RGB laser light in cinema projection

Kommer Kleijn SBC, March 8th, 2024, IMAGO ITC Meeting

On March 8th 2024 an IMAGO ITC (Imago Technical Committee) meeting was held on the subject of issues cinematographers and color graders had noticed with the use of RGB laser D-cinema projectors. I was asked to provide some explanations, as I have been following this subject for some time now as both an audiovisual perception researcher and a cinematographer. I wrote the following notes in preparation for this meeting.

Intro

When the change from film projection to digital presentation first came about, much attention was given to continue to guarantee to filmmakers that their creative decisions about color and contrast will remain unaltered in the commercial cinema theatre, as had been the case with analog film projection. With electronic projection, it was feared that, like with television, individual projectors would be each adjusted differently and also that movies would look different on projectors using different imaging technologies, as there were DLP, DILA and SXRD imagers and Xenon and UHP light sources. Great care was taken to alleviate all the concerns and the filmmakers' community was assured that movies would look exactly the same on all current and future projectors and systems. To practically realise this, a series of technical measures were taken which were among others disabling access to the contrast, saturation and black level settings on the projectors and the design and adoption of a new DCP file format that defines "to be perceived colors" (XYZ co-ordinates in the CIE1931 diagram) rather than RGB values to be projected. This file format defines what must be seen, and not how the projector must be steered. Projector steering then is calculated by the projector itself, who's manufacturer takes responsibility for the steering needed in order for the correct colors to be seen. Now color rendering becomes independent from the physical projection technologies used. All decisions are done in the grading room and should reproduce in every commercial cinema with precision. This promise has been a condition for the film making community to embrace digital projection and we must say that this promise has been kept quite well for numerous years. I think this is worth a serious congratulation to all involved in cinema presentation, equipment manufacturing, standardisation, and filmmaking.

Now, decades later, there seems to be some trouble on the horizon however, as some of you reported not to retrieve what you decided on in the grading room, when seeing your movie in certain commercial theatres.

This apparently lies with a new projector illumination source called RGB laser. Having a triple-monochrome spectrum rather than a continuous spectrum, this seems to cause some practical differences. I have tried to separate these into groups. Two concern color perception, one concerns an artefact, and one concerns image texture perception. A fifth is about a separate projector advancement and is not color, but contrast related.

I have detailed these below, in no particular order.

Before I start, I must note that there are actually two families of "laser sources" proposed on the market today: Phosphor and RGB. For small to medium size screens so called "phosphor laser" projectors are proposed. These use either one laser (blue) or two lasers (blue and red) and then use phosphor wheel systems to generate the remaining color(s).
The light produced by laser-exited phosphor wheels has quite similar spectral properties as the light from a xenon lamp. As in a laser-phosphor projector only one or two of the three primaries are a narrow spike, and the remaining are again spectral like before, the issues outlined below seem to manifest themselves less strong compared to the full RGB

laser source projector. It is important to note that on laser-phosphor projectors the effects described below can be almost imperceptible or are often noted with less strength. The effects outlined below were noted on RGB laser projectors. See also figure 2 on page 5 below for curves of the emitted spectra of these new light sources.

1) "Broken" color science (Illuminant metameric failure)

Using a triple-monochrome RGB light source in stead of a continuous spectrum light source apparently breaks the color science that is actually in common use in the cinema industry. The color science used in the cinema industry today is based on the CIE1931 standard observer and the subsequent math. It seems, however, that this mathematics did not take into account the possibility of triple-monochrome RGB light sources. I also note that in the year 1931, there probably weren't that many laser light sources around...

The practical problem that this causes is a perceptually different white point, even when the currently used color science and measurement methods affirm that everything is set up correctly. The color theory that is used to let us predict with certainty and precision what a human observer will see, does not seem to apply any more when a triple-monochrome light source is used. The currrently used validation system or theory seems to be "broken".

A projector using triple RGB monochrome light sources can measure O.K. towards the SMPTE reference projector standard, and satisfy the criteria for being "DCI compliant", while it is actually rendering color in a way a human perceives it differently than intended. And so while in fact, this was what the XYZ DCP standard was designed for to avoid …

If the currently applied color science, based on the CIE1931 observer, and the XYZ DCP standard that is based on it, turn out to be "broken" when used with narrow bandwidth primaries, then maybe we need a new color theory to make it work again?

Possibly, new color science can solve this problem. However, that would imply to rewrite the SMPTE DCP standard (and the DCI specification). That then could allow for a stable white point and color rendering independent of the light source type, including Xenon, UHP, all flavours of phosphor-laser and all flavours of RGB laser[1]. However, rewriting the standards would require a considerable amount of work. Someone would need to step up and propose to start it...

Barco has recently announced[2] a solution called "Metameric Offset Correction (MOC)"[3]. By applying a 3x3 correction matrix to the calibration values of the RGB laser projector, the perceptual differences are reduced, without the need to change the actual DCP standard. It must be applauded that Barco is actively researching and working on this issue. This solution is at this time proposed for projectors in grading rooms. Theatre projectors are not (yet) mentioned. That may raise the question how the so graded work will show on theatre projectors, if not so equipped, and on projectors made by other brands. And if the MOC-modified projector will still measure conform the actual standards, given the "broken standard" issue[4]. If not, this might restrict this solution to the grading room indeed, until an industry standard for this correction method would be created and licensed. That may not

[1] Flavours: Triple-monochrome RGB laser light source projectors may use different wave length for primary colors depending on brand or model. Some use different RGB wavelength for the left and right eye in 3D projection.

[2] https://www.cinionic.com/white-paper/advancing-color-accuracy-in-cinema-postproduction/

[3] https://cinionic.com/direct-downloads/partners/documents/whitepapers/Barco_Metamerism.pdf

[4] We then might on one hand have RGB laser projectors (without MOC) that measure conform the actual standards but look different, and on the other hand have projectors that look more conform (using MOC) but then don't measure conform the actual standards any more… Could "broken color science" have resulted in having "broken standards"?

be trivial either, but could be much easier than rewriting the actual DCP standards… So I think that the Barco "MOC" system may eventually be a promising development indeed.

2) Individual metameric variations (Observer metameric failure)

The spectral sensitivity curves of the receptor cells in the human retina vary from person to person. The brain behind each individual pair of eyes however, is accustomed/trained to the specific spectral sensitivity of the eye retinas of that person and takes this into account. However, this natural compensation mechanism has evolved with continuous spectrum light sources. When triple-monochrome light is used, the overlaps with the spectral sensitivity curves of the retina become cross-points rather than areas (See figure 3 below).

As a result, individual differences in spectral sensitivity curves may have a greater effect on the resulting trichromatic stimuli with RGB laser than with a continuous spectrum. And the brain is not trained for this and may not be able to compensate for the individual sensitivity differences in the same way. The perceived differences may then be bigger and this may become a concern. I found only few studies about the severity of the effect. An interesting study by Yuta Asano et all[5], presented in November 2014, shows with practical images that the visual differences can be significant when working with a laser projector an LCD display. This triggers concerns that the effect might be more severe than marginal, and creates an interest towards further quantitative research.

If it would be confirmed that the perceptual differences between individuals can become significant in a cinema theatre setting, then these differences could trouble grading sessions as the different players in the room (Director, Producer, Cinematogra-pher, Colorist, ...) need to agree on color decisions. If each individual actually sees something different on the same screen, then this could make obtaining a consensus more difficult. Subsequently it could diminish the control that filmmakers have over what the final viewers see in the RGB laser equipped commercial cinema theatre. If possibly individual patrons each see something different while watching the same screen, then it may also be different from the filmmakers' intentions.

I would like to propose to do further research on this. I am looking for support, as well as for test persons. Please let me know if you are interested or if you can participate.

3) Color Fringing

Presentation systems using monochrome, or very narrow bandwidth primaries can produce a color fringing effect for the viewers. I found that this effect also is a result of incompatibility between the human visual system and narrow bandwidth primaries. It visually looks like registration errors between the color channels, showing thin colored lines, there where the image contains high contrast sharp borders. It is most visible on subtitles and credits but also on in-picture elements of high contrast, like specular highlights, window borders, horizons and reflections on water. However, such colored fringes are not actually physically there. Walking towards the screen allows to confirm this: Close to the screen the effect disappears, walking away from the screen makes it larger, also with a well-aligned projector. The effect is proportional with the distance between the viewer and the screen, while with an actual mis-aligned projector this is exactly the other way around. The strength of the effect also varies from person to person and it is often stronger for persons wearing prescription glasses or contact lenses. Some persons don't notice it at all. As it also changes with contrast, it is more present with HDR.

[5] Yuta Asano, Mark D. Fairchild, Laurent Blondé, Patrick Morvan, "Observer Variability in Color Image Matching on a LCD monitor and a Laser Projector" in Proc. IS&T 22nd Color and Imaging Conf., 2014, pp 1 - 6, https://doi.org/10.2352/CIC.2014.22.1.art00001

My view is that this effect occurs as a result of the workings of the human visual system: One must realise that, contrary to modern camera or projection optics, the human eye optical system is not equipped with compensation for chromatical aberration. Nor are prescription glasses or contact lenses.

Therefore, high contrast sharp borders are projected on the retina with the chromatical aberration. In practice this means a slightly soft border with a soft rainbow pattern between the light and dark part. The unconscious image processing parts of our brain will recognise this specific border structure pattern as chromatical aberration and will correct for it. The unconscious brain will remove the rainbow pattern and the fuzziness and will reconstruct a sharp border, before passing the image on to the conscious part of the brain.

However, with a triple monochrome RGB light source, the rainbow pattern can not form, nor will the fuzziness, as there are only three narrow primaries, and all other wavelength are absent in the light. On the retina, three sharp borders will form instead of gradients, and the rainbow pattern will not be formed. The brain then may not recognise this as chromatical aberration and may not correct nor reconstruct. It then passes the sharp colored borders on to the conscious brain and these will be perceived.

4) Speckle

Coherent monochrome light waves of laser light allow it to interfere with itself and create random dark and brighter spots in the image. This interference appears as grainy and moving “speckle”. This can be mitigated[6] by applying diversity or mechanical vibration, each of which, however, comes with a cost in projector manufacturing or installation.

Speckle free projection has been achieved and shown and at times it was believed to be considered a problem solved. However, in practice, complaints apparently still occur. Speckle not only can cause viewing discomfort; it also can change the perceived texture (grain structure, noise structure) of the image and as such change the creative intent of the filmmakers. When several primaries work together, this already is some form of diversity, therefore speckle has a tendency to show more on saturated reds or greens, when a single primary color is active in a majority.

5) Contrast Changes (This one is not triple monochrome spectrum related)

Recent laser projectors are often capable of deeper blacks than lamp projectors are. This is a positive development but it also can raise issues if not managed carefully by us: It is possible that details in dark picture areas, not visible on Xenon projectors, unexpectedly become visible on a laser projector. If those details contain foreign elements (like cables running over the floor), then this can be bothersome for the cinema going experience.

Secondly, deeper blacks, if unintended, can result in a different lighting atmosphere, and can potentially change the intentions of the Director of Photography, Colorist, Director, Producer, for the feeling of the scene.

Both effects can be explained when values lower (darker) than what a xenon projector can render are (unintentionally?) put into a DCP, and went unnoticed because of a Xenon projector in the grading room that was not capable to render these. When the DCP is then presented on a laser projector, these values can be displayed. During grading we probably best avoid to put values in the output file, which the system in the grading room can

[6] https://en.wikipedia.org/wiki/Speckle_(interference)#Mitigation

not display. Maybe grading software could help by issuing a warning in such case? Or one could check on both display systems. Deeper black, like HDR, is a valuable asset we can use, but for some time we will need to deal with the fact that not all theatres can display it.

Note also that this issue is not entirely new, as Sony SXRD projectors (now discontinued) were also capable of displaying some deeper blacks.

Kommer Kleijn SBC, Brussels, March 8th, 2024© imago@kommer.com www.kommer.com

Annex:

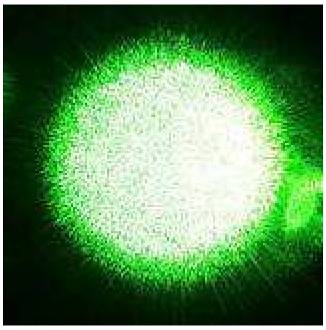

Figure 1. Laser speckle. Source: https://en.wikipedia.org/wiki/File:Laser_speckle.jpg

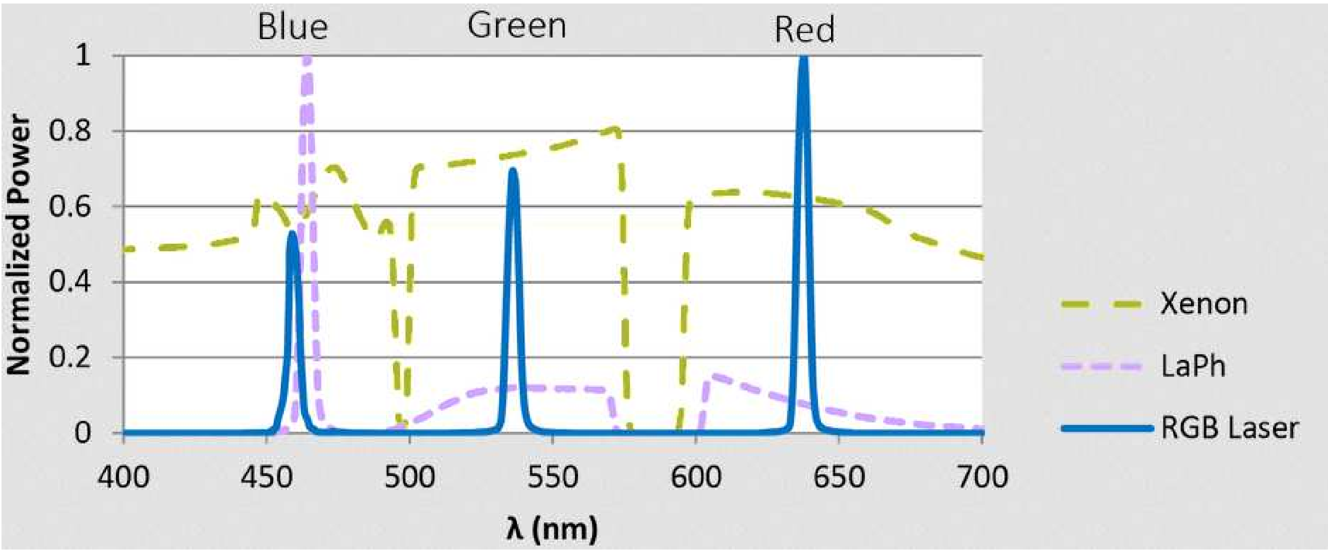

Fig 2a. Spectrums for Xenon, Phosphor-laser and RGB laser light sources for D-cinema
Source: https://spie.org/news/spie-professional-magazine-archive/2018-july/the-days-of-the-xenon-lamp-are-numbered

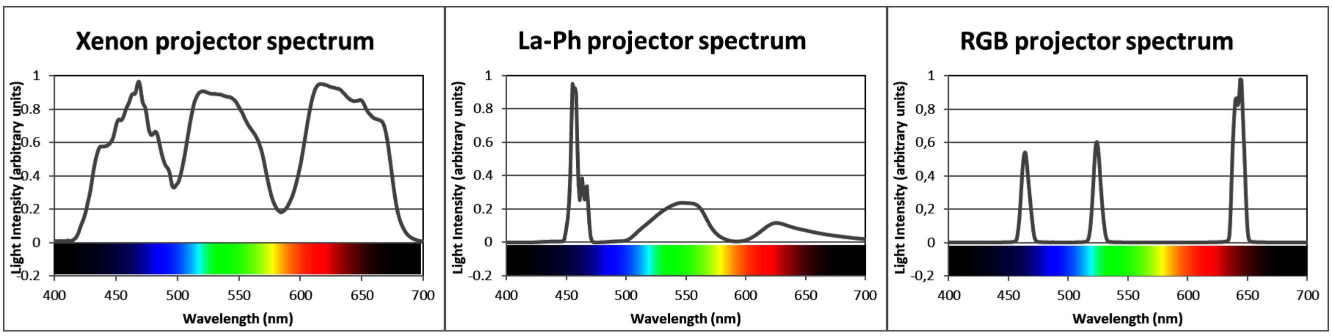

Fig 2b. Spectrums for Xenon, Phosphor-laser and RGB laser light sources for D-cinema
Source: https://cinionic.com/direct-downloads/partners/documents/whitepapers/Barco_Metamerism.pdf

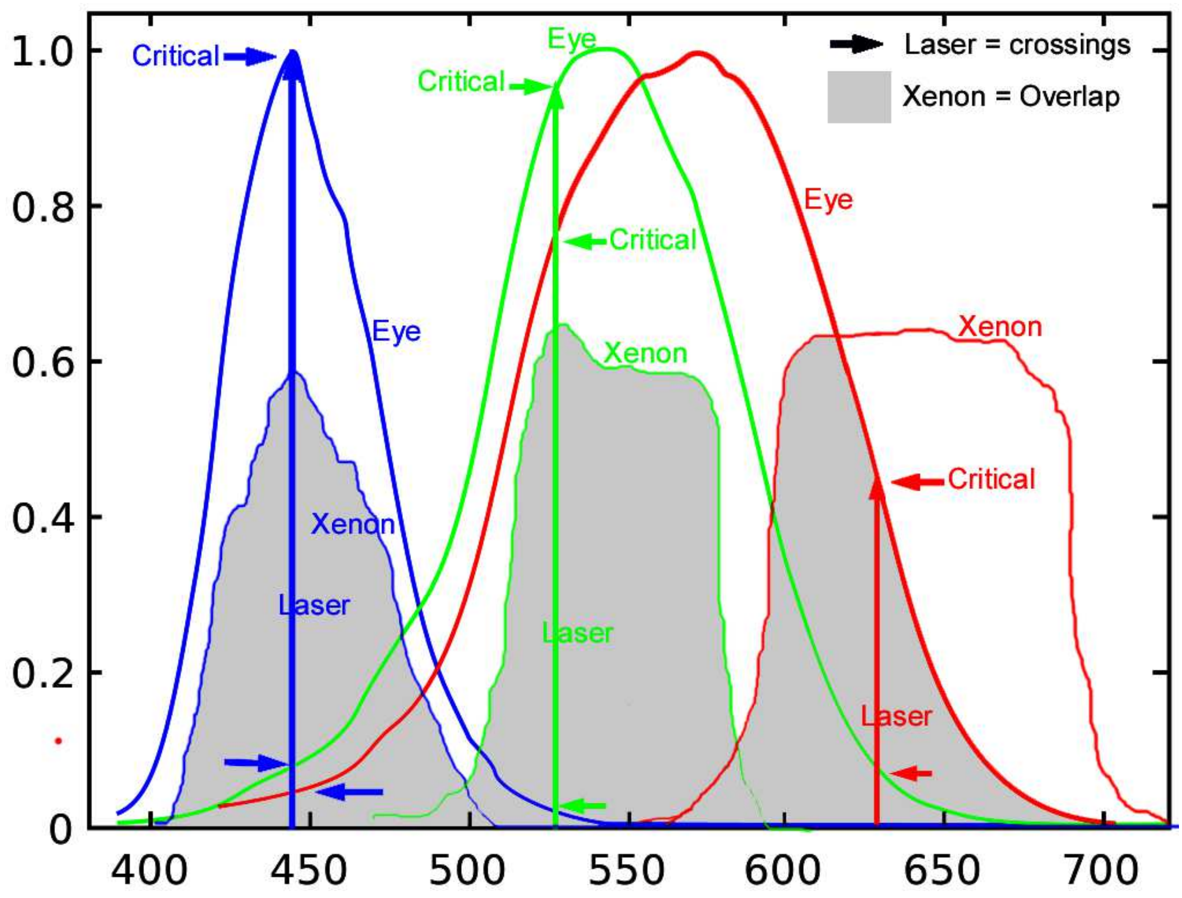

Figure 3. Overlap between spectral sensitivity and Xenon, and crossings with laser.
Source: http://www.kommer.com/20230616_Kommer_Kleijn_Laser_def.pdf

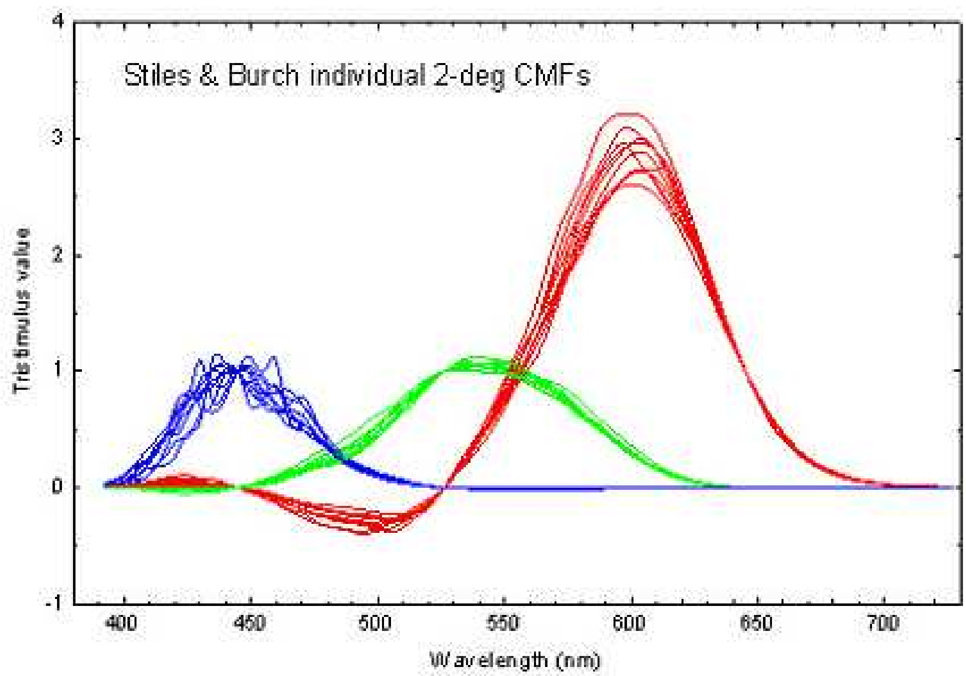

Figure 4. Individual spectral sensitivity curves as measured by Stiles and Burch

Figure 5. *sRGB rendered test image 01 adjusted by extreme observers and the CIE 1964 observer.*

Source: Yuta Asano et Al, "Observer Variability in Color Image Matching on a LCD monitor and a Laser Projector", https://doi.org/10.2352/CIC.2014.22.1.art00001

Figure 6. *sRGB rendered test image 03 adjusted by extreme observers and the CIE 1964 observer.*

Source: Yuta Asano et Al, "Observer Variability in Color Image Matching on a LCD monitor and a Laser Projector", https://doi.org/10.2352/CIC.2014.22.1.art00001