WHITEPAPER

RGB laser projection – Realizing Rec. 2020 color

CHRISTIE®

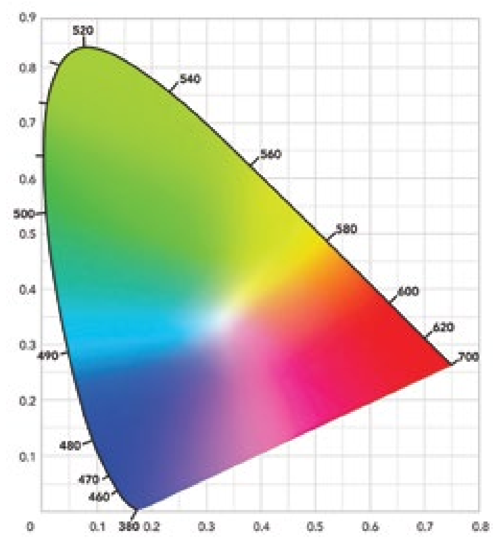
Entering the world of Rec. 2020 color

In 2012, the International Telecommunications Union (ITU) published RECOMMENDATION ITU-R BT.2020 (Rec. 2020) for ultra-high definition television (UHDTV).[1,2] This recommendation covers the image parameters for next generation television display systems, including recommendations for high resolution, high frame rates and extended color performance. The motion picture community is studying the wider color gamut of Rec. 2020 for cinema and is very interested in the opportunity presented by applying laser projection technology to the task. This white paper will discuss the meaning of color recommendation of Rec. 2020, the need for extended color and the challenges to achieve this in practice.

How do we define color?

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. These colors are represented in the CIE 1931 color space diagram (Figure 1). Each color is uniquely assigned a coordinate pair (x,y), with the luminance or brightness of the color represented as a separate value.

The (x,y) color representation forms the basis of conventional color science and we use it to understand the current color space representations, their limitations and the opportunity to deliver richer images through extended color performance.



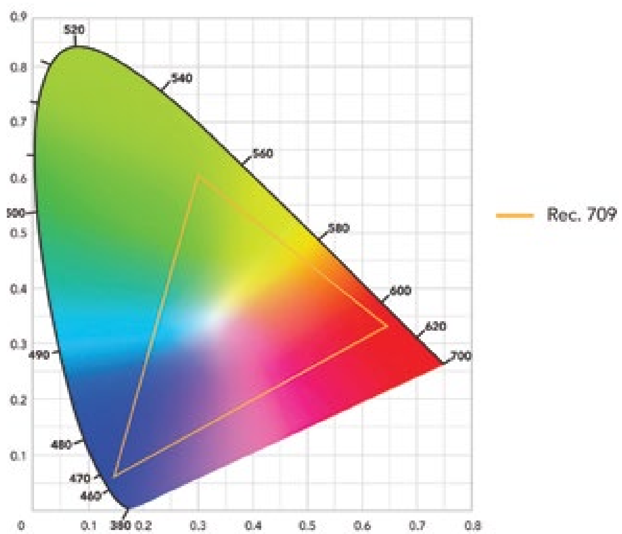
▲ **Figure 1: CIE 1931 color space.** There are three key parts to this diagram. The horizontal (x) and vertical (y) axes are used to define any point on the plot with a pair of numbers. These are called the chromaticity coordinates. Note that the center of the diagram is white, while the colors become 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.

Color displays: how do we reproduce color?

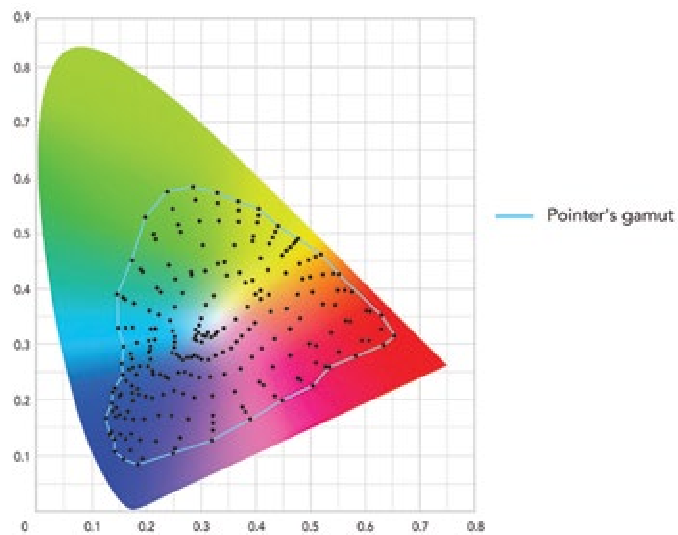
In the digital display world, color is generally reproduced by mixing red, green and blue color primaries. A desired color is created by proportional mixing of these primaries. Color science allows us to determine the overall color capability of a display by plotting the chromaticity coordinates (x,y) 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. Any color inside the triangle is possible to achieve while colors outside cannot be reproduced. For example, the current television color gamut is defined by Rec. 709 and results in the gamut shown in Figure 2.

Real world colors: what are they in practice? What colors do we need to represent?

An obvious consideration for gamut choice is the ability to display real world colors. While the CIE 1931 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 colors3 which is widely referenced as representing the gamut of naturally occurring reflective colors. The result was an irregular gamut of colors that naturally occur. These are plotted in Figure 3. In addition to real world reflective colors, there are emissive colors, such as neon signs, LED brake lights on cars and light sabres, which are highly saturated and largely fall outside the Pointer color set.



▲ **Figure 2: 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.



▲ **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.

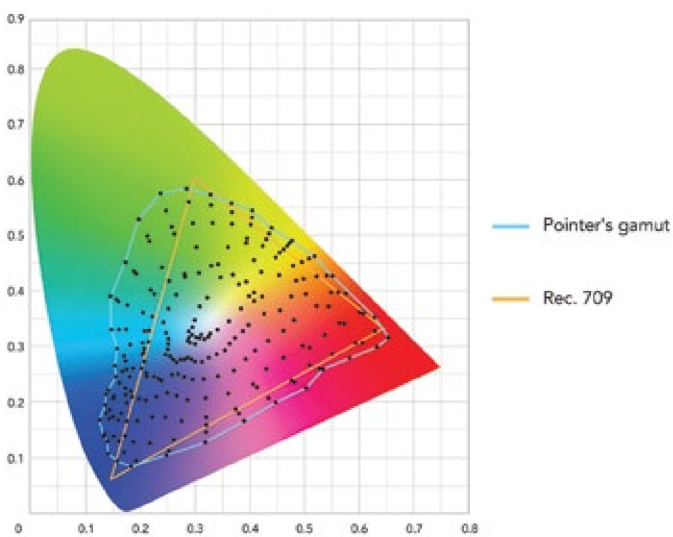
How do the color standards compare to the real world colors?

We can compare any color gamut to the Pointer gamut of real world colors and determine how well it will represent these colors. Figure 4 shows the Pointer color set with the color gamut of current high definition television standards (Rec. 709). Clearly, there are a number of colors that cannot be reproduced by the current standard. Of the missing colors, there are a number that are visually important. These occur in particular in the yellow and gold area (skin tones) and the cyan and blue area (tropical water and sky).

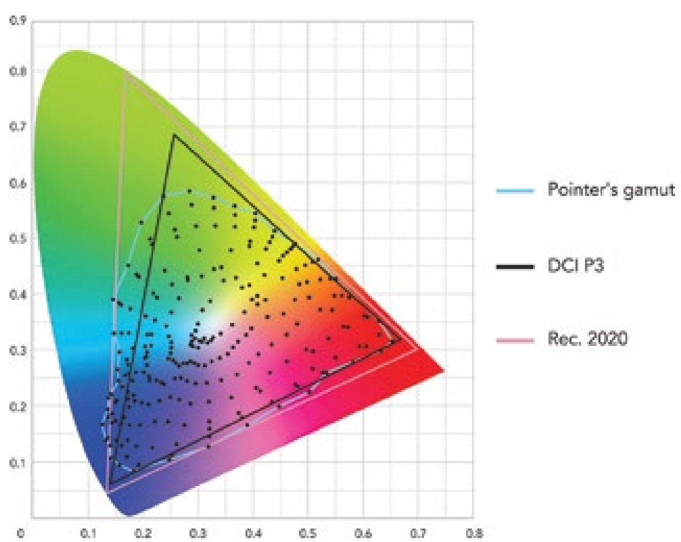
Rec. 2020 wide color gamut: what is it and how does it compare to cinema DCI P3?

The Rec. 2020 recommendation addresses an expanded color gamut. This gamut was developed in an attempt to capture real world colors in a three primary system. The standards committee for Rec. 2020 chose color primary coordinates that are at the extreme edge of the visible color space. These color primaries are achievable with RGB laser illuminated projection technologies. Figure 5 shows the gamut of Rec. 2020 overlaid on the CIE 1931 color space diagram, with the Pointer's colors plotted, and the DCI P3 cinema color gamut for reference.

Digital cinema color space does a better job of capturing Pointer's gamut, but still leaves a number of colors outside the capability, in particular in the area of cyan (Figure 5). Essentially all of these missing colors are captured in the Rec. 2020 color gamut, as illustrated.



▲ **Figure 4: Current HDTV color gamut overlaid on the Pointer real world color set.** This illustrates that the current high definition television standard is lacking in the ability to display naturally occurring yellow and gold and green-cyan-blue colors.

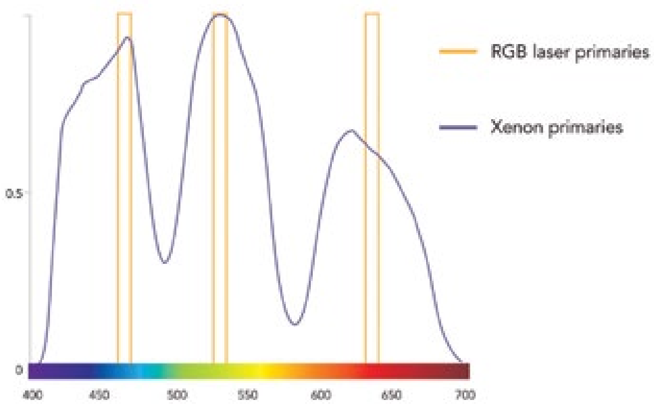


▲ **Figure 5: Pointer's real world colors with DCI P3 (cinema) and Rec. 2020 gamuts marked.** Note that the DCI P3 gamut covers the yellow gold segment, but falls short in the cyan and blue colors. Rec. 2020 encloses essentially all the Pointer's gamut colors.

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

Rec. 2020 has defined its primaries to be at the spectral locus. This means that a very narrow bandwidth primary is required to achieve the chromaticity at the primary point. For practical reasons, it is 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 reasonable measurement accuracy.

RGB laser projectors, such as the Christie® 3P RGB laser projection system, have wavelengths chosen to optimize the delivery of Rec. 2020 color primaries to achieve the full Rec. 2020 color gamut for a wide gamut color experience.



▲ **Figure 6: Spectrum of the Rec. 2020 laser projector compared to a conventional cinema Xenon based digital projector.**
The much narrower band of the laser system yields the more saturated primary colors needed for Rec. 2020 color gamut performance.

Conclusions

Rec. 2020 color provides the opportunity to display a better representation of real world colors than the commonly used color spaces for television and cinema. Practically achieving these primaries is not limited to single wavelengths, but can be accomplished with a bundle of wavelengths. Laser illuminated projectors are ideal for achieving this.

Matt Cowan

Matt Cowan is co-founder of Entertainment Technology Consultants and is a color scientist who works in image quality for cinema. He has significantly contributed to the standardization of color and dynamics for digital cinema, and is a frequent speaker at cinema industry conferences and meetings.

[1]http://www.itu.int/md/R12-SG06-C-0221/en
[2]http://www.itu.int/rec/R-REC-BT.2020-1-201406-I
[3]M. R. Pointer, The Gamut of Real Surface Colours, Colour Res. Appl. 5, 145- 155 (1980)

Corporate offices

Christie Digital Systems USA, Inc.
USA – Cypress
ph: 714 236 8610

Christie Digital Systems Canada Inc.
Canada – Kitchener
ph: 519 744 8005

Independent sales consultant offices

Italy
ph: +39 (0) 2 9902 1161

Worldwide offices

Australia
ph: +61 (0) 7 3624 4888

Brazil
ph: +55 (11) 2548 4753

China (Beijing)
ph: +86 10 6561 0240

China (Shanghai)
ph: +86 21 6278 7708

Eastern Europe and
Russian Federation
ph: +36 (0) 1 47 48 100

France
ph: +33 (0) 1 41 21 44 04

Germany
ph: +49 2161 664540

India
ph: +91 (080) 6708 9999

Japan (Tokyo)
ph: 81 3 3599 7481

Korea (Seoul)
ph: +82 2 702 1601

Republic of South Africa
ph: +27 (0)11 510 0094

Singapore
ph: +65 6877 8737

Spain
ph: +34 91 633 9990

United Arab Emirates
ph: +971 4 3206688

United Kingdom
ph: +44 (0) 118 977 8000

Certified System
ISO 9001
ISO 14001
Kitchener, Ontario

For the most current specification information, please visit www.christiedigital.com

Printed in Canada on recycled paper. 4049 Apr 15

CHRISTIE®