TECH BRIEF

A color revolution
Realizing real-world color with Rec. 2020

Memorable visual spectacles come from the brightest, most vibrant colors. Whether you're telling stories through cinema or thrilling theme park rides, color is one of your most powerful tools. It influences the audience's reaction and connection to what they see on screen, helps create an emotional response and brings your images to life.

When you're looking for the right projection solution for a theatre, theme park attraction, or planetarium, understanding the science of color makes it easier to choose the technology that's right for you:

› How do we define color?
› What's 'real-world' color?
› What are the differences between color standards?
› How does RGB pure laser achieve the Rec. 2020 color gamut?

Let's dive into the science behind the colors you see on screen.

CHRISTIE®

The science of color

How do we define color?

In 1931, color scientists with the International Commission on Illumination (CIE) created a numerical definition for every color we can see based on the color sensitivity of the eye and plotted them on a diagram, assigning each color a unique coordinate pair (x,y) with the luminance[i] of the color represented as a separate value. The CIE 1931 color space diagram (figure 1) is a visual representation of all the colors a typical human eye can see. The basis of conventional color science, CIE's color space is the standard used to understand current color space representations and their limitations, and identify the color gamut capabilities of specific digital displays, which in turn challenges us to deliver richer images through extended color performance.

How do we reproduce color in the digital display world?

Color on digital displays is generally reproduced by mixing red, green, and blue color primaries. Color science allows us to determine the overall color capability of a display by plotting the chromaticity coordinates (x,y) of each of the primaries on the CIE diagram and drawing a triangle through the primaries. This triangle defines the 'color gamut' of the display. The display can achieve the colors inside the triangle, while it can't reproduce colors outside it. For example, the current HDTV color gamut is defined by Rec. 709 and results in the gamut shown in figure 2.

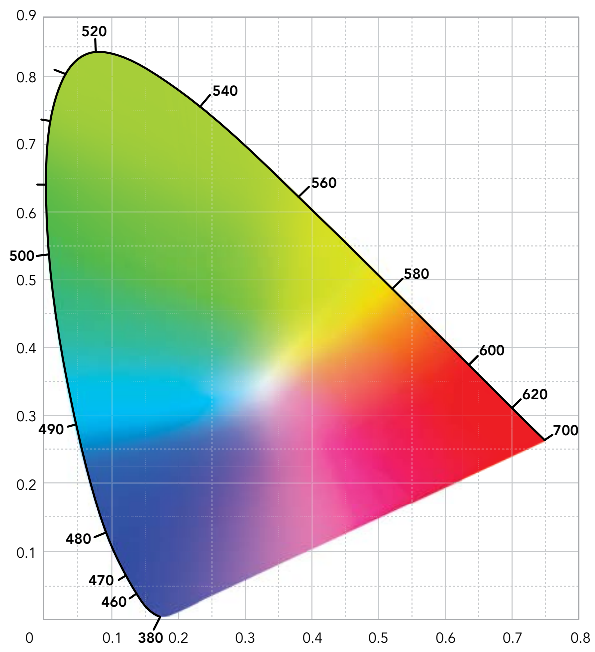


Figure 1: CIE 1931 color space

There are 3 key parts to this diagram. The horizontal (x) and vertical (y) axes are used to define any point on the plot with a pair of numbers. These are called the chromaticity coordinates. Note that the center of the diagram is white, while the colors become more saturated as they move towards the periphery. The periphery is called the spectral locus. The numbers around the spectral locus indicate the wavelength of the light that would make that color.

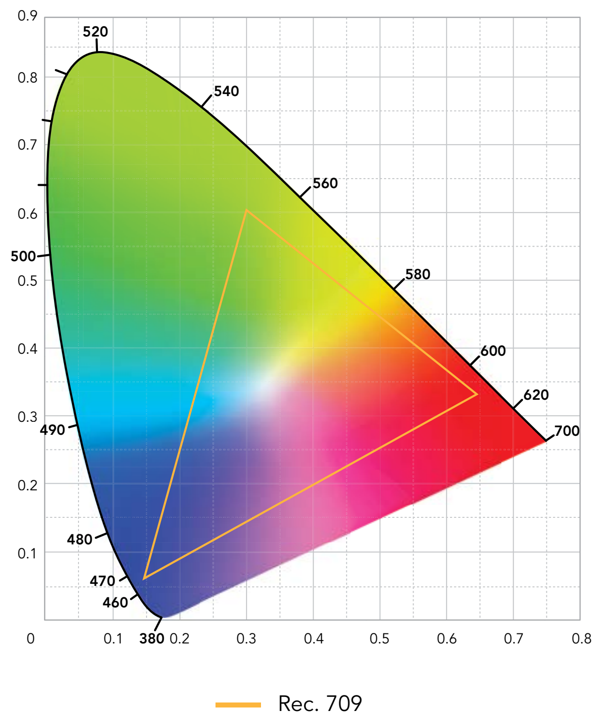


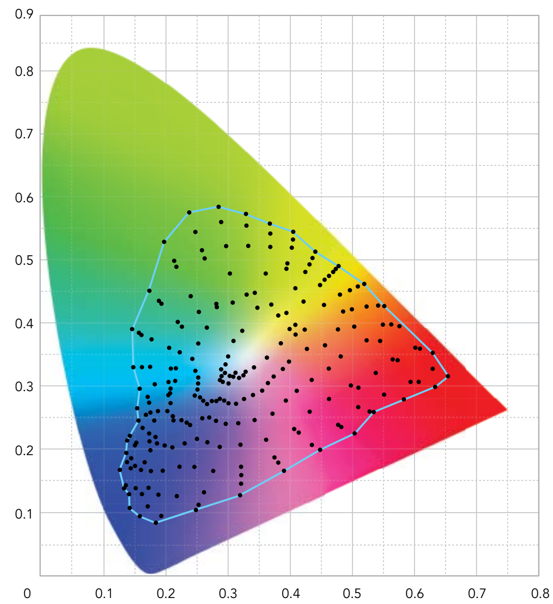
Figure 2: Rec. 709, the color gamut of television

Red, blue and green color primaries of current television standards (Rec. 709) are the vertices of the triangle. The colors contained within the triangle can be reproduced using these primaries. Note that many of the more saturated colors are outside the triangle and not reproducible with this color gamut.

Charting real-world colors: understanding the colors we need to represent

An obvious consideration when reproducing color is the ability to display 'real-world' colors. While the CIE 1931 chart provides a view of all the colors that are visible, it doesn't tell us which colors are common in everyday life.

In 1980, Dr. Michael Pointer published a collection of 'real-world' colors, widely referenced as representing the gamut of naturally occurring reflective colors. The result was an irregular gamut of colors that naturally occurs called 'Pointer's gamut' (figure 3). In addition to real-world reflective colors, there are emissive colors, such as neon signs, LED brake lights on cars, and lightsabers, which are highly saturated and fall outside the Pointer color set.



^ Figure 3: Pointer's gamut of real-world colors

Pointer's real-world colors are plotted on the CIE diagram. A boundary is drawn around these colors, representing the gamut of his "'real-world' colors.

Meet the Rec. 709 and DCI-P3 color standards

Rec. 709 (Recommendation ITU-R BT.709)
The most commonly used standard today, it defines picture characteristics as having an aspect ratio of 16:9, 1080 active lines per picture, 1920 samples per line, and a square pixel aspect ratio. Rec. 709 was developed for camera encoding and signal characteristics of HDTV.

DCI-P3
With a larger color volume than Rec. 709, it's the standard for cinema. This color palette allows DCI-P3 to offer slightly more realistic and lifelike colors through more greens and reds. The DCI-P3 color space has regulated digital cinema projectors and the movie industry since its introduction in 2007 by SMPTE (Society of Motion Pictures and Television Engineers).

So, what's Rec. 2020?

In 2012, the International Telecommunications Union (ITU) published ITU-R Recommendation BT.2020 (Rec. 2020) for ultra-high-definition television (UHDTV). This recommendation covers various image parameters, including definitions for resolution, frame rates, bit depths, and color space. Since then, the ITU published 2 further editions and it was expanded in several aspects by Rec. 2100 in 2016 for High Dynamic Range television (HDR-TV).

The Rec. 2020 recommendation addresses an expanded color gamut. The development of this gamut helped capture real-world colors in a 3-primary system. The standards committee for Rec. 2020 chose color primary coordinates at the extreme edge of the visible color space, achievable with RGB pure laser-illuminated projection technologies.

Since its publication, Rec. 2020 has been widely recognized as the color space standard for 4K digital displays.

How does RGB pure laser projection achieve the Rec. 2020 color gamut?

Rec. 2020 defines its primaries at the spectral locus, a very narrow bandwidth primary required to achieve the chromaticity at the primary point. For practical reasons, it's desirable to mix a few nearby wavelengths to achieve the color primary, and theoretically, this will take the chromaticity of the primary off the spectral locus. In practice, however, mixing a few close wavelengths will reach the target chromaticity within a reasonable measurement accuracy. RGB pure laser projectors have wavelengths chosen to optimize the delivery of Rec. 2020 color primaries to achieve the Rec. 2020 color gamut for a wide gamut color experience.

Let's compare Rec. 2020 with DCI-P3 and Rec. 709

Rec. 709 DCI-P3 Rec. 2020

Figure 4
Colors as you've never seen them before on screen: Since we can't see Rec. 2020 colors without a compatible projector and Rec. 2020 content, we created this illustration to represent the difference between the 3 color standards.

With Rec 2020, you get color that is much more vibrant than Rec. 709 and DCI-P3 (figure 4). The reason for this is that unlike Rec. 709 and DCI-P3, Rec. 2020 covers practically the entire Pointer's gamut of real-world colors.

While it doesn't represent everything we see as humans, Rec. 2020 has a far greater color volume and comes much closer to doing that than the other color standards.

The DCI-P3 color space does a better job of capturing Pointer's gamut than Rec. 709 (figures 5 and 6). While it adequately covers yellow and green, several colors are still excluded, particularly around cyan and darker blue areas. Essentially all these missing colors are captured in the Rec. 2020 color gamut, as illustrated.

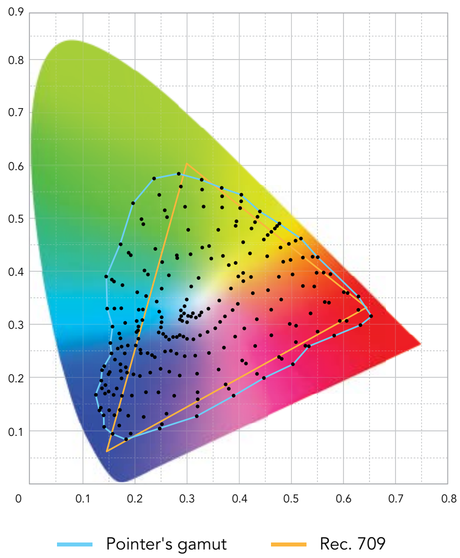


Figure 5: Current HDTV color gamut overlaid on Pointer's real-world color set

This illustrates that the current high-definition television standard lacks the ability to display naturally occurring yellow and gold and green-cyan-blue colors.

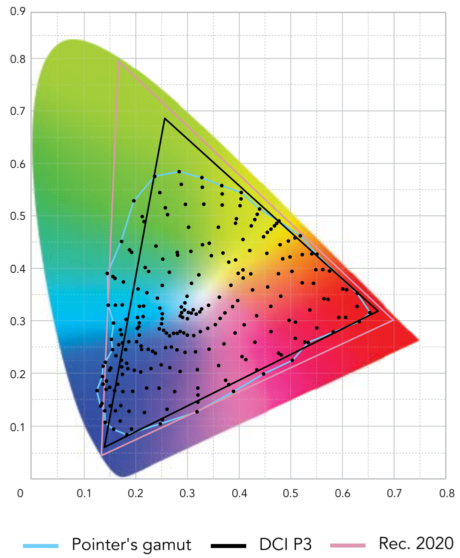
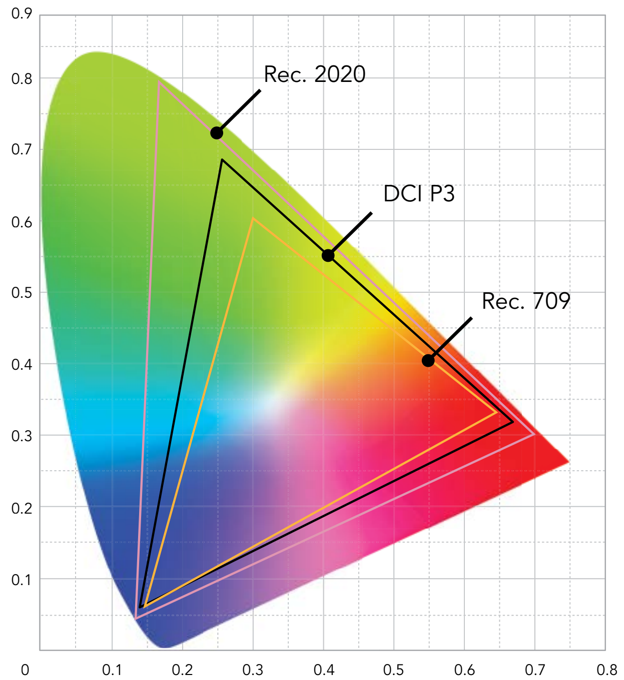


Figure 6: Pointer's real-world colors with DCI-P3 (cinema) and Rec. 2020 gamuts
colors.

The color volume comparison chart (figure 7), shows how Rec. 2020 includes more of the CIE 1931 color space than both DCI-P3 cinema and Rec. 709. The Rec. 2020 color space covers 75.8% of the CIE spectrum, DCI-P3 covers 53.6% and Rec. 709 covers 35.9%. In other words, Rec. 2020 offers more than twice the color of Rec. 709 and 41% more than DCI-P3.



Color gamut	Illumination type
Rec. 2020	› RGB pure laser › The only projection technology to support Rec. 2020
DCI-P3 (Digital Cinema Intiative)	› Xenon lamps › Some laser phosphor
Rec. 709 (HDTV)	› Mercury lamps › Some laser phosphor

^ Figure 7:

A color volume comparison of Rec. 2020, DCI-P3, and Rec. 709 and where they fall on the CIE 1931 chart. Each color gamut has its own benefits and can be achieved by different types of illumination.

What does Rec. 2020 offer?

The Rec. 2020 color space delivers a big impact on the quality of the visual experience. With a wider color gamut, content is more vibrant, and the perception is that the content is brighter. More lifelife colors make the audience experience more immersive, helping creatives and filmmakers tell their stories and bring their visions to life. In short, everything looks more realistic and feels more believable.

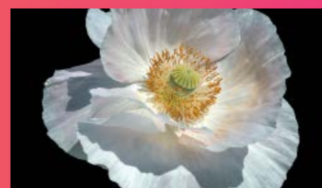
Having more colors also means it's possible to reproduce exact brand or IP (intellectual property) character colors. That means you see superheroes in precisely the right shades and accurately displayed logo colors. And audiences can experience the real-world colors we see in nature.

Rec. 2020 and RGB pure laser projection – a more colorful space

RGB pure laser projection is the only projection technology that can support the Rec. 2020 color space. While you can get Rec. 2020 colors with some LED displays, they're often a much more costly solution for large screens. RGB pure laser projection offers the purest colors, an expansive color palette, incomparable detail and contrast, and the brightest images.

The purest colors

A new, expansive color palette



Incomparable detail and contrast

The brightest images

Reproducing colors: comparing RGB pure laser projection with laser phosphor

Aren't all laser projectors the same? When you take a closer look, you'll find the difference is night and day (figure 8).

Laser phosphor projection uses blue laser diodes as the primary light source to generate red and green, with advanced projectors using a direct red to boost the low output of red. These projectors deliver good color performance for Rec. 709 or DCI-P3, but they can't offer the same color performance as RGB pure laser projection.

RGB pure laser projection technology uses individual red, green, and blue laser diodes to create pure colors. RGB pure laser projection wavelengths, chosen to optimize the delivery of Rec. 2020 color primaries, achieve the full-color gamut for a more expansive color experience. This exceptional color reproduction, combined with game-changing brightness, makes RGB pure laser projection superior to laser phosphor projection. Even Rec. 709 and DCI-P3 content looks brighter and more vibrant through RGB pure laser projection!

With Christie® RGB pure laser projectors, achieving the Rec. 2020 color space is possible. This wider color gamut allows for more deeply saturated colors and more accurate and natural on-screen colors. When 'good' isn't quite good enough for your needs, RGB pure laser pushes boundaries to colors outside the lines that were set back in 2007 when the DCI-P3 standard was introduced.

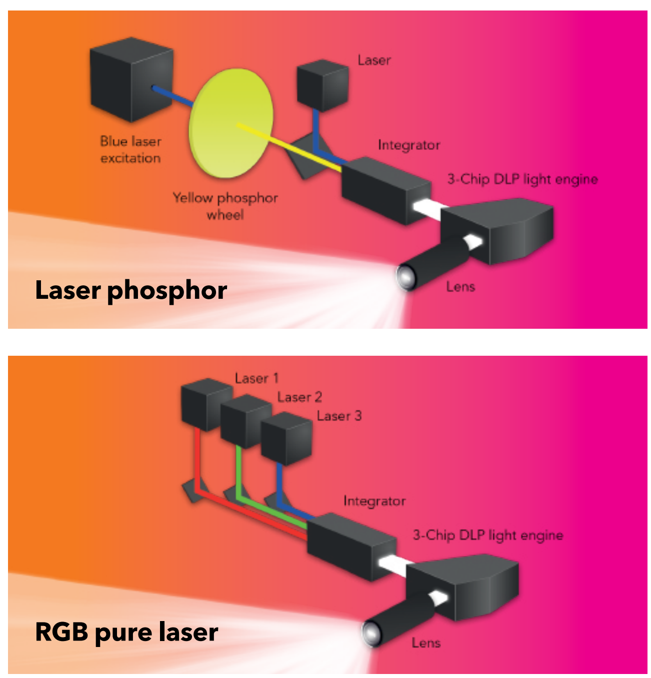


Figure 8:

Not all projectors are created equal: a comparison of laser phosphor and RGB pure laser systems.

Facilitating illusions: what Rec. 2020 can do for your audience

Light and perception are all relative, however, our brains and visual systems can perceive a 'reality' that we create for them. And whether you're a filmmaker or a creative in the themed entertainment or live events industries, you create illusions for your audience – making them feel like they're momentarily somewhere else. With Rec. 2020 and RGB pure laser projection, you can create a reality that thrills audiences and helps you tell stories like never before.

Once you see it, you can never go back.

Ready to learn more?

Whether it's for large venues and projection mapping or cinema and post-production, we have an RGB pure laser projector to fit your needs.

Explore our full range of projectors »

LiteLOC white paper

Read our LiteLOC™ white paper to find out about brightness and color stability in Christie RGB pure laser projectors

RGB laser webinar

Watch our webinar, **RGB laser – a leap forward in color space**, to learn even more about color

Are you interested? Have any questions?

We're here for you.

Let's connect today!

Footnote

i. Luminance describes the amount of light that is emitted from, passed through, or reflected off an object. It's often confused with brightness. Luminance is objective and can be measured with a luminance meter. Brightness is subjective. It is perceived by the human eye and cannot be measured.

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