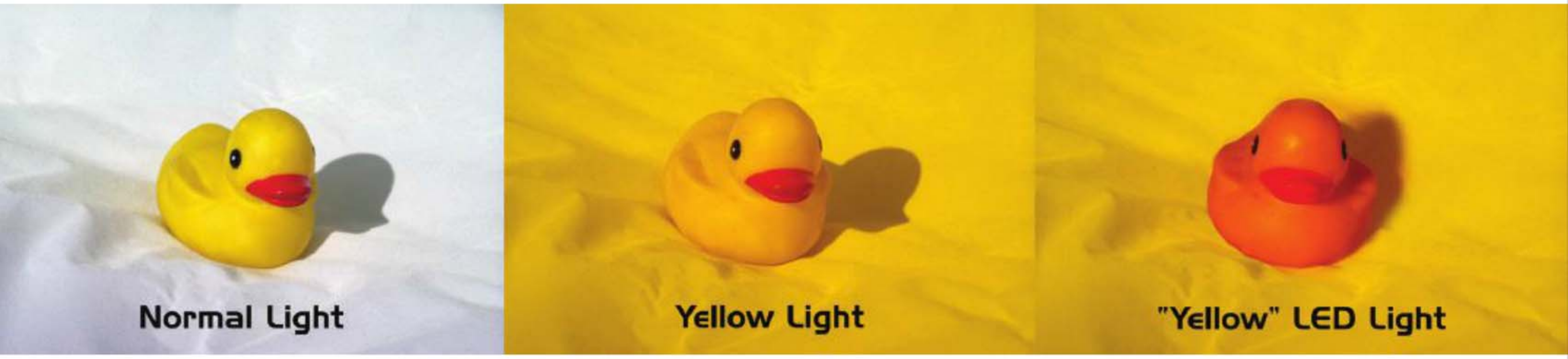

Evil rubber Ducky, or, the honesty of LEDs

BY **TONY HANSEN**

Tony Hansen will present "LED: The State of the Technology" as part of the Professional Development Program at PLASA Focus: Orlando, Wednesday, May 15, from 9-10 a.m. at the Wyndham Orlando Resort in Florida

SEVERAL YEARS AGO, while I was working a promotion at the opening of a new water ride that I had designed LED lighting for, I noticed an anomaly. To me at least, it was a pretty major discovery. The observance was that light created by an LED color mixing source did not illuminate an object as I would have expected. There were several rubber duckies floating through this darkened room lit only by RGB (red, green, and blue source) LED lights. As they floated, I noticed that they never looked quite natural to me. This was my first large-scale LED installation, and it was an early one for the industry. I had made many assumptions about the new technology, and it turns out a few were unfounded.

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Take my poor friend, Ducky. After absconding with one of the hundreds of them and bringing him back to our office, I decided to play with him in a lightbox one day. (It was a slow day.) I took a regular PAR can, placed a random piece of amber gel over it, and the duck appeared as I expected. I then took an RGB mixing LED fixture and matched up the amber color as best I could to the naked eye—no fancy testers were involved, just instinct. The amber on the white area of the light box appeared pretty darn similar to me. The oddity came when I moved Ducky between the two sources. As I stated earlier, he appeared normal under the amber PAR can, but when he was moved under the amber appearing LED, his entire persona changed, and he became evil looking. Whenever I regale an audience with this bit of storytelling, I expect a member of the Monty Python troop to appear and go on about *Evil Rubber Ducky* to great length, maybe with Ducky taking over a castle somewhere or attacking a woodsman. Alas, it is just me and the child's toy and an odd reaction to LED light—but I digress.

A quick color primer

Ducky did not turn amber colored or maybe more vibrant as I would have expected. Instead, he turned an evil-looking red hue. After playing with this for a while, I noticed that his naturally red beak was a vibrant red, so the duck had some colors acting naturally.

The way to make amber light with an RGB source is by blending of the output of the red and the green LEDs. At some point, most of us learned in school that all visible colors to the human eye can be created using the primary colors of red, green, and blue, the additive color system. These are the colors in your computer monitor and television, even a bag of M&Ms—no, those are subtractive mixing, but that's another discovery, and now I'm hungry. Actually these M&Ms in front of me fall under the other color system, the subtractive color system for pigments and dyes. In school we learned about these two color systems, but we maybe didn't go into much detail about their interaction. Ducky is amber in pigment, but he can only appear that way if there is amber light for the pigment to reflect back to us.

This is where CRI or Color Rendering Index comes into play. Basically, CRI is a measure of how well light can help us see and differentiate the colors of the world around us. You can find some wonderful formulas online that go into great detail of how this works, but in simplest terms, a scale of 1 to 100 is used, the closer you get to 100 the closer you are to absolute accuracy in distinguishing color. So, in order for the objects around us to appear as natural to their pigment colors as possible, you would need a light source with a CRI of 100 to illuminate them. This is why the paint in your house looks different in daylight than it does when lit by the compact fluorescent lamp on your desk. The CFL has a lower CRI than daylight, so it does not provide the same spectrum of available light for the pigment to reflect, and thus it becomes a different color in appearance. Obviously, the actual pigment does not change from night to day, but its appearance is greatly altered by the light it can reflect.

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The problem with CRI is that it is a relatively old-fashioned measurement that does not take all of the unique properties of LEDs into play. A newer formula is now available called Color Quality Scale (CQS), it still uses the familiar 0-100 scale but it is weighted to consider the light properties of our sources in a manner that better considers what we "perceive" as good light. A CQS scale takes into consideration the light source's ability to provide the light we want to see using different sources and wavelengths. An entire article can be taken up about the advantages of CQS, but there is some good reading on this new scale on the National Institute of Standards and Technology website at http://www.nist.gov/pml/div685/grp03/vision_color.cfm.

Back to LED

We like to say that LED is digital light, so that would then make the sun or an incandescent lamp analog, I guess? It is easy to understand how we get the light and spectrum from an incandescent light bulb. If we put electricity through a metal filament, it will heat up and glow red, orange, and finally white hot; the temperature of the glow is what gives us the light we want. Pretty analog, I guess. There are many other ways to create light, but I had never heard the process described as "digital light" until the LED came around. An LED makes light by passing an electron from the cathode to the anode across a semiconductor diode's junction, and as the electron passes, a photon of light is released. Again, the Internet is your friend if you want to go into more technical detail, but if I put anymore into this, I will need more candy. The photon of light created is pretty pure and close to a single wavelength of color. Although practical LEDs date back to the 1960s, we didn't have the last one we needed to mix colors effectively until 1994 when a practical blue LED was invented. Ironically, the white LED came very soon after because of the blue, but not because we needed the blue along with the red and green to make white. The common white LED is actually just a modified blue LED, but more on that later. So what does all this have to do with the Ducky and LEDs?

We know that we can mix the light from LEDs to make any color we want, right? **Right?** Well, we can mix any color we want on a neutral surface, such as white. Anything that needs colored light to accurately reflect its pigment color may not be so lucky. In order to make amber, we mix red and green. The problem is that it does not put amber light out there. It puts some red and some green; the amber that Ducky needs isn't in the light. Ducky probably had some red pigment mixed in during his manufacture, and that is what is able to react with the light provided by the RGB LED unit. This is why the LED turned Ducky evil: It had no spectrum to make him amber. Now, I could tweak the color mix and get Ducky to look pretty good in his amber, but that would cause other colors to go off. Remember how I had a nice yellow background to start? When I tweaked the color so the duck looked natural, the background became very green, and his red beak looked dull. This is what I mean about the honesty of LEDs: They do not do all colors equal justice when using simple RGB color-mixing. I often times tell folks that asking an RGB LED to provide full spectrum light is akin to reproducing an entire symphony using only three distinct audio frequencies.

I will often hear the argument that televisions and monitors all use only three colors: RGB. This is very true, but remember that they use the colors against a neutral surface to allow the best blending. Take an old style video projector with three visible lenses of RGB, if you show that onto a white screen, it looked pretty good, but on a red curtain, not so much.

White, amber, cyan! Oh my!

If I take three PAR cans and gel them red, green, and blue, I can mix a pretty good white on the stage. The science here is in the analog vs. digital source thing. A PAR can has a pretty full spectrum lamp to begin with. We then gel or filter out all but the color in our target range: red, green, and blue. If you look at the light spectrum on a scope, it would be a nice hill centering on our target color. Properly chosen colors will allow you to blend the hills back together and have a pretty full spectrum again.

Now take the digital light of the LED and look at those three colors on a scope and you will see three very distinct spikes of color with not much in between. It is that area in between that we need. If we go back to the audio analogy above, the PAR can is closer to a three-way speaker where the audio overlaps; the RGB LED is still just three unique frequencies. If we add in amber, cyan, et cetera LEDs, we are adding in more distinct frequencies, which give us something closer to—but still not—a complete spectrum.

The white LED is the game-changer here. The white LED is actually a blue LED with a phosphor coating that emits a broad spectrum of yellowish light when lit by the blue LED. Some of the blue LED light leaks through the phosphor and mixes with the light from that phosphor to give us a white light. I am seeing white LEDs now that claim to have a pretty decent CRI/CQS in the mid 90s from major manufacturers. I am still a tad bit skeptical because the early white LEDs had a problem with shifting back toward blue as they aged, but that is being addressed.

If we use white LEDs as the light source in our fixtures, we need to use traditional gel or dichro to get our colors since you can't color-change a white LED. This is all good and fine, but we are back to having moving parts. I also find it a bit ironic that we take a blue LED, modify it to produce white, and then filter it back to blue. This is not efficient, which is supposed to be the big advantage of LEDs.

You can certainly add a white LED into an RGB fixture as a highlight, but unless you are doing pure white light, you will lose out on CRI. Just having a white LED present does not fix the CRI issue with colors. If you are only using the blue and red LEDs to make a magenta sunset, you have the same CRI issues, as we had above. How honest you want your light to be is going to be the question as you blend your sources.

Should I not use LEDs at all then?

LED technology has allowed us to place and work with lights in a lot of ways that we never have before. It just isn't ready to replace every light yet. I use LEDs all the time for my design work. They are great for certain architectural lighting, perfect for cyc lights, great eye candy and truss warmers, beautiful in clubs, best for fountains and water rides, and museums and retail are prime locations for LEDs. I do not use them as my primary front lights in theater yet, but I will mix them in with some traditional sources. Often times, I will use LEDs for my moving wash lights but keep my moving spots as arc source so that I have the best of both worlds.

I had an interesting discussion with a younger designer about technique and design style recently, and I questioned the current role of a designer and his or her commitment and responsibilities with all these new tools. What I was getting at is that back in the day, a good part of my show budget would be on gel and patterns. I had to commit weeks to my colors so they could be purchased, cut, and loaded during the show hang. Today, there appears to be no pre-commitment because our lights will give us any color at the push of a button. If that blue isn't quite right, I can change it. How glorious! The only dangers are getting too lax in our color awareness and its power to change things, and not knowing how honest we are being as designers to the scenery, costumes, building, church, stores, and people that we are being asked to illuminate. ■

Tony Hansen has served as the Head Lighting Designer and Systems Sales Consultant at Techni-Lux Lighting in Orlando, FL for the past 10 years. He is a 25 year veteran of the lighting industry. Tony previously worked at The Children's Theater Company in Minneapolis, Universal Studios and Disneyworld in Orlando, as well as Vari-Lite Production Services. Tony specializes in lighting design for houses of worship, themed attractions, and architainment.