It's not all black and white

A journey through projector contrast specs

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Introduction

Cinema has come a long way since the first digitalization wave. Initially, together with the forming of the DCI initiative, the target was to replace film projectors with digital projectors that comply with a set of requirements that would guarantee a minimal and consistent level of quality compared to film. Now, more than a decade later, and looking towards the prospects of the "second wave" in cinema, the market expectations are changing.

On one hand, we have the strive for operational efficiency: reducing operational costs by going to laser projectors, less service and maintenance, and other operational savings on a level of the whole multiplex. On the other hand, there is an increased focus for creating better, different, premium audience experiences, which lead to concepts like Premium cinema, VIP or boutique rooms, PLF concepts, etc.

One of the key differentiators for a premium image quality is good contrast (or a deep black level) which, in combination with a higher 2D brightness, paves the way towards true cinema HDR.

When talking about contrast, we can make a distinction between projector contrast and ANSI contrast, as recently explained in a Barco whitepaper by Tom Bert [1]. We warmly recommend reading that paper first. This current whitepaper takes the story further and provides guidance about realistic expected on-screen contrast values for different auditorium designs, average scene brightness and different projector technologies.

Before we start

For a start, it is helpful to clarify some concepts that are frequently used when talking about the contrast of an image.

First, we should distinguish between "**native**" projector values, and "**on-screen**" values. Native projector values are measured looking directly toward the projector lens, excluding any impact from the environment (screen, auditorium, ambient light, etc.), while on-screen values are measured on screen, including all ambient influences.

For example, projectors can specify a certain ANSI contrast, and this is measured in the lab by having the measurement probe looking directly at the projection lens, while using specific enclosures to eliminate ambient reflections. Measuring a projected ANSI test pattern on the screen will typically yield a much lower value because many types of reflections take place that influence the "on-screen ANSI contrast" value.

So when we talk about properties such as contrast, ANSI contrast or black level, we will distinguish between "native projector" values and "on-screen" values.

Another clarification that's worth making is the difference between "**contrast**" and "**black level**".

These two parameters are very much interlinked. "Contrast" is a ratio between the luminance of a white field (white level) and the black field luminance (black level). The typical (native) projector sequential contrast value for cinema projectors is 2000:1, which means that if the white level is calibrated to 14 fL (48 nits), the black level will be 0.007 fL (0.024 nits).

In fact, when we talk about (ANSI) contrast decreasing in certain conditions, this happens because the black level increases, so it's relevant to make this distinction as well as noting the link between the contrast and black level.

Modelling on-screen contrast in a real-life auditorium

Since 2015, Barco has ventured into examining the impact of different parameters on visible, on-screen contrast in a cinema auditorium, and we have developed a model to quantify this depending on projector and auditorium parameters [2].

Figure 1 explains the concept visually, in a step-by-step way. On the top left (1) you have a projector that produces an ANSI contrast image. If the optics were perfect, then the ANSI contrast would be exactly the same as the sequential contrast. However, due to scattering inside the imaging optics and lens, the projector ANSI contrast is lower than its native sequential contrast. In addition, the port window also adds scattering. So there is always a bit of a "haze" coming through the lens and the port window (2), which is proportional to a certain **scatter coefficient 's'** that is a combination of the lens and porthole performance.

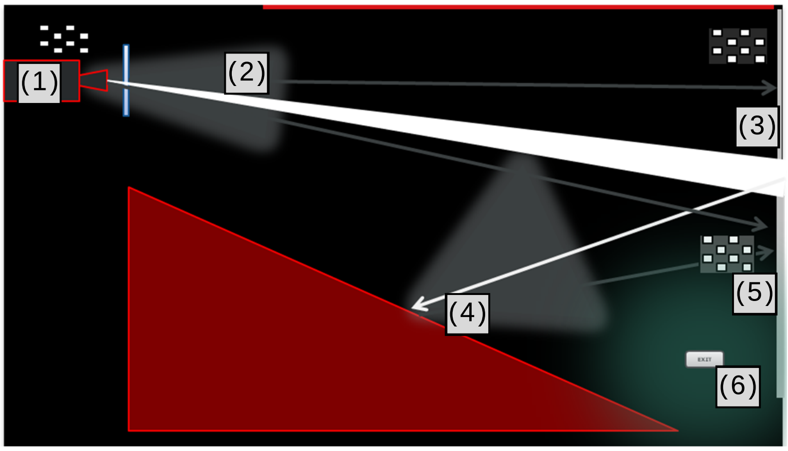

Figure 1: A model for calculating the on-screen ANSI contrast

Next, the light from the projector together with the haze hits the screen (at the right-hand side of the image (3)). But this is not yet what we observe. This light reflects off the screen and hits different auditorium surfaces (seats, floors, people, etc. (4)). A part of this reflected light, proportional with the **auditorium reflectivity coefficient '*r*'**, falls back on the screen and further increases the black level and decreases the on-screen contrast (5).

The final result, the one we see, is quantified by the "on-screen ANSI contrast" (5) - a measure of how much scattered light in the optics, as well as reflected light from the auditorium, pollutes and increases the black level in the ANSI pattern.

In reality, there is always even more light pollution: from the exit signs, stair lighting, cracks between the exit doors, etc. (6). This, of course, does not depend on the image content or projector type and is very different for every auditorium, so we won't consider it further.

How does average image brightness impact on-screen contrast?

So far, we have spoken about the ANSI contrast (native or on-screen). However, most scenes in a movie are much darker than even the ANSI pattern. In order to quantify this, let us introduce the concept of "APL" - Average Picture Luminance - which, simply put, is the total light the image carries as a percentage of the total light available in a full white field.

The APL of an ANSI contrast pattern is 50%, since half of the image is white and half of it is black. Figure 2 shows generalized test patterns that are derived from the ANSI pattern, but with APL levels varying between 1% and 50%. Such patterns are used to represent any realistic image that has the same average luminance as the test pattern.

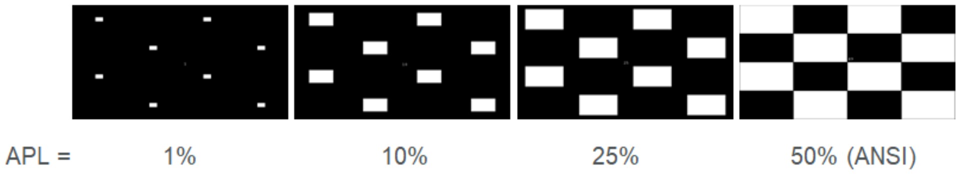

Figure 2: ANSI-like patterns with varying levels of white field representation (APL) between 1% and 50%.

There is nothing special about the on-screen ANSI contrast value as this is simply the case when APL=50%. However, the ANSI test pattern is still relevant because it is easy to understand, wide spread and easy to measure due to the relatively large surfaces of the white and black rectangles.

How do scatter (*s*) and reflectivity (*r*) coefficients and the APL impact the on-screen contrast that we experience?

When the APL is 0% (full black image), the black level is obviously the native projector black level. When we start increasing the white content, the black level also increases because of scatter and reflectivity, according to the qualitative model presented in the previous section. In fact, the increase in black level luminance is equal to $(s+r)*APL*W_{projector}$, where $W_{projector}$ is the luminance of the white field, e.g. 14 fL. Since contrast is inversely proportional to the black level, the higher the optics scatter and/or auditorium reflectivity, the lower the on-screen contrast will be. The higher the APL of the image, the lower the on-screen contrast as well. Using our method [2], we have determined the range of scatter and reflectivity coefficients in a number of cinema auditoriums with DLP projectors. They are summarized in Table 1.

Table 1: Measured ranges of scatter and reflectivity coefficients and resulting on-screen contrast ranges in a number of real-life auditoriums

	Range	Typical value
Lens+porthole scatter coefficient *"s"*	0.5 – 1.8%	1%
Reflectivity coefficient *"r"*	1.1 – 2.5%	1.5%
"s+r" coefficient	1.6 – 4.0%	2.5%
On-screen contrast for 5% APL	770 – 380:1	570:1

Knowing these coefficients for each projector and auditorium, we can predict the actual on-screen contrast value for any realistic image if its APL value is known.

In Table 1, we can already calculate the range of on-screen contrast value, e.g. for an image with 5% APL. We can see that just due to the spread of parameters, the on-screen contrast value decreases as much as twofold between the best (770:1) and the worst case (380:1) we measured.

Table 1 gives a contrast value for 5% average picture luminance. How does the on-screen contrast change for a range of APL values? Figure 3 gives that answer. We used a standard DC lamp projector with a native sequential contrast of 2000:1 and a scatter coefficient *s*=1.5% that represents a realistic situation. One can immediately notice the drastic decrease of on-screen contrast with increasing image brightness, even for the best auditorium reflection of *r*=1%. Also notice that the on-screen ANSI contrast (50% APL) is in the range of 40–80:1. A huge drop from the 2000:1 native sequential contrast value! And for a given low APL of say 5%, there is a significant difference in the on-screen contrast between the best and worst case auditorium reflectivity. Reference [3] provides some guidelines for good auditorium design for minimizing reflections, and points to further research.

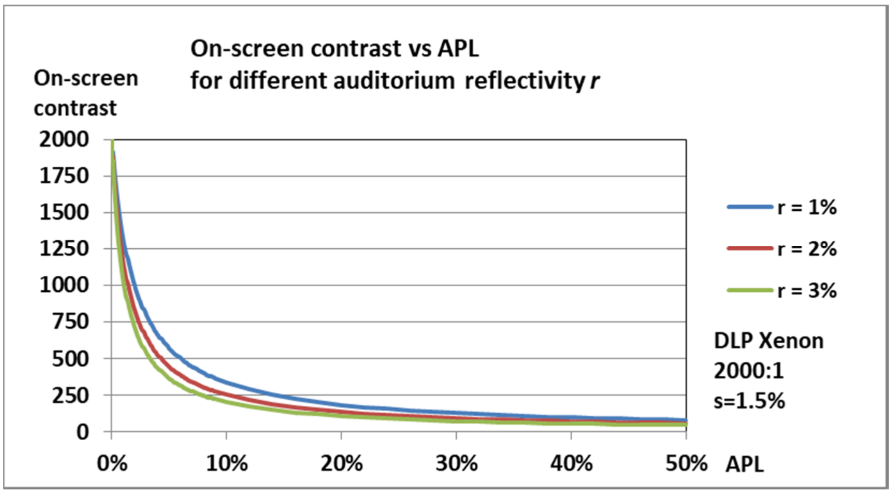

Figure 3: The impact of the auditorium reflectivity on the on-screen contrast when the average picture luminance (APL) increases to 50%.

Comparison of different projector technologies

How do different projector technologies score when it comes to on-screen contrast, given the same auditorium parameters?

Barco has done some evaluation there as well [4], and the results amended with recent updates are presented in Table 2. For different projector types, we list the projector sequential contrast, native ANSI contrast and the lens scatter coefficient *s*. You might notice that the scatter coefficient in Table 2 is significantly lower than the field-measured values presented in Table 1. The reason is that the *s* value in table 2 is the native projector value, not containing the influence of the port window. The higher real-life values in table 2 contain additional scattering by dust on the lens and by the port window. These factors add to the ‘haze’ leaving the port window.

Table 2: Sequential and ANSI contrast values for different projector technologies

Technology	Sequential contrast	Native ANSI contrast	Lens scatter coefficient s
DLP Xenon	2000:1	250:1	0.7%
DLP RGB (Barco)	2800:1	500:1	0.3%
DLP High Contrast RGB (Barco)	6000:1	1000:1	0.2%
DLP High Contrast laser phosphor (Barco)	5000:1	600:1	0.3%
High Contrast LCoS	10000:1	180:1	1.1%

Using the derived projector and auditorium parameters, let's take a look at how the on-screen black level is impacted by different projection technologies.

Figure 4 shows the on-screen black level for different average picture luminance (APL) but zooms in on a more relevant movie APL range of 0–10% [4]. We use the typical auditorium reflection and scatter values, and focus on the economic lamp and laser phosphor projector models.

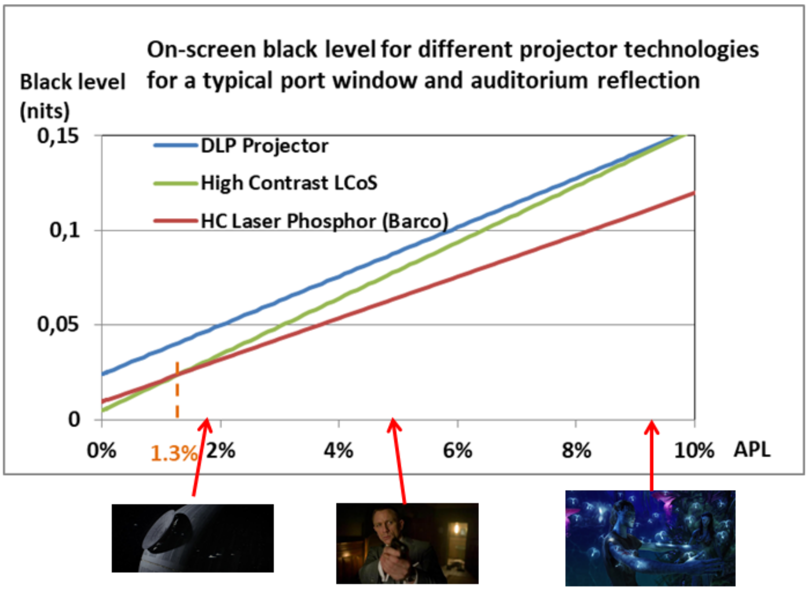

Figure 4: The impact of projection technology on the on-screen black level for typical auditorium reflection of 1.5% and typical port window scatter of 1%.

The standard DLP projector (blue curve) produces the highest on-screen black level (lowest contrast). The LCoS projector (green curve) starts with a low black level due to the highest sequential contrast, but then the on-screen black level increases rapidly. In fact, at 10% APL, the black level of the LCoS projector is as high as on a standard DLP projector, and continues to increase at the same pace. This happens because of its low ANSI contrast value of an LCoS projector. The red curve shows the Barco high-contrast laser phosphor DLP projector. It starts with a low black level as well, but even as of very dark images (1.3% APL), the Barco HC laser phosphor projector maintains the lowest black level (thus highest image contrast) between the three compared technologies.

When comparing the average brightness of some well-known movie frames that have an average picture luminance between 2% and 10% [4], we see that even for the darkest frames, a high-contrast laser phosphor DLP projector can outperform an LCoS technology projector. The combination of high sequential and the high ANSI contrast of DLP high-contrast projection is the determining factor for good on-screen contrast for both darker and brighter movie frames.

Summary

Image contrast becomes an increasingly important metric for premium image quality in today's cinema market. There are a lot of factors that influence the on-screen contrast. Auditorium reflectivity and scatter on the port window are some of the most crucial ones—if designed and maintained properly, then can easily increase the perceived contrast twofold, even with the same projector in the booth.

Furthermore, once the reflections and port window are under control, the next most important choice for contrast is the projector. As we have seen, good sequential contrast but poor ANSI contrast will not provide the overall best image. A combination of high native (sequential) and high ANSI contrast does provide the best overall image performance.

Key messages

- On-screen contrast is an increasingly important metric for premium cinema screens.
- Auditorium reflections and port window can adversely influence on-screen contrast, so attention should be paid to auditorium design for higher contrast.
- Different projector technologies have very different contrast behavior for a range of images from dark to bright: High Contrast DLP laser projectors provide the best balance between high native and high ANSI contrast with an overall best image performance.

References

[1] "The importance of ANSI contrast ratio in cinema", T. Bert, Barco, July 2018

[2] "Modelling of achievable contrast and its impact on HDR projection in commercial cinema environments", C. Tydtgat, et al., SMPTE Annual Technical Conference and Exhibition, Hollywood, CA, October 2015.

[3] "How to design your cinema auditorium for higher contrast?", T. Bert, December 2017

[4] "HDR in Cinema: Achievable contrast", JP Jacquemin, G. Stojmenovik, Barco, HPA Tech Retreat, February 2017