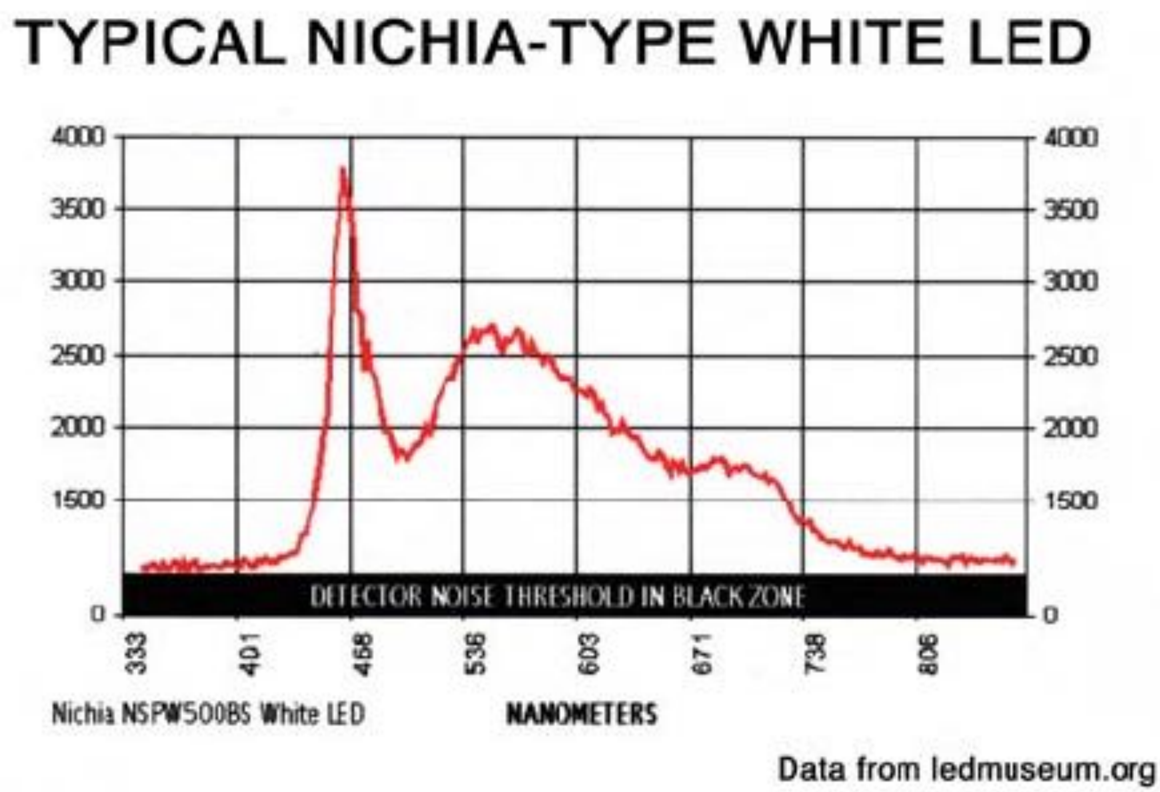


Don't Be LED Down The Garden Path (Part 1)

COLOR IN "WHITE" LEDs

Hearing a lot about "white" LEDs? So are we. If you've seen our Lightfair interview with the boss in *Architectural Lighting*, you know some of what is going on. If you haven't, that's what this article is all about.

Just so you know where we're going with this series, LEDs are great for a lot of things. Unfortunately, lighting art and artifacts isn't one of them. For low-voltage, intermittent use, monochromatic color (RGB or even Y), or long life, LEDs can't be beat.

But they don't do so well where color rendition is important or UV is a problem. And wired together in banks, they loose a lot of their reported efficiency. People are making lots and lots of claims for LEDs right now. Let’s take a look at LED lighting.

"White" LEDs work somewhat like fluorescent lights. Fluorescents pass current through a mercury vapor generating UV. The UV then excites phosphors on the inside of the fluorescent tube that in turn emit "white" light. "White" LEDs use two surfaces with slots or holes as a diode to pass current through generating bright blue light (450nm) to excite the same kinds of phosphors. That is why the spectral power distribution above looks so strange.

The spike is the LED true emission. The flat curve is the phosphor filling in some of the other colors. The jagged or ragged data (often smoothed to an average so an LEDs output looks a lot nicer and cleaner) is the responsiveness of the patch of phosphors printed over the circuit.

UV free fluorescents are not possible. While more phosphor means better color, it also means less efficiency. Make the phosphor coating think enough to absorb all of the UV, and the outside layer stays dark. You don't get any light out.

For exactly the same reasons, you can't make a "white" LEDs without a strong monochromatic color component (usually blue) overriding the phosphor emissions. You'll find a lot of variation among "white" LEDs in terms of color and efficiency as companies experiment with different phosphors, but you'll never find a true "white" LED. You can find information including color temperature and photographs of beams for dozens of manufacturers' "white" LEDs at www.ledmuseum.org.

But the same problem of phosphor thickness applies. As more and more phosphor is added as a coating, the LED shifts to a warmer and warmer color temperature. The lamp gets less energy efficient. But too much, and the LED gets dark. The LED can’t get the light out.

Scientists are experimenting with building RGB emitters into a single LED. Some are now available on the market. These LEDs create a tri-stimulus metamer to fake your eye into seeing "white" light.

The problem so far is that each of the LEDs, red, green and blue, degrade at a different rate. The LEDs change color over their life. Engineers are talking about individual color monitors for each RGB LED. A "beta" version not yet on the market is supposed to have a cost "marginally higher" than high end HID fixtures. Who knows what that means?

But RGB color is never like white. Artwork, objects, even food, look different and not as appealing, colorful, beautiful, vivid or with complex color. Something is missing, mostly all those odd colors that make a big box of crayons so much fun. But back to “white” LEDs.

Most of today's "white" LEDs have a strong blue component. Often the blue shows in splotches through the whiter phosphor emissions. Manufacturers mixing orange based "warm-white" LEDs with blue based "cool-white" LEDs advertise 3000°K to 6000°K color temperatures. Actual measurements are more like 3700°K to 8100°K. Mixing LEDs will help the overall average color temperature. But it won't give you a more even beam.

It makes things worse. Be aware that you are not going to have good color and then try to blend colors by maintaining long throws. It does not work well and the colors are off.

But there are other issues too. Beside making many things look marginal, blue is exactly the wrong color for preservation in a museum or archive. Blue light isn't reflected by the yellows and browns of parchments, faded textiles or ancient artifacts. It is absorbed. It doesn't aid vision. *And it increases damage.*

That is why the National Archives (NARA) set a 500 nm cut off for light sources for charter documents. Check the "white" LED power distribution again. Where would the 500nm cut off fall?

As we mentioned above, LEDs are great for some applications. But where color is important, they just aren't “there” yet. And unless a new way to make LEDs emerges, the physics of how these lamps work pretty well determine that the color will always be so-so marginal to poor.

You can literally get better color (and more efficiency) out of top-quality fluorescent or HID sources at a much lower cost. Color matters. Beauty in our world matters.

And, we wouldn't be NoUVIR if we didn't remind you that none of these sources meet IESNA guidelines for museum (or commercial) lighting by filtering all non-visible radiation. No UV, no IR: NoUVIR®. Our fiber optic lighting is superior for showing off fine objects and collections.

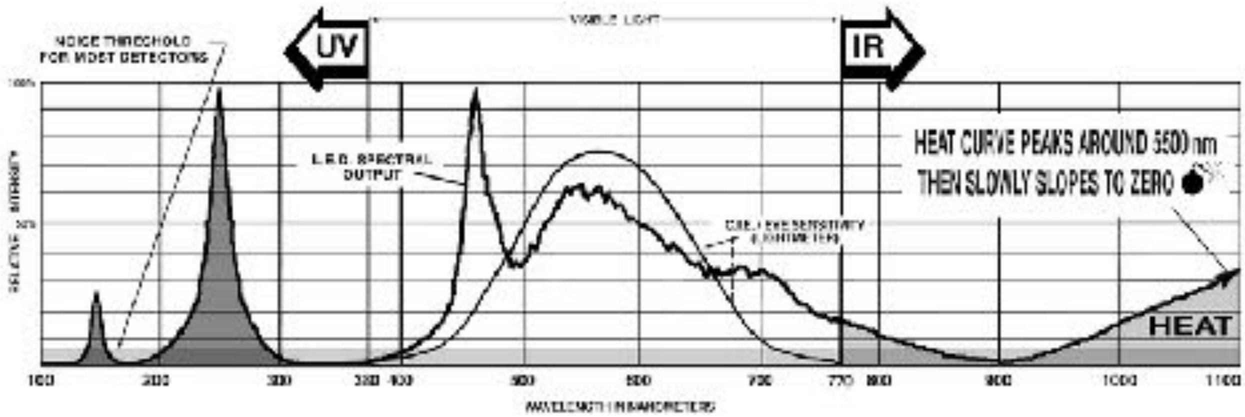
Don't Be LED Down The Garden Path (Part 2)
UV AND IR IN "WHITE" LEDs

Hearing a lot about improvements to “white” LEDs? We are too. And some of what we're hearing just isn't true. Especially LED claims about UV and IR. So, let’s look at some actual LED test data and separate the science from the science fiction.

We started this series with a spectral power distribution for a typical "white" LED (just the center of the graph above). Typical "white" LEDs have a blue spike at 450nm and a lower phosphor curve centered around 560nm. Phosphors, beams and color temperatures may vary slightly as manufacturers use different blends of materials. But, the basic curves remain the same.

The problem is, lighting manufacturers tend to limit their data to the visible range. Until recently UV and IR were not considered problems. Then they either extrapolate (believe without testing) that the data continues along the same curves, or if they know better. And they let you believe that the data continues along the same curves.

The fact is that it doesn't. The low points at the end of the visible range are not the tail ends of the LED spectral outputs, they are simply low points (valleys) in the data. You need to know that significant UV and IR emissions continue past the data points most manufacturers show you.



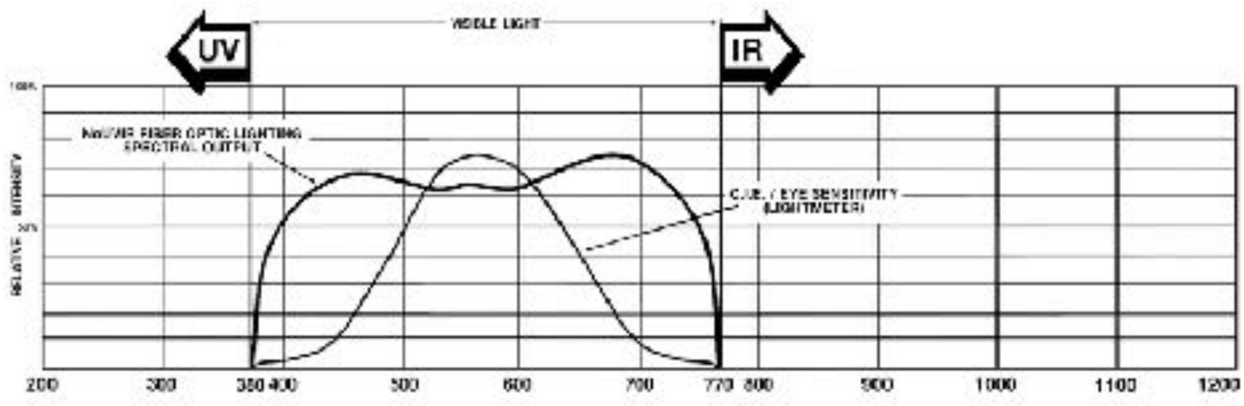
All LEDs emit UV. The graph above is what the full spectral power distribution of a "white" LED looks like. Notice that the UV output matches the intensity of the LED visible light output. Notice, too, that the IR output matches that of a steam radiator.

To be fair, we found no measurable UV in the long wave 300-380nm range. This range is the only UV that most museum quality UV meters measure and the fact that many LEDs claim to be without UV may just be a coincidence. Regardless, there is a big difference between no long wave UV and no UV at all. (That's why the government sets UVB filtering standards for sunglasses.)

The photo above shows an UVX Radiometer using a 200 nm - 300 nm head (UVB and UVC) in the actual testing of a major brand "white" LED luminaire. The meter shows an UV output of 3.8"W/cm2 for their "cool white" LEDS. The spectral power distribution from the manufacturer's website shows peak output for this LED to be roughly the same intensity, 3.7"W/ cm2. Their "warm white" LEDs show even worse results, a peak output of 1.9"W/cm2 and a short wave UV output of 2.9"W/cm2. The bottom line is that many of these fixtures put out as much UV as they do visible blue light.

All LEDs also emit IR. As a matter of fact, heat dissipation is a major factor in LED design and LED life. While manufacturers may say sales-jargon things like, "all thermal energy is conducted through the housing and not radiated in the beam," the fact is that these LED luminaires stabilize around 50°F above ambient temperature. The whole unit radiates IR. No object that radiates heat can be considered IR free.

Despite some manufacturer claims, LED sources are not UV and IR free. Their high short wave UV output makes them particularly dangerous for art and artifacts. Without significant secondary UV filtering, LEDs are not acceptable light sources for fugitive or fragile materials and do not meet IESNA guidelines for museum lighting.



For comparison, here is the spectral output in the same scale for a NoUVIR fiber optic luminaire. There is no UV. There is no IR. The name “NoUVIR” is a promise that science proves.

Don't Be LED Down The Garden Path (Part 3)

EFFICIENCY AND LIFE EXPECTANCY OF "WHITE" LEDs

Hearing a lot about "white" LEDs? So are we. We hear things like “50,000 hour life" and "huge energy savings." That sounds terrific. But, let's see the numbers!

LEDs are current sensitive. An LED circuit needs to regulate current to the diode circuitry as the LED's temperature changes. It needs to do this for each LED individually. You can't have one LED burning out and take out the whole array like a string of old style Christmas lights. You dim LEDs by limiting current, not voltage. A rheostat won't do it. All this requires very sophisticated, and not terribly efficient circuitry.

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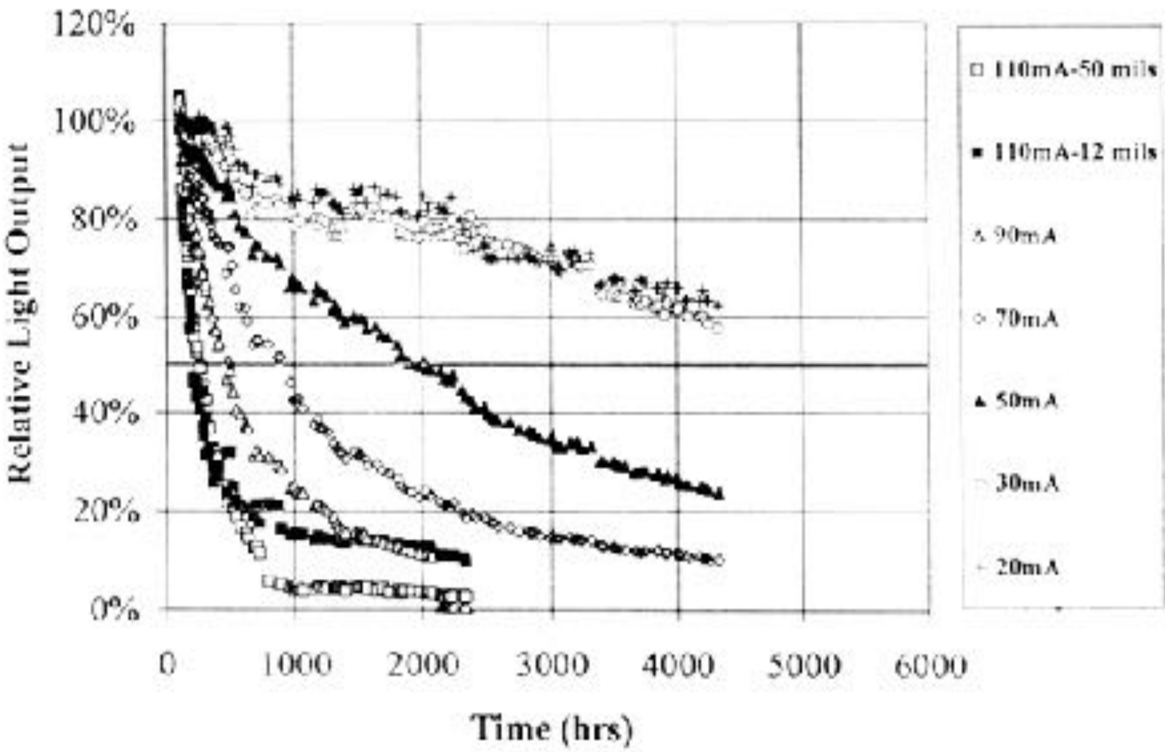


Figure 10: Light output data as a function time and drive current

The major supplier of the "white" LED equipment we tested listed an efficacy of 6.4 to 7.7 lumens per watt for their linear LED unit. Other products went as high as 10.7 lumens per watt in the "cool white" range (8100°K). Nevertheless, a standard 60 watt GE warm white light bulb has an efficacy of 14 lumens per watt. The "best" LED unit we tested was only 75 percent as efficient as a plain frosted electric light bulb and the worst had 45 percent the efficiency. Considering that an electric light bulb is 94 percent IR and only about 5 percent visible light, these are not very impressive numbers.

However, if you look up information on the internet or just read the marketing printed on an LED light bulb box, a 9-watt or 13-watt LED is the equivalent of a 100-watt incandescent light bulb. How can this be? Lumens per watt take into account all the light generated by the source. A light bulb has a sphere of light as it generates random photons coming off the filament in random directions. A diode has directed light with dark spots. If the focus is on the beam, the efficiency of an LED is superior. But the watts per lumen are less. Considering how much more expensive and how many more resources are consumed to make an LED compared to a filament lamp, maybe LEDs are not all that green.

The point is that LEDs have applications in which they excel. But they have other applications in which they perform poorly. Lighting artwork, museum exhibits and valuable private collections is usually not a good application for LEDs.

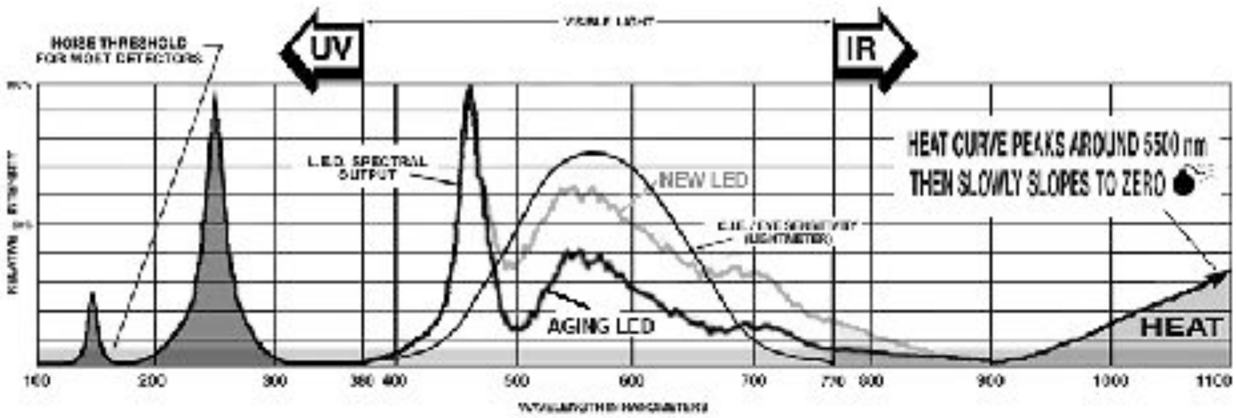
What abut lamp life? LEDs started with a published lamp life of over 100,000 hours. To increase the lumens per watt, the circuitry is more heavily stressed. The drive current is increased. Lamp life numbers went to 80,000 hours then 65,000 then 50,000 and in some cases are 35,000. This is the lamp life in hours for the actual diode. The circuitry that runs the diode can have a lower lamp life.

Regular electric lamp life is measured by the average age (under absolutely ideal conditions) at which they fail. We know that overdriving LEDs can make them brighter. But over driving significantly shortens their life.

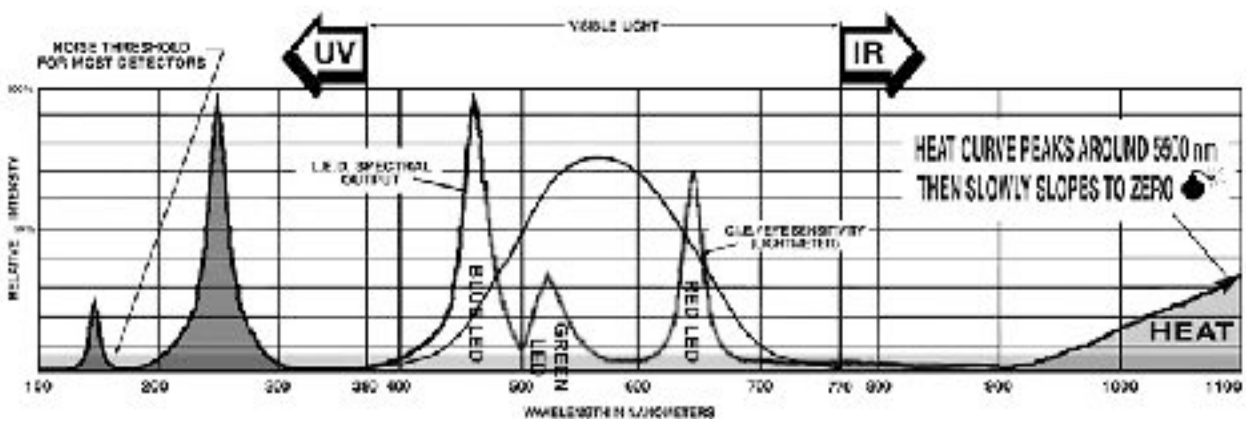
We also know that LEDs tend to change color and loose intensity as they age. While LEDs advertise extremely long life numbers, one begins to wonder just how useful those final years of life truly will be.

The chart above along with reported research by RPI shows that under the good conditions, LEDs can be expected to loose 40 percent of their intensity in the first 4000 hours. Under overdrive conditions the graph seems to indicate that this loss can be as much as 90 percent. With new products coming out almost daily, it will be some time before really accurate life data is available. Bear in mind simple life testing itself (running 24/7) will take eight years. We are on uncharted ground. But, it would be best not to count too heavily on extended life until test data is available.

Testing at NoUVIR has shown a 20% drop in output that happens fairly rapidly. Then the LED tends to stabilize at about 50% output. Life tests continue. Known manufacturers tend to be better with the drop in output happening further into the lamp life. New manufacturers, off-brands and cheaper imports tend to test with a rapid drop in performance.



RGB LEDs fail in a more unique way as the lamp's circuitry ages and looses tight control over one of the colors used to blend into a metamer that fakes "white" light. A new RGB LED's output is shown in the same scale below. As one of the peaks drops in intensity, the color shifts. For presentation, the change in color means replacing the lamp. These RGB lamps also can accelerate photochemical damage.



Finally, keep an eye on LEDs. There is a tremendous amount of R&D going into LEDs. Some of these hurdles may be overcome.

Some problems, like the monochromatic nature of the LED itself and the significant UV output, appear to be integral to the technology.

For now, LEDs are perfect for signs, displays, low intensity applications, intermittent flashing, safety lighting in areas that are not cold, certain low-voltage applications and monochromatic applications. They may be excellent solutions for effects, color changing applications and architectural and outdoor lighting where access is difficult. They may also be applied to general lighting, occasional use illumination like basements, attics or closets, sealed light sources and faux Edison lamps, but the cost effectiveness and overall energy efficiency can be questionable.

They are not appropriate where color rendition is important or in any indoor lighting applications with fugitive or fragile materials. The UV content makes them dangerous in museum applications. Sealed in cases, the IR content accelerates damage. Other options for light sources are superior.

Like any other lighting technology, LEDs are good for some applications and terrible for others. The trick is in knowing which is which. Knowing the true numbers help. Remember to do your homework.