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Digital Darkroom Lighting - Critical Element of Color Management

Introduction
Successfully editing images in the digital darkroom is difficult if not impossible if what you see on your monitor doesn't match your prints. Thorough color management is the only solution to this problem. However, there is one particular element of color management that is not widely understood and often ignored. The type and intensity of lighting used in the digital darkroom can cause a serious mismatch between the monitor and printed output.

Why this mismatch occurs
There are three major reasons for this mismatch:
- The color temperature of the digital darkroom lighting used to illuminate the printed image does not match the color temperature of the monitor
- The digital darkroom lighting exhibits spikes in its color spectrum
- The brightness of the monitor does not match the brightness of the digital darkroom lighting

Why you may have this problem
- Digital darkroom lighting often has a color temperature below 5000K
- Monitors are often set at a color temperature of 6500K or higher
- Most types of digital darkroom lighting have enormous spikes in their color spectrum
- Many LCD monitors are set too bright

A mismatch of 1500K is significant
Here is how to demonstrate this to yourself and others. Compare an image on your monitor with the same image printed on paper and illuminated by your current digital darkroom lighting. Observe the match between the two: it can be anywhere between extremely good and extremely bad. Now, if your monitor was originally set at 6500K, change it to 5000K; if it originally was set at 5000K, change it to 6500K. Either way, the match between monitor and print will change dramatically. A mismatch of 1500K is significant. A mismatch of only a few hundred K makes already a noticeable difference in the way we perceive color.

Why a significant mismatch is likely
Take a look at color temperatures of the most common indoor light sources, ranging from 2500 to 5000K. When the monitor is set at the typical color temperature of 6500K, there is a considerable mismatch of 1500 to 4000K.

Indoor light source	Color temperature
60-100W incandescent lamp	2500 to 2900K
Tungsten photoflood lamp	3000 to 3400K
Generic low-voltage tungsten-halogen bulb	3000K
SoLux low-voltage tungsten-halogen bulb	3500, 4100, 4700 or 5000K
"Cool" CFLs (compact fluorescent lights)	5000K

Here are the calibration and lighting combinations that I tried
I experienced a significant mismatch in my very first digital darkroom and tried many different fixes: color management, monitor calibration, different types of lighting and other good digital darkroom practices (see list below).
This table shows the results of the various combinations:

CRT Monitor Calibration	Digital Darkroom Lighting	Color match between monitor and printed output*
6500K, gamma 2.2 using Adobe Gamma	Cool fluorescent	Poor
6500K, gamma 2.2 using Adobe Gamma	5000K fluorescent	Poor
6500K, gamma 2.2 using Adobe Gamma	3050K generic low-voltage tungsten-halogen	Poor
6500K, gamma 2.2 using calibration program 1 + sensor	3050K generic low-voltage tungsten halogen	Poor
5000K, gamma 2.2 using calibration program 1 + sensor	3050K generic low-voltage tungsten-halogen	Improved, but still pretty poor
5000K, gamma 2.2 using calibration program 1 + sensor	4700K SoLux low-voltage tungsten-halogen	Acceptable, but still minor issues
4700K, gamma 2.2 using calibration program 2 + sensor	4700K SoLux low-voltage tungsten-halogen	Excellent; a near-perfect match
5000K, gamma 2.2 using calibration program 2 + sensor	5000K SoLux low-voltage tungsten-halogen	Excellent; a near-perfect match

*: Photographs printed on Epson Stylus Photo printers using Epson ink and Epson matte photo paper

Good digital darkroom practices for color-critical work

- CRT monitor electron guns and phosphors age noticeably over time. LCD monitors age also, albeit at a slower rate. Calibrate your monitor every 3 months or more frequently after a warm-up of at least 30 minutes; a simple routine like Adobe Gamma is OK, a calibration program plus sensor that actually measures your monitor's light output is infinitely better; see my recommendation.
  Many LCD monitors have a markedly reduced color gamut and are not recommended for color-critical work; see my LCD monitor recommendations below.
- Let your monitor warm up for at least 30 minutes
- Switch off all lighting in your digital darkroom other than the special lighting used to view printed output
- Shield light from the outside and other rooms/work areas from your digital darkroom
- Use a screensaver that darkens your monitor screen after five or 10 minutes of non-activity to reduce the effects of aging
- Use a neutral gray monitor screen background color
- Use a neutral gray or black monitor hood
- Paint digital darkroom walls and ceiling in neutral gray or white "colors"
- Wear clothing that is not colorful to avoid a color cast on your monitor screen
- Use appropriate profiles when scanning, particularly for color negatives
- Use appropriate color spaces for importing and editing images
- Use appropriate profiles for your printer/ink/paper combinations
- Let prints dry 30 minutes to one hour before judging them
- ***Understand the issue of a mismatch in color temperature and brightness between your monitor and your digital darkroom lighting and make corrections as described in this article***

You can objectively test for a color temperature and/or brightness mismatch

There is a relatively simple method to more objectively test for a color temperature and/or brightness mismatch then eyeballing it; it requiring the use of a digital camera that allows you to set it for a particular color temperature (it really doesn't matter which color temperature; any setting will do). If you are interested, drop me an email and I will send you the description.

What does "daylight" really mean?
Many advise to use "daylight" lighting in the digital darkroom to have a "good" match with the "daylight" setting of the monitor. Since there is no widely accepted definition for "daylight", this advice is too vague and inaccurate to be of any practical use. The sources that I have researched use many different definitions, both in terms of the name and the corresponding color temperature.

Description	Color temperature
"Horizon Daylight"	2300K
"D50 Noon Sky Daylight"	5000K
"Equivalent of daylight"	5000K
"Average daylight"	5500K
"Noon daylight"	5500K
"Daylight"	5500K
"D65 Average North Sky Daylight"	6500K
"Daylight"	6500K
"Standard daylight"	6500K
"D75 North Sky Daylight"	7500K

What about using "full spectrum" lights?
The term "full spectrum", while sounding good, has no useful meaning since it is not defined in any scientific way.

What about using special fluorescent lights?
Many manufacturers offer fluorescent tubes for so-called critical viewing applications. All these lights have significant spikes that vary between makes and models and include spikes in the violet, purple, green, yellow and orange range of the color spectrum. In addition, there is a significant reduction in output at the red end of the visible color spectrum. As a result, errors in color evaluation using these lamps are significant.
Also, these lights age considerably over time. Their color spectrum changes significantly well before they stop working. This requires replacement after a certain amount of hours by means of manually keeping track of the time the lights are used (tedious and error prone) or automatic timers (expensive).

What about using a viewing booth?
Viewing booths or stations are also used for viewing prints, art, pre-press artwork, product samples, etc. There are many types and sizes. Most use the special fluorescent lights mentioned above; only a few use low-voltage tungsten-halogen lights. There are significant drawbacks:

- The above-mentioned color spectrum issues when fluorescent lights are used
- Most take up a significant amount of real estate
- They are expensive

Does calibrating at a lower color temperature cause accelerated CRT wear-out?
Many years ago, this may have been a valid concern. However, the effect on reliability of lowering the color temperature of today's CRTs is negligible. For instance, when lowering the color temperature of my Sony 21" Trinitron CRT from 6500K to 4700K while maintaining the same overall brightness, the red channel brightness increased by only 13%, the green by 3% and the blue decreased by 14%. There are good reasons to calibrate your monitor at 5000K versus 4700K, as explained below in my recommendations.

My recommendations

- **Good digital darkroom practices**
  Always follow good digital darkroom practices (see above).
- **Use the best photo-quality printer you can afford**
  I have obtained excellent results with Epson printers. Photos printed on my Epson Stylus Photo 2200

printer will last for at least 61 years before noticeable fading occurs when displayed under glass, longer if in an archival quality album, according to Wilhelm Research.

- **Use the best quality monitor you can afford**
  In the past, high-quality CRT's have been the standard for color-critical work. Now some LCD monitors are available with favorable characteristics for the digital darkroom. Here is a list of specifications that I believe to be crucial for LCD monitors for this type of work:
  - Size: 19" or larger
  - Native resolution: at least 1280x1024
  - Brightness: 200 cd/m^2 or more
  - Backlight adjust: backlighting must be adjustable to reduce brightness to between 80 and 120 cd/m^2
  - Contrast ratio: 600 or more
  - Gamma correction: 10 bit or more
  - Gamma range: at least 1.8 to 2.2
  - Viewing angles: at least 170 degrees horizontally and vertically
  - Color temperature: adjustable to at least 4900 or 5000K
  - RGB controls: R, G and B must be independently adjustable
  - Color gamut: at least sRGB (about 70% of the Adobe RGB (1998) color space)
  - LCD Pixel defect rate: defective pixel (intermittent, always on or always off) rate per ISO13406 Class II

  So far I have been able to find only a handful of LCD monitors that meet most of these specifications. I particularly like the NEC Series 90 monitors with the letter "i" in the product name, indicating the use of an IPS LCD panel.
- **Color temperature and brightness matching**
  <u>Monitor calibration</u>
  The goal is to match your monitor color temperature to your digital darkroom lighting color temperature. Use a calibration program that actually measures your monitor's light output with a sensor. When you light your digital darkroom with SoLux 5000K bulbs, calibrate your monitor at 5000K/gamma 2.2. Invest in a calibration program that lets you choose your own values for color temperature.
  <u>Digital darkroom lighting</u>
  The goal is to install the best possible digital darkroom lighting and match its brightness to the brightness of your monitor. I strongly recommend SoLux 5000K 35W low-voltage halogen bulbs. A case could be made to use the 4700K versions, since they are close to 5000K in terms of color temperature, are available in both 35 and 50W versions and have an estimated life of 4000 hours versus 500 hours for the 5000K version. However, at 4700K monitor calibration, the red electron gun of a CRT needs to be turned up quite a bit, which leaves less margin for its aging. At 5000K, the red gun is turned up less, creating more of a margin for aging over time, resulting in a longer useful monitor life.
  These bulbs have been specifically designed for critical viewing applications. They have the best match to the D50 color spectrum and their spectrum is very smooth without spikes. They also have ultra-low UV and IR output, which significantly reduces fading of sensitive materials. These bulbs do not age noticeably. Total light output decrease by less than 5% over their life and the color spectrum does not change by more than 30K degrees over their total life span. At the time of this writing, you can buy the 5000K bulbs only from SoLux, as other vendors seem to carry only the lower color temperature versions. SoLux also offers a variety of fixtures for these bulbs. There are reasonably priced clip-on lamps, fixtures that screw into standard light bulb sockets, table lamps, floor-standing lamps, adjustable spotlights, track systems, etc.
  A ceiling track system allows for the greatest flexibility in where and how many fixtures you use and where you aim each fixture. The 5000K 35W 36-degree beam spread SoLux bulbs will give you a decent size of illuminated area on your desk or table surface to view your printed output if you mount them about 4 feet above your work surface. Two of these bulbs would be a good starting point to see if you get a good match between the brightness of your calibrated monitor and your printed output.
  If you use SoLux bulbs in non-SoLux fixtures, make sure to use fixtures with the proper power rating and make sure that those fixtures have no glass window in the front to prevent it from changing the color

temperature. Use “closed” fixtures without venting holes; the back of the bulbs emit a significant amount of light with a strong red cast; this light will escape from venting holes and “contaminate” your viewing area. The bulbs will get pretty hot in a closed fixture, but they can take the heat.

- **Image editing software color space**
  Don’t change the color workspace of your image editing software; you only want to change the appearance of the colors on the monitor.

Recommended manufacturers/researchers:

- **Epson:** www.epson.com
- **NEC: :** www.necdisplay.com
- **SoLux**: www.solux.net
- **Wilhelm Research**: www.wilhelm-research.com

Frans Waterlander is a retired quality and reliability professional from the electronics industry. Digital photography is one of his hobbies. His Internet address is frans2001@gmail.com.