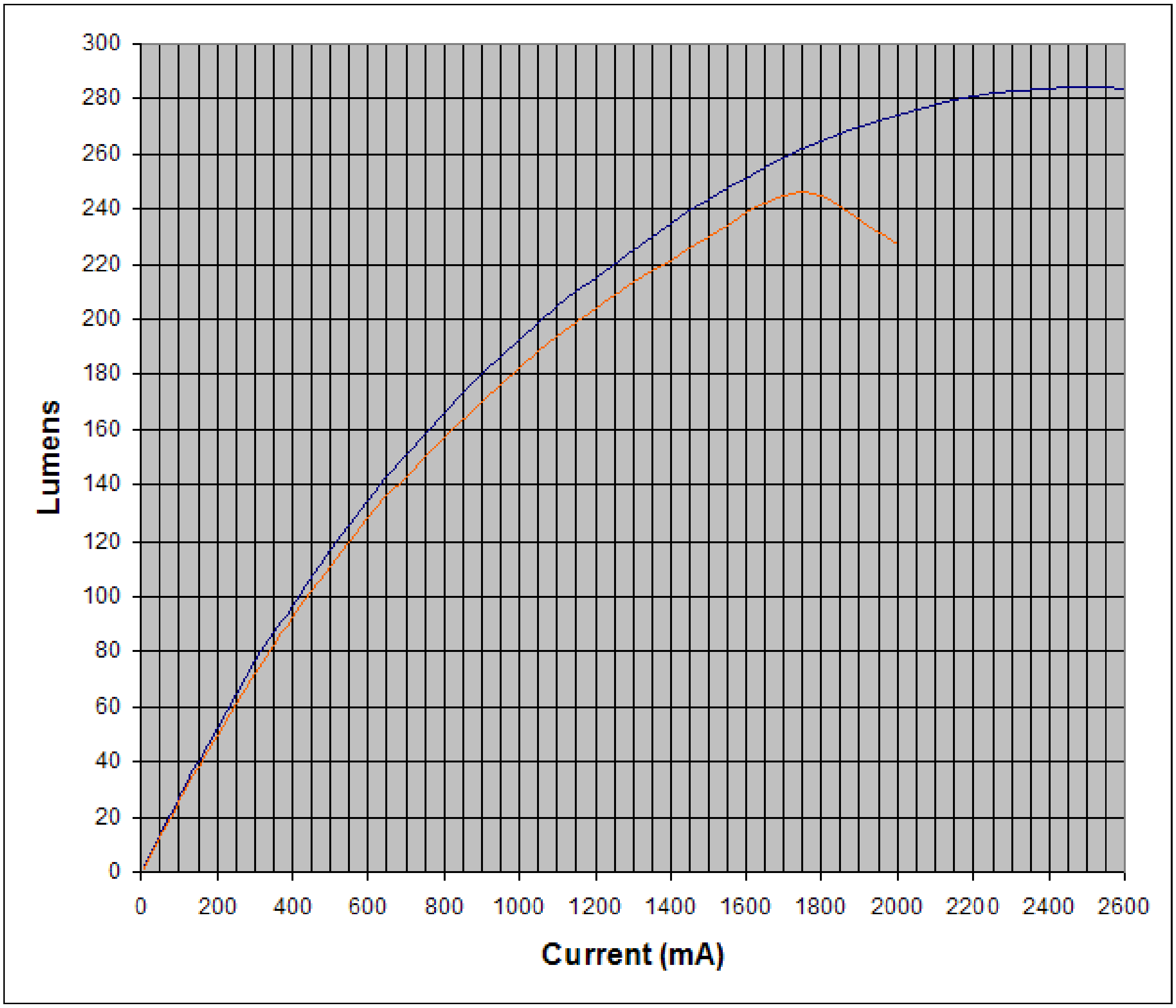


I also ran some tests under typical flashlight conditions. I decided to go with a 60°C constant baseplate temperature for these tests to simulate conditions in a typical flashlight. I used one of my thermoelectric cold plates in heat mode for my testing. Here are the results:

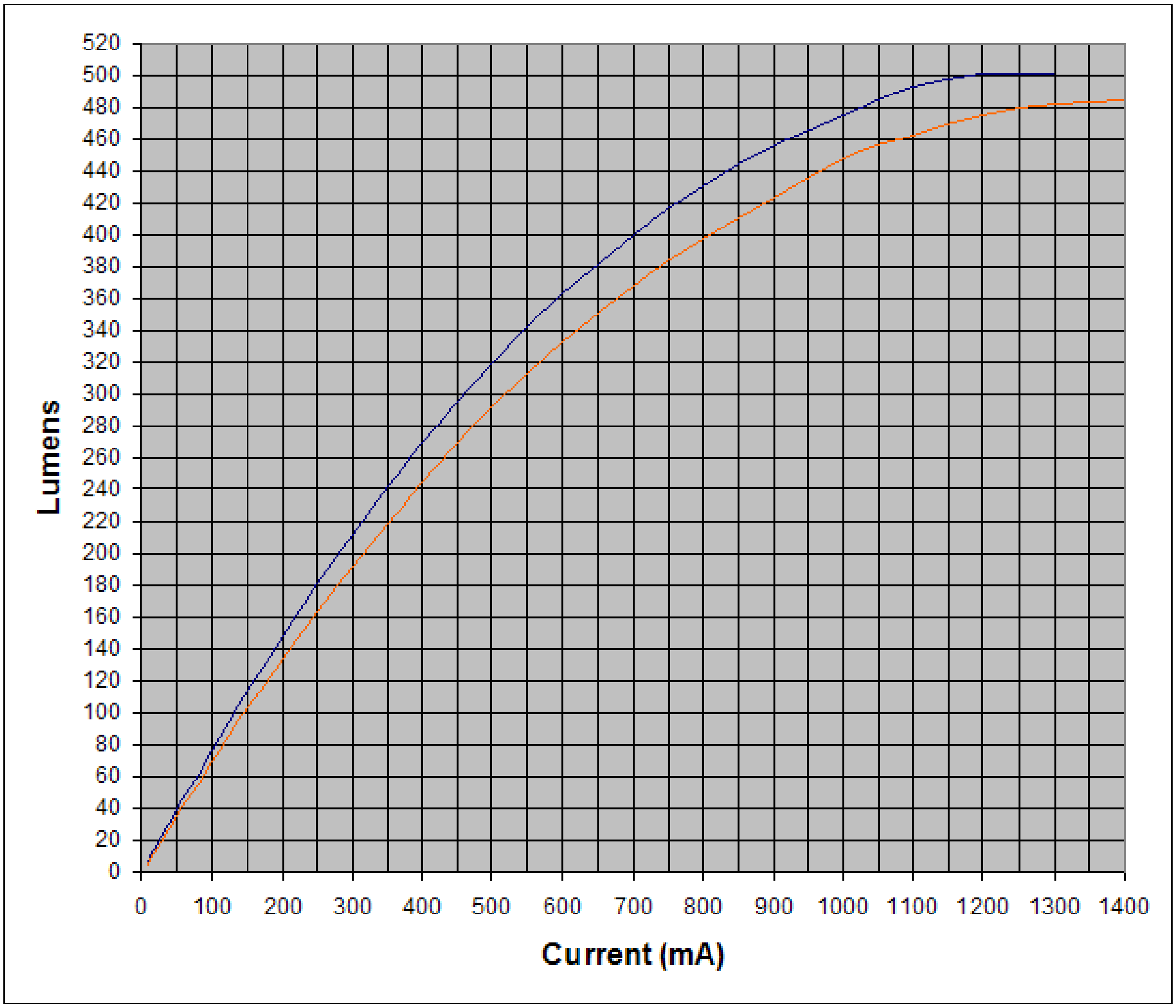
K2 Cool White -220



K2 Neutral White -180



LEDEngin LZ4-40NW10



The results are pretty much what I thought they would be except for the K2 neutral white. The K2 cool white lumens output more or less tracked the output at room temperature across the entire range, except scaled by a factor of roughly 92% to 94%. Same thing for the LEDEngin except the scale factor was closer to 90% over most of the range (although it did rise to 96% by 1300 mA which I thought was strange).

The K2 neutral white started out like the other two, holding at roughly 94% to 95% of room temperature output until maybe 1.7 amps. Above that the output dropped like a rock as seen in the chart. Yet at room temperature output continued to rise until about 2.6 amps (although this was still less than the 3.1 amps managed by the K2 cool white). Only thing I can think of here, since the dice are likely the same, is the phosphor. Perhaps the neutral white phosphor is a lot more temperature sensitive. That would explain my results here, and also to a lesser degree the results at room temperature where the neutral white maxed out at a lower current than the cool white.

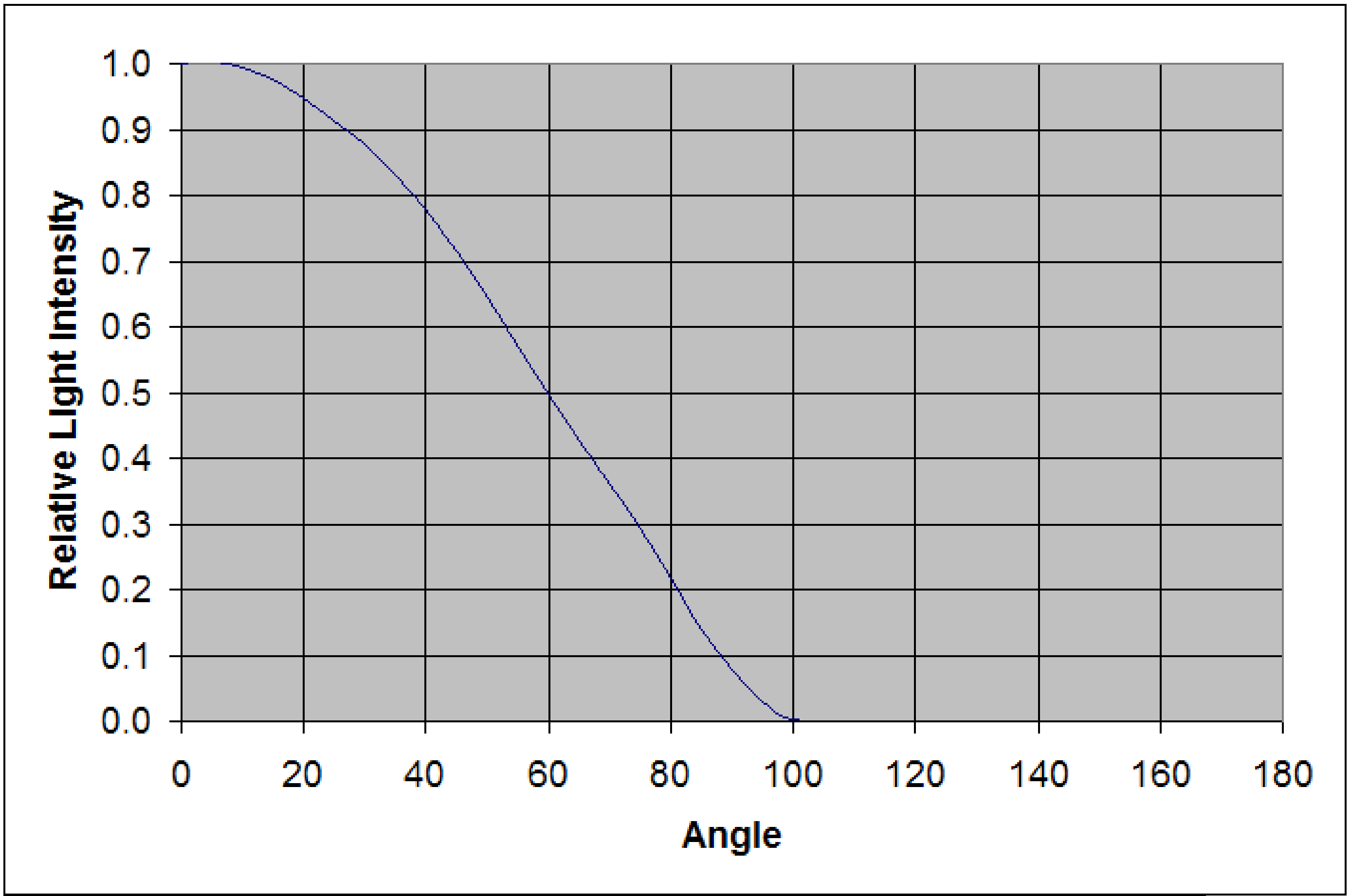
Just for kicks after I finished these tests I put the thermoelectric back into cooling mode. I managed to get **463.7 lumens** out of the K2 cool white at a plate temperature of 0° C and a drive current of 3100 mA. I was even able to get **328.6 lumens** at the maximum rated current of 1500 mA by cooling the base plate down to -12.5°C (9.5°F).

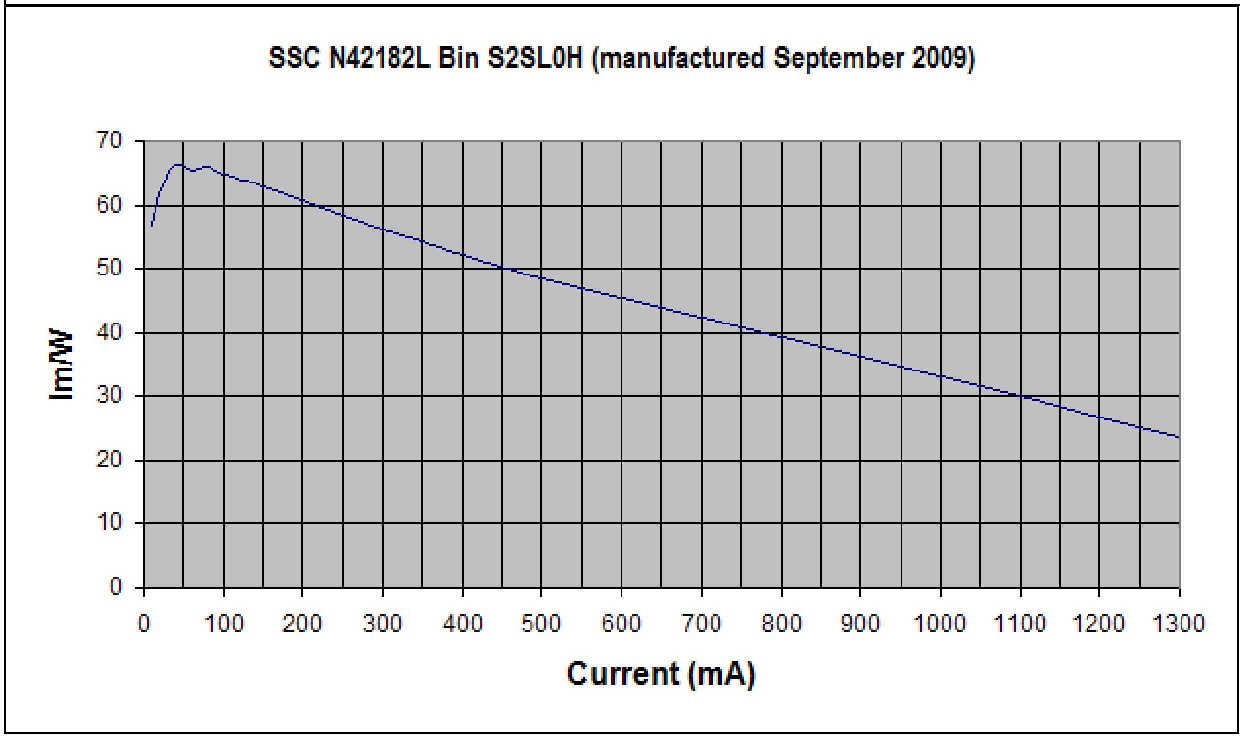
09-26-2009

Here are the results of my most recent round of testing:

Seoul Semiconductor N42182L bin S2SL0H warm white high CRI star (acquired September 2009)

This is the first high-CRI LED I've tested. The S2 flux bin is speced at 60 to 70 lumens at 350 mA, and the SL0 tint bin is between 3250K and 3500K. Here are the results:


Relative Light Intensity
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
Angle

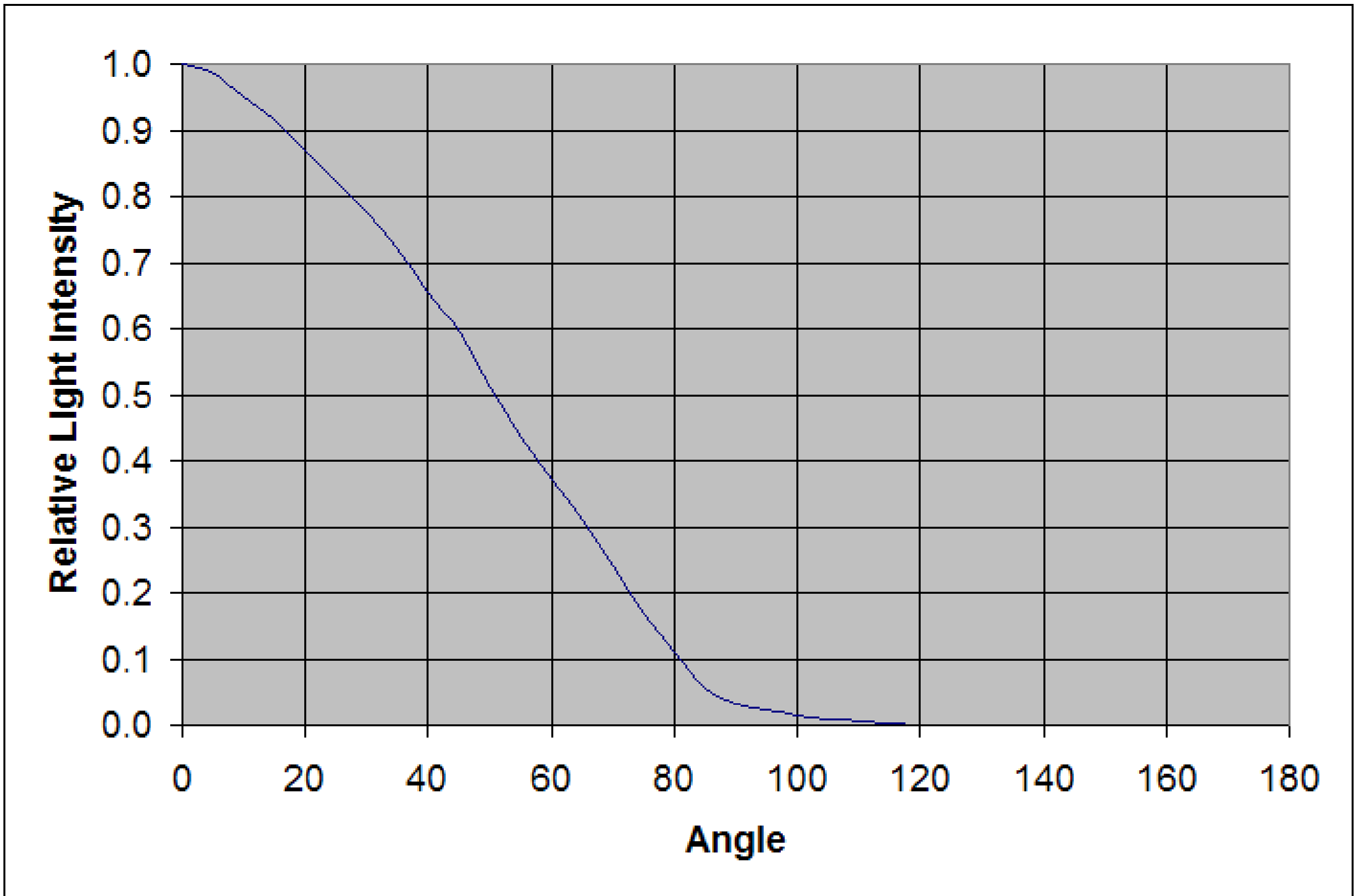

SSC N42182L Bin S2SL0H (manufactured September 2009)
lm/W
70
60
50
40
30
20
10
0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
Current (mA)

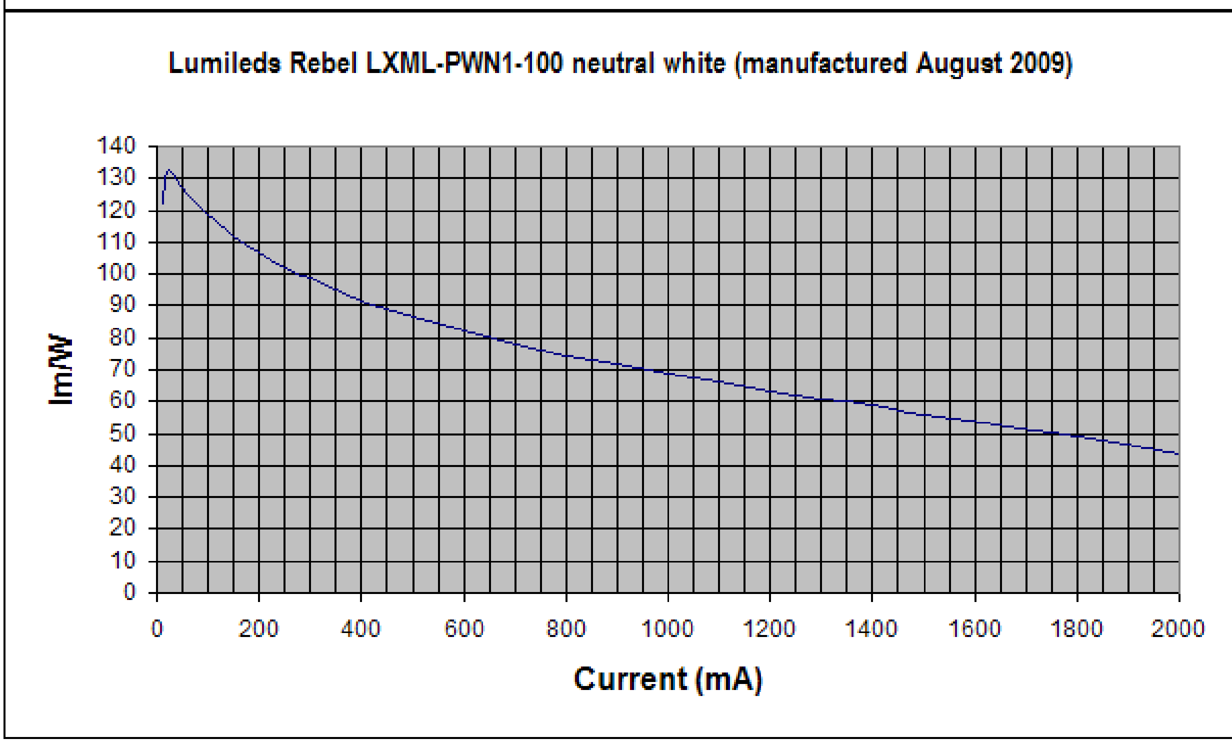
current	Vf	Pin	lumens
10	2.62	0.03	1.49
20	2.67	0.05	3.30
40	2.74	0.11	7.26
60	2.78	0.17	10.90
80	2.82	0.23	14.86
100	2.85	0.29	18.49
150	2.91	0.44	27.41
200	2.96	0.59	35.99
250	3.01	0.75	43.92
300	3.04	0.91	51.18
350	3.08	1.08	58.45
400	3.11	1.24	65.05
500	3.16	1.58	76.61
600	3.21	1.93	87.51
700	3.25	2.28	96.09
800	3.29	2.63	103.36
900	3.32	2.99	108.31
1000	3.35	3.35	111.28
1100	3.37	3.71	111.28
1200	3.39	4.07	108.64
1300	3.41	4.43	104.68

The N42182L slightly missed the S2 bin at 58.5 lumens at 350 mA. However, this is only marginally low, and likely within the margin of error of my tests. Vf is a low 3.08 volts at 350 mA, rising to 3.35 volts at 1000 mA. Efficiency at 350 mA is a pretty decent 54.2 lm/W given the nature of this LED (lower CCTs and high CRI both significantly reduce luminous flux). CCT did indeed appear to be in the low-middle 3000s as per the spec. Color rendering, especially with warmer colors, was much better than that of cooler LEDs. The N42182L didn't do particularly well at higher currents. Output peaked at 111.3 lumens at 1000 mA, only 1.9 times the value at 350 mA. This seems to be part of a general trend I'm noticing where warmer-tinted LEDs don't scale as well with current as their cooler cousins. It may have to do with the phosphor used perhaps being more sensitive to heat. There are certainly greater Stokes losses, which in turn translates into heat, in a phosphor outputting more longer wavelengths.

Lumileds Rebel neutral white -100 (acquired September 2009)

This is the highest available bin of Lumiled's neutral white Rebel presently available. Here are the results:


Relative Light Intensity
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
Angle

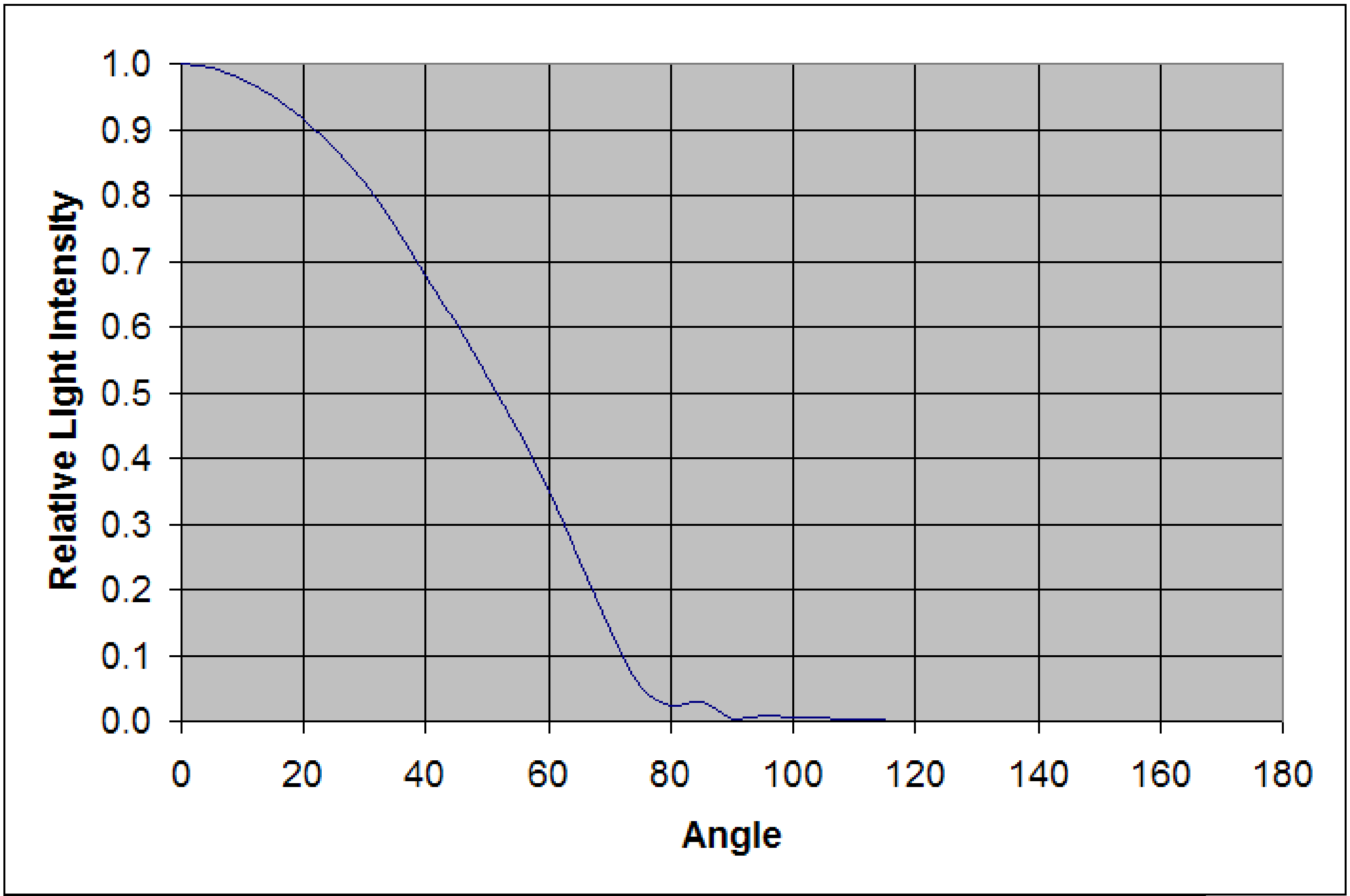

Lumileds Rebel LXML-PWN1-100 neutral white (manufactured August 2009)
lm/W
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Current (mA)

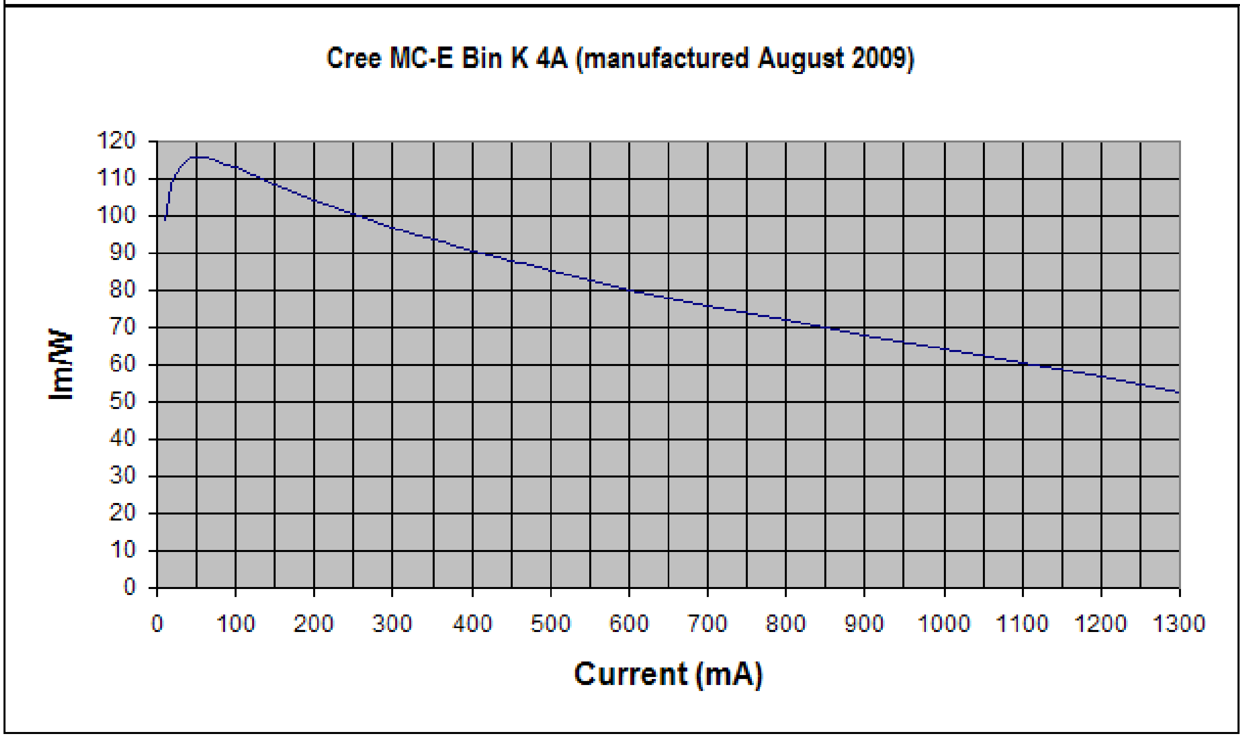
current	Vf	Pin	lumens
10	2.63	0.03	3.22
20	2.66	0.05	7.02
40	2.71	0.11	14.05
60	2.74	0.16	20.49
80	2.77	0.22	26.93
100	2.79	0.28	33.07
150	2.84	0.43	47.71
200	2.88	0.58	61.47
250	2.91	0.73	74.35
300	2.94	0.88	86.93
350	2.97	1.04	98.64
400	2.99	1.20	109.76
500	3.04	1.52	131.42
600	3.07	1.84	151.03
700	3.11	2.18	170.06
800	3.14	2.51	187.03
900	3.16	2.84	203.72
1000	3.18	3.18	218.94
1100	3.20	3.52	232.40
1200	3.22	3.86	245.28
1300	3.23	4.20	256.40
1400	3.24	4.54	266.35
1500	3.26	4.89	274.55
1750	3.28	5.74	287.43
2000	3.30	6.60	288.31

Color temperature looks to be around 4500K. This is no surprise. Due to nature of LED manufacture at present cooler bins tend to emit more output, and therefore the cooler binned neutral whites will be most likely to hit the -100 spec. The -100 neutral white actually falls a little short of the spec, coming in at 98.6 lumens at 350 mA. However, the margin of error in my testing likely exceeds the amount that the spec was missed. Vf at 350 mA is a very low 2.97 volts, and rises to a mere 3.30 volts at 2000 mA. Output with current scales even better than the cool white Rebel -100 I tested last year, and maxed out at 288.3 lumens at 2000 mA. Despite marginally missing the spec, efficiency at 350 mA is 94.9 lm/W (compared to 98.2 for the Rebel -100 cool white) due to the very low Vf. Overall the Rebel is slowly but steadily improving.

Cree MC-E bin K tint 4A (acquired September 2009)

I finally received an MC-E to test courtesy of **saabluster**! The K flux bin is 370 to 430 lumens at 350 mA per die, and the 4A tint bin is 4500K to 4750K. Here are the results:


Relative Light Intensity
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
Angle

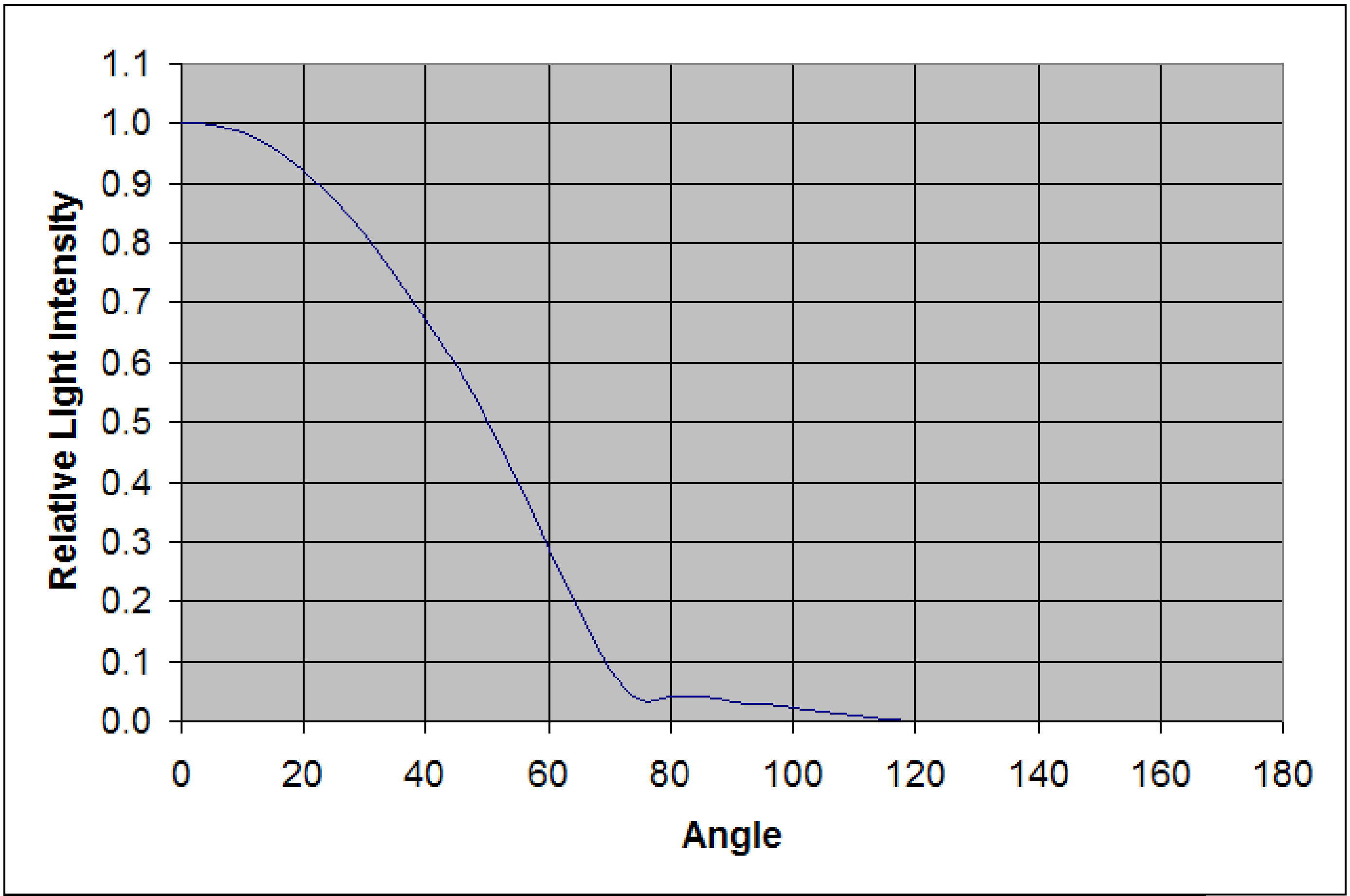

Cree MC-E Bin K 4A (manufactured August 2009)
lm/W
120
110
100
90
80
70
60
50
40
30
20
10
0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
Current (mA)

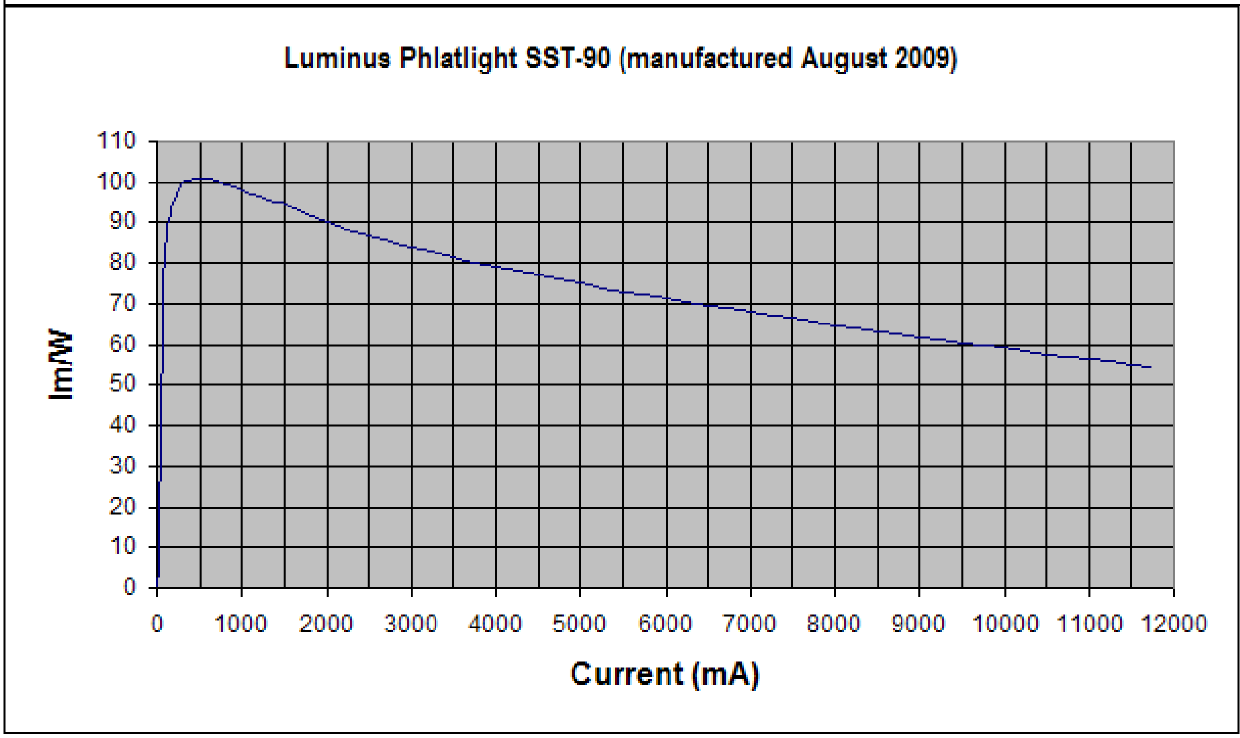
current	Vf	Pin	lumens
10	10.44	0.10	10.35
20	10.65	0.21	23.42
40	10.92	0.44	50.39
60	11.12	0.67	77.08
80	11.28	0.90	103.23
100	11.41	1.14	128.84
150	11.68	1.75	190.12
200	11.88	2.38	248.14
250	12.05	3.01	302.62
300	12.19	3.66	353.82
350	12.32	4.31	403.67
400	12.43	4.97	450.79
500	12.62	6.31	538.50
600	12.78	7.67	614.49
700	12.92	9.04	685.04
800	13.04	10.43	750.41
900	13.14	11.83	802.71
1000	13.24	13.24	849.83
1100	13.33	14.66	889.06
1200	13.37	16.04	915.20
1300	13.40	17.42	912.48

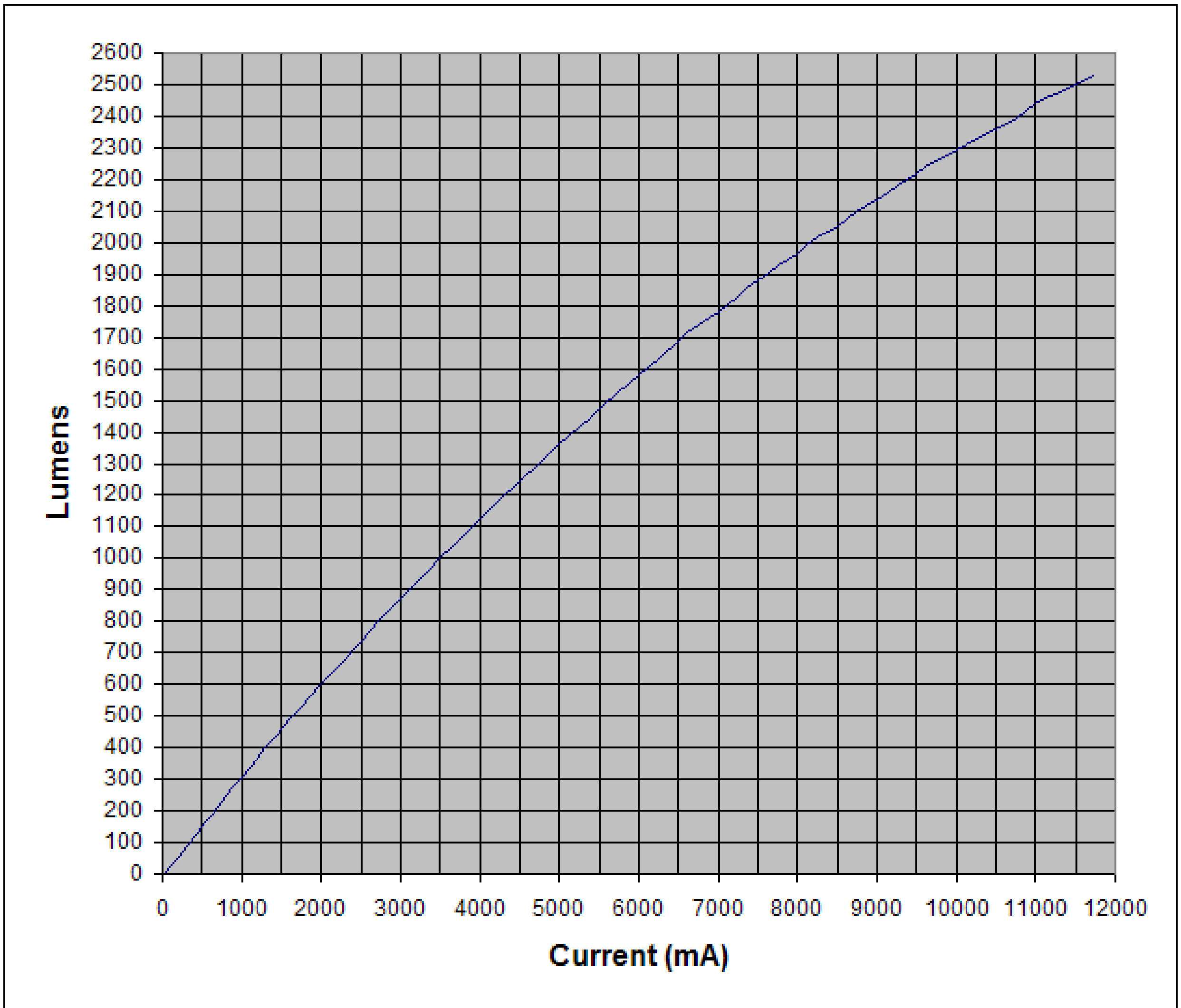
I connected the dies in series as it was the easiest way for me given my power supply. As can be seen, the MC-E falls right in the middle of the K bin with 403.7 lumens at 350 mA. Efficiency at that current is an excellent 93.6 lm/W. Vf at 350 mA is a low 12.32 volts, or 3.08 volts per die. Output peaks at 915.2 lumens at 1200 mA. Vf at 1200 mA is 13.37 volts (3.3425 volts per die), and efficiency is a pretty decent 57 lm/W. CCT does indeed appear to fall into the 4500K to 4750K range. Overall, this is a very nice LED which handily meets specs, and provides an output sufficient for general lighting.

Luminus Phlatlight SST-90 (acquired September 2009)

Along with the MC-E, **saabluster** sent me a Phlatlight SST-90 mounted on a copper slug for testing. The SST-90 is a single die LED using a huge die of roughly 3mm x 3mm. Multiple bond wires and photonic lattice technology enable even surface current distribution. The die is bonded to the thermal pad with a resistance of only 0.64°C/W. The SST-90 is speced at 3.2 amps. After using my usual test apparatus to plot the radiation pattern I mounted the SST-90 on a fan-cooled Pentium 4 heatsink. It was obvious given the specs of this LED that the smaller extruded heat sink on my test apparatus would not be up to the task. I had installed a temperature sensor in the P4 heatsink for testing thermoelectric modules. This would come in handy and allow me to determine the LED's slug temperature. The thermal resistance of this heat sink is about 0.24°C/W. Therefore, the total thermal resistance between the die and ambient should be around 0.24 + 0.64, or 0.88°C/W. Without any further ado, here are the results:


Relative Light Intensity
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
160
180
Angle


Luminus Phlatlight SST-90 (manufactured August 2009)
lm/W
110
100
90
80
70
60
50
40
30
20
10
0
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
Current (mA)



current	Vf	Pin	lumens
10	1.86	0.02	0.00
20	2.46	0.05	0.26
40	2.58	0.10	4.50
60	2.63	0.16	10.07
80	2.67	0.21	15.89
100	2.70	0.27	21.99
150	2.76	0.41	37.62
200	2.80	0.56	53.51
250	2.84	0.71	69.67
300	2.87	0.86	85.83
350	2.90	1.02	101.73
400	2.93	1.17	117.89
500	2.97	1.49	149.94
600	3.01	1.81	182.00
700	3.04	2.13	213.52
800	3.08	2.46	245.05
900	3.10	2.79	276.31
1000	3.13	3.13	307.04
1100	3.16	3.48	337.50
1200	3.18	3.82	367.70
1300	3.20	4.16	398.17
1400	3.22	4.51	429.16
1500	3.24	4.86	458.83
1750	3.29	5.76	529.83
2000	3.33	6.66	600.30
2250	3.36	7.56	668.91

2500	3.40	8.50	737.52
2750	3.43	9.43	806.13
3000	3.46	10.38	872.36
3200	**3.48**	**11.14**	**925.35**
3500	3.51	12.29	1001.91
3750	3.53	13.24	1063.10
4000	3.55	14.20	1124.03
4250	3.57	15.17	1185.23
4500	3.59	16.16	1246.16
4750	3.61	17.15	1304.70
5000	3.63	18.15	1363.25
5250	3.65	19.16	1416.50
5500	3.67	20.16	1472.39
5750	3.68	21.16	1528.55
6000	3.70	22.17	1581.80
6250	3.71	23.19	1635.32
6500	3.73	24.21	1686.18
6750	3.74	25.25	1737.04
7000	3.75	26.25	1782.87
7250	3.76	27.26	1828.44
7500	3.78	28.31	1879.30
7750	3.79	29.37	1925.13
8000	3.80	30.40	1965.93
8250	3.81	31.43	2014.14
8500	3.82	32.47	2052.29
8750	3.83	33.51	2098.12
9000	3.84	34.56	2136.27
9250	3.85	35.61	2182.10
9500	3.86	36.67	2217.60
9750	3.87	37.73	2255.74
10000	3.88	38.80	2293.89
10250	3.89	39.87	2329.66
10500	3.90	40.95	2360.12
10750	3.91	42.03	2395.62
11000	3.92	43.12	2438.80
11250	3.93	44.21	2471.91
11500	3.94	45.31	2500.00
11750	3.95	46.41	2530.46

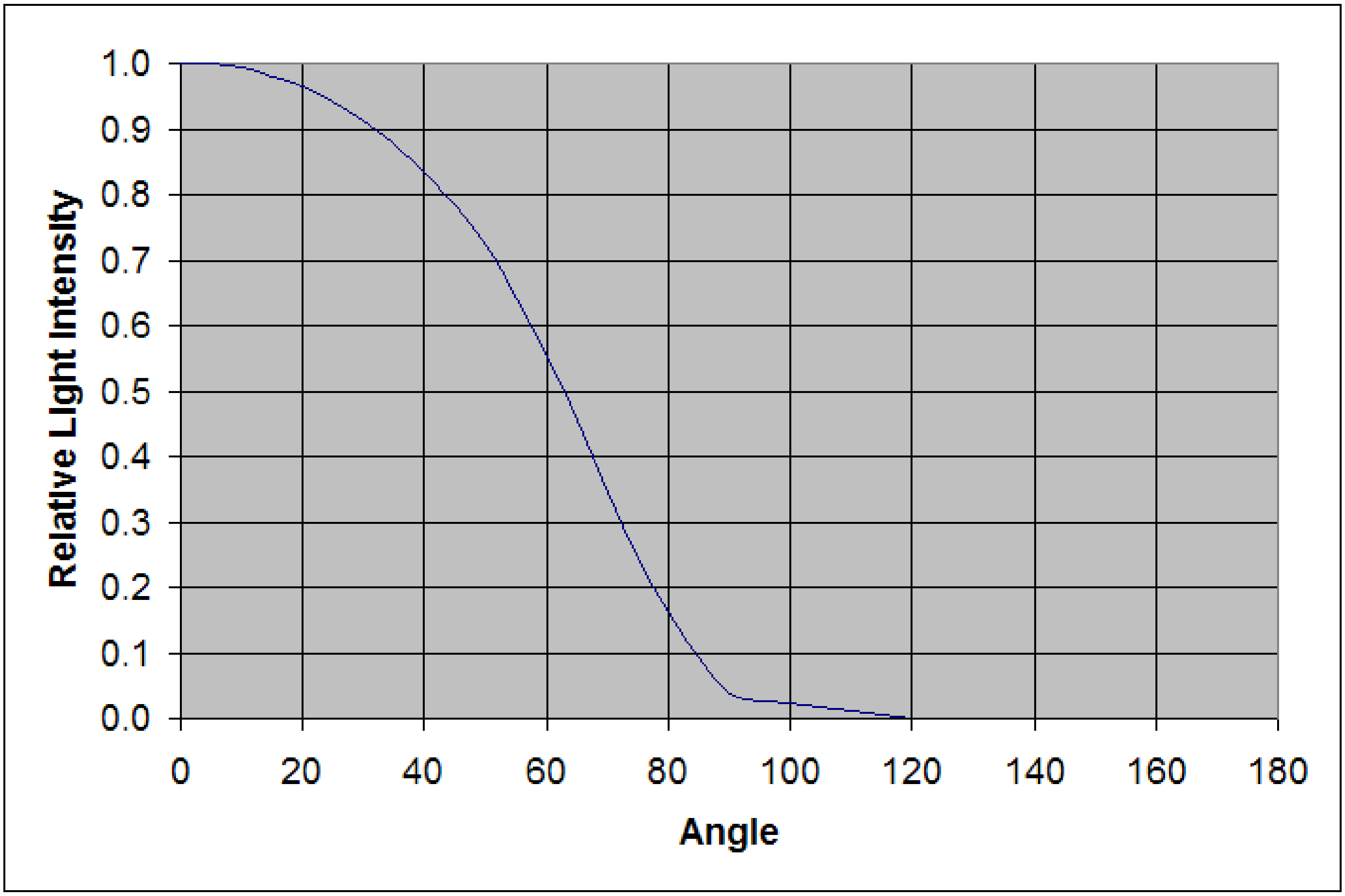
As can readily be seen, the SST-90 is impressive. Output at the rated current of 3200 mA is 925.4 lumens, Vf is 3.48 volts, and efficiency is 83.1 lm/W. To put things into perspective, the closest competitor to the SST-90 which I tested was the Seoul Semiconductor P7. At the same current the P7 only managed 842.6 lumens and 72.3 lm/W. As current rose, the SST-90 only increased its lead. The P7 ran out of steam at 7 amps and 1195.8 lumens. The SST-90 managed 1782.9 lumens, or 49% more, at the same current. By that time, I was muttering Will Smith's line from "Men in Black" when he fired off the big laser gun: "Now that's what I'm talking about". On the other end of the current scale, behavoir at low currents was very interesting. The die doesn't even emit light until drive current reaches 13 mA. Efficiency starts out low, and doesn't peak until 500 mA. It remains above 100 lm/W in the 350 to 700 mA range. And it falls very slowly, remaining above 60 lm/W even at the maximum rated current of 9 amps.

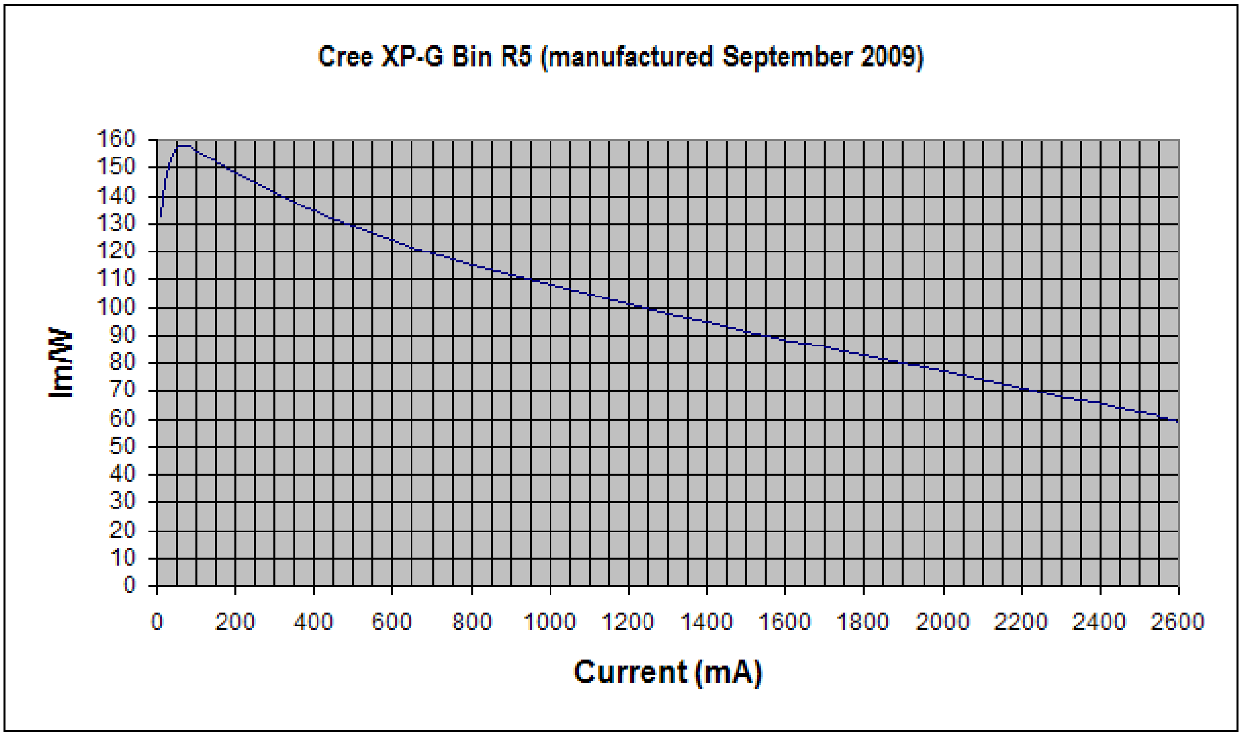
The SST-90 bought me into uncharted territory in terms of output and drive current. I continued to ramp up the current, expecting that eventually it would run out of steam and output would level off, but output kept increasing. I started telling my power supply in Star Trek fashion "Can you give us any more?" (anyone remember that line from the first Star Trek pilot?). By the time drive current hit 11.75 amps the answer was no, but the SST-90 would gladly have taken more if the power supply could have given it. Vf at 11.75 amps was still only 3.95 volts while output was 2530 lumens! And as can be seen in the lumens versus current chart, output wasn't even close to leveling off. I think the SST-90 could have exceeded 3000 lumens at perhaps 15-16 amps, assuming the bond wires were up to the task. However, since this SST-90 was a loaner, I wasn't about to try to parallel supplies to get more current into it. 2500+ lumens was impressive enough, as was 2136.3 lumens at the maximum rated current of 9 amps! And for good measure, intensity at 1 meter exceed 1000 lux. I dread to think about the intensity the SST-90 can put out with a suitable aspheric.

10-10-2009

Cree XP-G bin R5 (acquired October 2009)

A package containing my XP-Gs arrived from Cutter today. I had ordered R4 bins but Cutter substituted R5s. Naturally, the first thing I did after opening the package was to set up my test jig. The R5 bin is specified as 139 to 148 lumens. Color temperature of my sample appeared to be roughly 6500K. The XP-G was rather difficult to set up for testing due to its form factor. I mounted it on a PCB I had made for Rebels. It was necessary to modify the board a bit due to the different pad layout. I then thermal epoxied this on to a brass tab which was bolted onto my test jig. I'll admit the thermal path could have been a little better, but it didn't appear to affect test results very much. Here are those results:

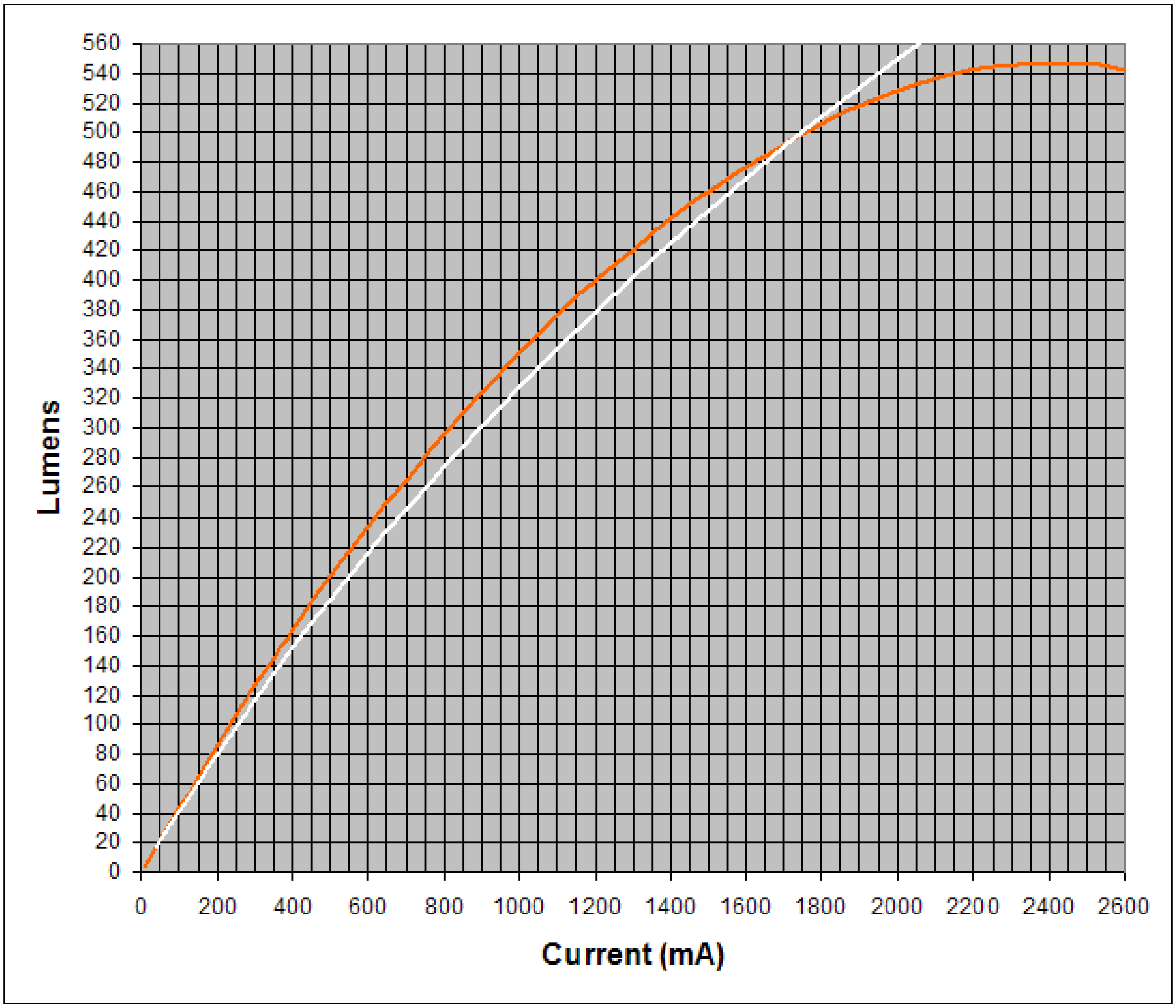




current	Vf	Pin	lumens
10	2.58	0.03	3.42
20	2.63	0.05	7.59
40	2.69	0.11	16.70
60	2.73	0.16	25.81
80	2.77	0.22	34.92
100	2.80	0.28	43.65
150	2.86	0.43	65.28
200	2.91	0.58	86.16
250	2.95	0.74	106.66
300	2.98	0.89	126.39
350	3.01	1.05	145.37
400	3.04	1.22	163.97
500	3.09	1.55	200.03
600	3.13	1.88	233.43
700	3.17	2.22	265.31
800	3.20	2.56	295.30
900	3.23	2.91	324.15
1000	3.26	3.26	351.09
1100	3.28	3.61	376.15
1200	3.30	3.96	399.68
1300	3.32	4.32	420.93
1400	3.34	4.68	441.43
1500	3.36	5.04	460.03
1750	3.40	5.95	499.12
2000	3.44	6.88	528.73
2250	3.47	7.81	544.29
2500	3.50	8.75	546.57
2600	3.53	9.18	542.77

Beam angle is 125.4°, Vf at 350 mA was only 3.01 volts, output was 145.4 lumens (well within the R5 bin), and efficiency was an amazing 137.8 lm/W! Owing to the larger die size, output and Vf scaled very well. Vf at 700 mA was 3.17 volts, output was 265.3 lumens. The corresponding numbers at 1000 mA were 3.26 volts and 351.1 lumens. Output at 1000 mA relative to 350 mA was 2.415, a bit short of the roughly 2.48 in the spec sheet. However, I'll attribute this small difference to my fairly lousy thermal path. Despite this, output continued to rise with current well past 2 amps, peaking at 546.6 lumens at 2500 mA! My previous highest result for a single die normal-sized emitter was 436.7 lumens, also at 2500 mA, for a Cree XR-E R2 mounted on a heat pipe and copper block. I've little doubt the XP-G could break 600 lumens on a similar setup. Another amazing thing was that efficiency remained above 100 lm/W until 1200 mA. Even at 2000 mA it was 77 lm/W.

It has been mentioned that the XP-G's superior performance can be attributed solely to a larger die size, as opposed to a better die. My test results also indicate a superior die. This is evidenced by the higher peak efficiency of the XP-G, as opposed to the best-binned XR-Es. My best result for an XR-E was 148.3 lm/W at 20 mA. The XP-G peaked at 157.6 lm/W between 60 and 80 mA. The chart below is further evidence of this. The red line is a plot of lumens versus current for the XP-G. The white line is a plot of lumens versus current for two XR-E R2s in parallel. Two XR-Es in parallel roughly simulates the die size of the XP-G. Note that the XR-E R2s I tested mostly likely have the larger die size Cree was using, prior to switching over to a slightly smaller size, due to the fact that I tested them in June 2008. This makes the comparison valid. Note how the XP-G outperforms two XR-E R2s in parallel up to roughly 1700 mA. Above that the XR-Es have an edge owing to their superior thermal path (heat pipe and copper block as opposed to brass tab and thermal epoxy).



Also interesting to note is that the XP-G outperforms 4-die emitters such as the MC-E up to roughly 1500 mA. Even at 2000 mA the XP-G managed 528.7 lumens, while a K bin MC-E I tested only managed slightly more, 538.5 lumens, at 500 mA per die. Granted, an M-bin MC-E would do somewhat better, but even there the difference wouldn't be huge.

Overall, the XP-G is another quantum leap in performance from Cree.

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White LED lumen tests

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