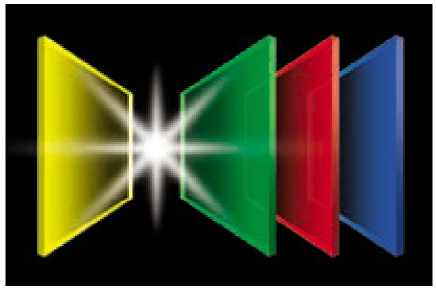

QuaDrive: A New Way To Project Color

A SANYO WHITE PAPER

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SANYO

Presentation Technologies

QuaDrive: A New Way To Project Color

It may be hard to believe, but over 20 years have passed since the first three-panel LCD projector was introduced to the world. Since then, LCDs have transformed the world of display technology, hastening the transition from raster-based imaging (with cathode-ray tubes) to pixel-based microdisplay imaging.

The first LCD projectors were heavy beasts and not terribly bright. Fifteen years ago, a typical "portable" LCD projector weighed about 30 pounds, generated about 300 to 500 lumens at best, and featured a maximum resolution of 640x480 pixels – equivalent to the VGA computer standard then in use, and a close match to analog (NTSC) video. The panels used in those early projectors were relatively large, too – measuring about 1.5 diagonal inches.

How far we've come! Today's LCD projectors come in all sizes and shapes, from ultra-lightweight models weighing less than six pounds to high-powered "light cannon" projectors capable of generating over 10,000 lumens.

In fact, advances in projector light output and reductions in size and weight have been accompanied by longer-lasting lamps, more efficient light engines, and higher pixel resolutions, such as 1920x1080 and new widescreen formats including 1280x800 (WXGA).

And of course, prices have dropped considerably. Today, you can purchase an eight-pound LCD projector with XGA (1024x768) resolution and 2600 lumens of brightness for all of $1,500 –one-sixth the cost of those LCD lightboxes from the early 1990s.

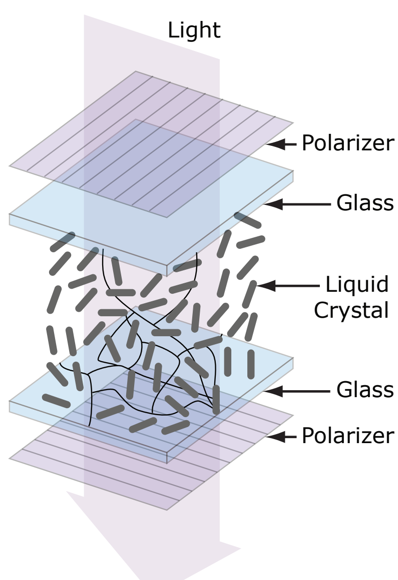
That's quite a list of accomplishments for any technology: Lower prices, higher brightness, smaller form factors, better efficiency, and higher resolution. So, what's left to improve? The answer to our question may surprise you, and lies within the heart of an LCD projector – the 3LCD imaging system.

HOW LCD PROJECTORS WORK

Let's step back for a quick refresher. The acronym LCD stands for Liquid-Crystal Display, and the "liquid crystal" part of it has the unique ability to twist light as it passes through the panel. In a liquid crystal (LC) panel, there are thousands of tiny pixels, each containing a small amount of LC compound.

In their normal state, liquid crystals align themselves in random patterns, and any light passing through them is minimally obstructed. Apply a voltage to the TFT, however, and the liquid crystals line up in orderly rows – sometimes vertically, sometimes horizontally, and sometimes tilting at angles (see images below).

The degree to which individual liquid crystals move into alignment is controlled by the voltage driving each TFT and determines how much light passes through the panel. For an everyday analogy, think of ordinary window blinds. As you pull on the cords, the blinds pass or block light, with each blade remaining parallel to adjacent blades. That's really all there is to it!



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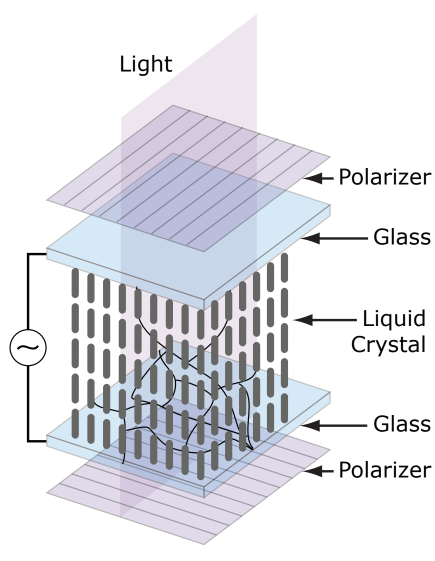
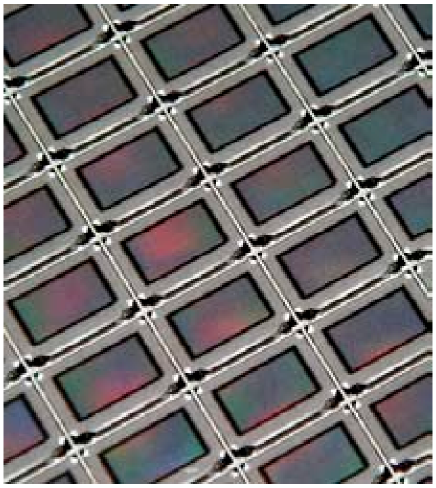
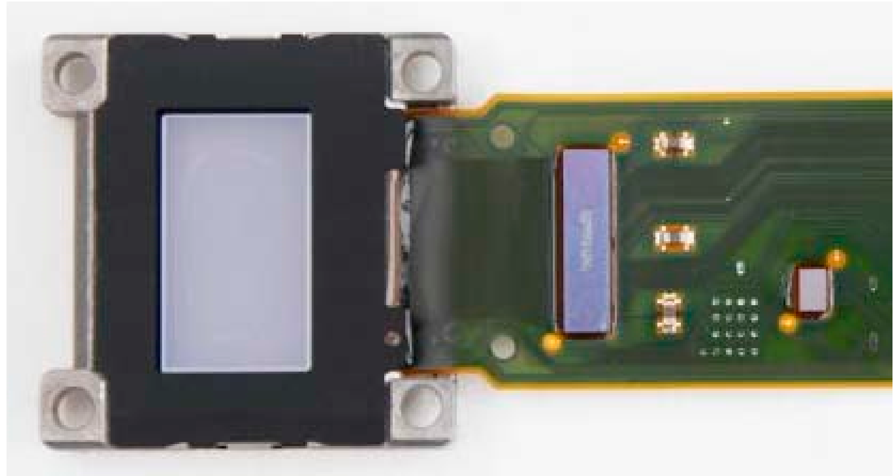


ON

Close-up of an 8-inch LCD wafer



Close-up of a .7” 1920x1080 LCD panel



The brightness of images from an LCD projector is a direct function of the alignment of individual liquid crystal molecules. When individual LCs are in perfect alignment with each other, most light is blocked. When the crystals are arranged in random patterns, maximum light passes through the lens.

Image contrast is dependent on the ratio of the brightest image passing through any pixel (or group of pixels) to the level of light being blocked by a pixel or group of pixels. In modern-day LCD projectors, this contrast ratio can be quite high, averaging 350:1 to 450:1 and peaking as high as 700:1.

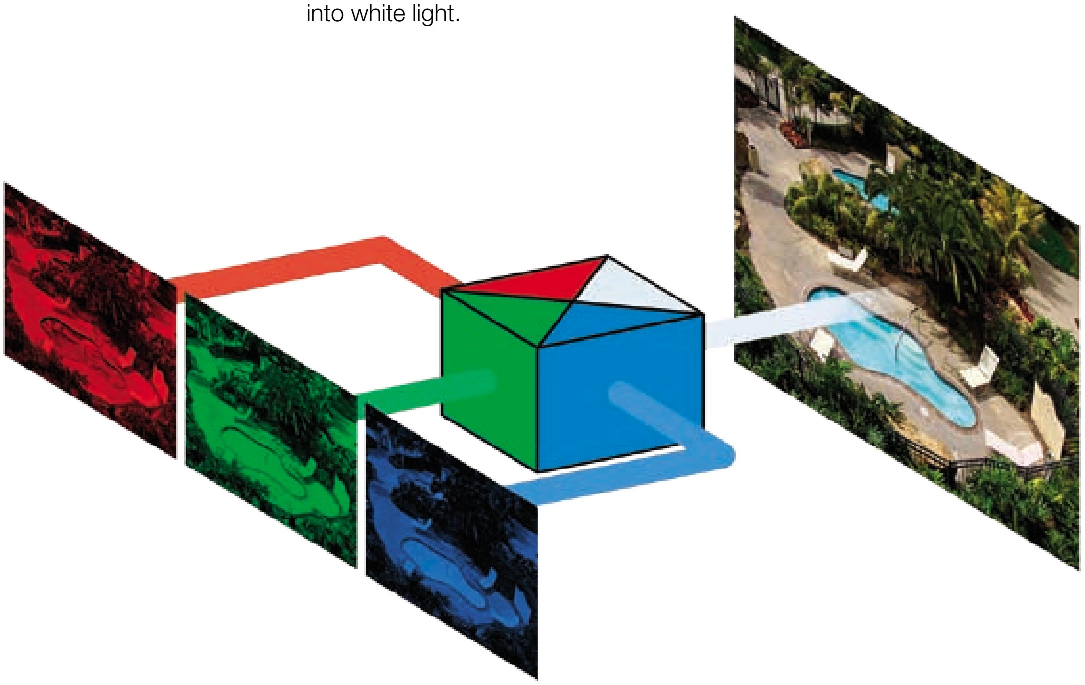
PRODUCING COLOR WITH LCD PROJECTORS

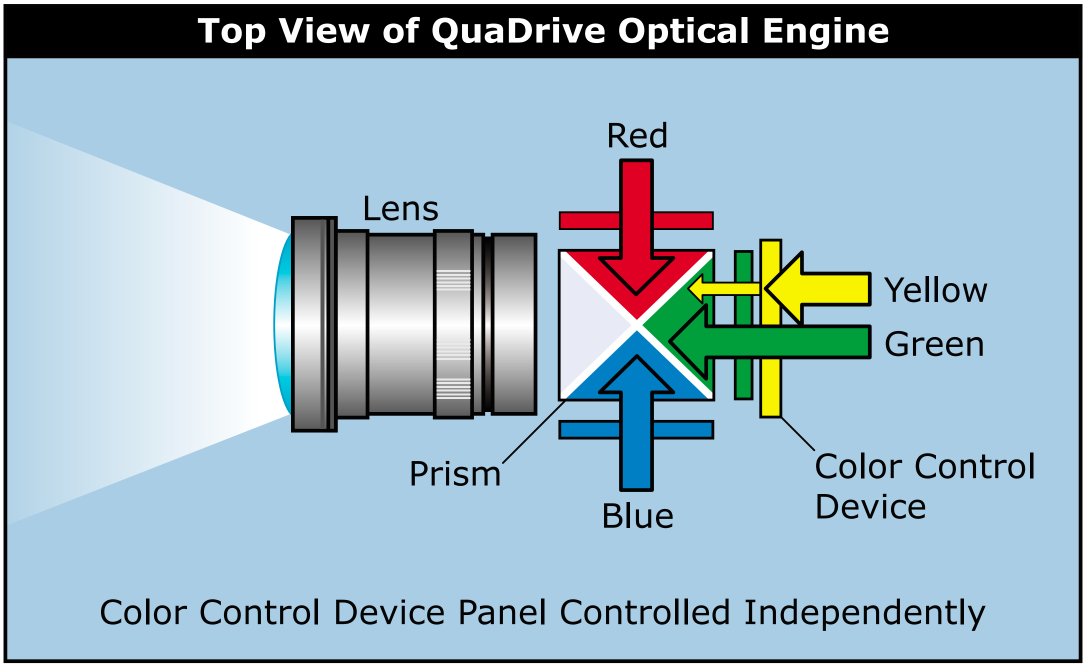
Each LCD panel in a projector works as a monochromatic light shutter, creating images consisting of black, white, and many shades of gray. For full color images, three identical panels mounted in precise registration must be used with special dichroic optical filters that extract red, green, and blue wavelengths of light from the projection lamp.

By adding the resulting red and black, blue and black, and green and black images from the three LCD panels, a full spectrum of colors and shades of gray is reproduced. This additive color system works in reverse from daylight: A prism refracts out the colors from the sun’s rays, but in a projector, the prism recombines red, green, and blue into white light.

This tri-stimulus, additive color process is the key to LCD projection. Unlike other projection systems that use scanning, sequential color wheels, the 3LCD systems blends red, green, and blue full-time, with different combinations of the three colors and levels of luminance creating millions of color shades.

The purity of the color and spectral balance of gray shades is determined by the type of projection lamp and all parts of the optical chain. Short-arc lamps commonly used in a projector typically have salts of mercury in them, so the resulting color spectral output of these lamps is strongest with blue-green wavelengths and weakest with reds and yellows.





FOUR EQUALS MORE

If you've guessed that the next level of improvements for LCD projectors lies in the area of color reproduction, you're right! Sanyo has developed the world's first QuaDrive projection system, introducing it at InfoComm 2008 in their PLC-XP200L large venue projector.

Sanyo's unique QuaDrive optical engine makes a noticeable difference in shades of color that contain yellow and range from green to red. As we've just seen, these color shades can be challenging to show correctly on conventional LCD projectors equipped with HID lamps. Here's how it's done:

Sanyo's QuaDrive system starts with a conventional 3LCD optical engine (lamp, light integrators, three dichroic filters, three LCD panels, and a combining prism) and adds a fourth, single pixel LCD panel to filter and pass yellow spectral energy as needed. It's just that simple.

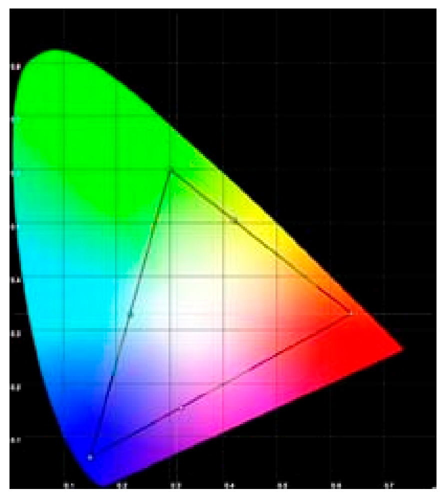
To make this work, the spectral response of a conventional 3LCD engine is changed slightly. Typically, a certain amount of yellow spectral energy passes through both the red and the green LCDs. In the QuaDrive engine, the frequency response of the red dichroic filter is narrowed considerably, passing most of the yellow energy to the green panel.

And here's where the fourth LCD panel comes into the picture. It's positioned ahead of the green LCD panel in the light path. This fourth panel is not the same as the other panels, however. It is a simple, single-pixel light shutter with an aperture the same size as its matching green panel.

Unlike the window blind analogy we read about earlier, all this fourth panel can do is block or pass yellow spectral energy. Shut it off, and a narrower band of green light flows through the LCD panel. Turn it on, and more yellow gets into the mix.

We can measure the impact of this added LCD panel by examining the gamut of colors produced by the projector and comparing it to a standard color space, such as the 1931 CIE color sensitivity chart.

1931 standard CIE chart

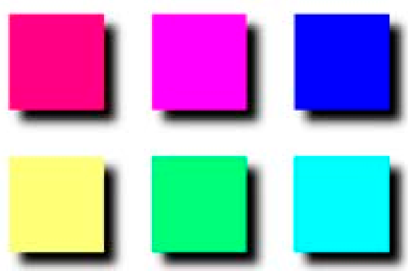


FINE-TUNING COLOR

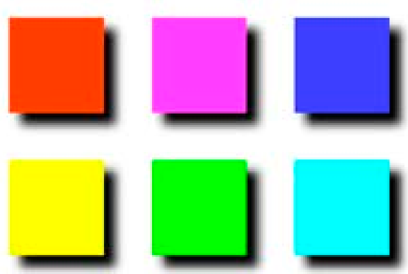
Would it surprise you to know your eyes are not equally sensitive to all colors? The 1931 CIE chart shows exactly that, expressing human color sensitivity to 59% green (with some yellow added), 30% red, and 11% blue. The NTSC color television systems developed in the 1950s uses this exact same weighted system – 59G+30R+11B – to carry the signals from transmitter to home.

Because green makes up almost 60% of the visible color space, it takes a lot more work to make large shifts in the values of green when calibrating a projector to a standard color spaces, such as the BT.709 space used for HDTV. And that's the motivation behind the QuaDrive – more control over color shading using yellow spectral energy to compensate for the color imbalance of projection lamps.

Here's an example: If you were to view a swatch of colors projected with a bluish (cold) color tint, you'd notice that many primary color shades resemble undersaturated pastel colors. Instead of an amber yellow, you'd see lemon yellow. Instead of a kelly green, you'd see a lime green. The problem is aggravated by the natural spectral imbalance of HID lamps.



Effects of Cyan Color Shift (above)
and Yellow Color Shift (below)



By adding yellow to the mix, you subtract blue and to a lesser degree, cyan. Now, our yellow shades shift back to amber tones; greens have a warmer feel, and reds become more saturated. Sanyo's new Color Control Device (4th LCD) panel gives us shades of colors that are closer to what we see in the real world under natural daylight.

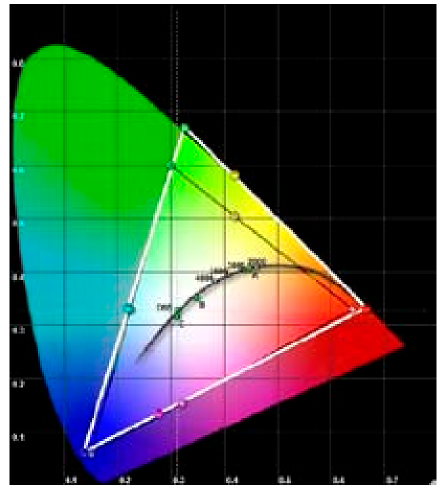
The effect can clearly be seen in the color space plots to the right. The first figure shows the calculated color gamut of the PLC-XP200L compared to the standard HDTV color space, using the 1931 CIE color reference.

Notice that, while the PLC-XP200L's normal color space is much wider than that required by the BT.709 standard, switching on the fourth LCD panel has extended that space even more, expanding the area available for shades of green and yellow and almost exactly extending the BT.709 space in a linear fashion along the green color axis.

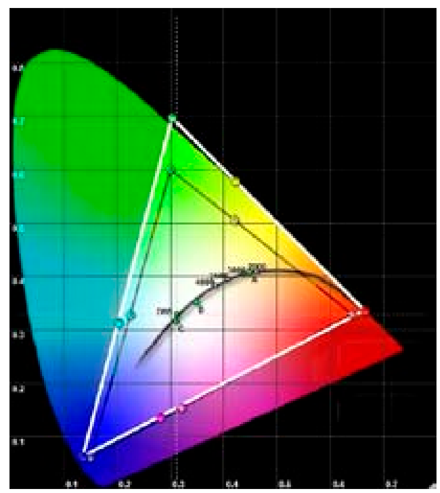
While the changes between the two color gamuts are not substantial – about a 20 percent expansion using QuaDrive – the difference in color shading is quite noticeable on-screen, particularly with shades of cherry red, orange, and amber yellows. All three colors appear to have greater saturation and brightness than when they're projected with conventional LCD color filters.

The PLC-XP200L's color gamut isn't the only thing affected by adding the Color Control Device. Image brightness also increases, typically by 20%, while image contrast remains about the same. Color contrast varies, with contrast between shades of blue and cyan reduced slightly and contrast between shades of reds, oranges, and yellows increased.

Surprisingly, Sanyo's QuaDrive system does not require a special projection lamp! Conventional short-arc lamps used in other projectors work just fine, as the lamp's inherent spectral imbalance is corrected by the specially-tuned dichroic filters and the resulting higher frequency response in greens and yellows.



Measured color gamut from
a Sanyo PLC-XP200L
without the QuaDrive system (above)
and with QuaDrive (below)



Side-by-side comparison of images projected with QuaDrive technology (left) and 3LCD technology (right)

WHO NEEDS QuaDrive?

Is QuaDrive's expanded color space all that important? Absolutely, particularly in markets that require a great deal of precision in color imaging. Here are some examples:

Packaging and industrial design: This is an extremely challenging application where designers and art directors try to match projected (additive) colors to surface (subtractive) colors used in inks, pigments, dyes, and dispersions.

One standard for specifying surface colors is the Pantone Matching System (PMS), which correlates values of colors to specific mixtures of printing inks. The subtractive (CMYK) color space used as a reference for printing is much smaller than additive color spaces used for projecting video and still images, so precise color matching is critical when specifying PMS colors for everything from automotive finishes to shampoo bottles.

There are hundreds and even thousands of yellow, orange, and red colors that can be derived from PMS matching. In the past, these shades and the subtle differences between them have been challenging to reproduce on LCD projectors. QuaDrive helps to close the gap.

Cosmetics are another class of products that use inks and dispersions. Because cosmetics are designed to enhance natural skin and hair colors, they contain a preponderance of reds and yellow shades that are blended every which way. The subtleties between different shades of lipstick are easily seen with the naked eye, but not as easily reproduced by a projection system.

Broadcast and post-production: Video and film production relies on standard color temperatures that tend to run warmer than cooler. Typical values would be 5400 Kelvin (outdoors under normal daylight) and 3200 Kelvin (studio lighting for film and video production).

However, projectors tend to run cooler, due to the previously mentioned spectral imbalance of short-arc mercury-vapor lamps. The QuaDrive system adds more color correction to that of the projector's existing optical engine, helping flesh tones, warm reds, and yellows show more accurately. This makes balancing rear-projected images on a fully lit set an easier job.

Medicine and diagnostics:
There are subtle color shading differences in everything from CAT scans and magnetic resonance imaging (MRI) displays to microphotography of cells and pharmaceutical compounds. Imaging systems that make use of reds and yellows to indicate heat or cell activity benefit from expanded color gamut spaces.

Blood and tissue analysis also requires expanded color gamut capacity in the yellow and red spectrum, particularly when diagnosing tumors or irregular cell structures, which may otherwise appear identical to healthy tissue in early stages of development.

Computer-generated graphics and 3D:
Much of what is displayed in these markets is computer-generated and modeled graphics, but color accuracy is just as important as it is in the world of printed inks and dyes. This is true when modeling human and animal figures. For a fully engaging 3D experience, color shades must reproduce those seen in real life, which means that incorrect shading will draw attention to itself and away from the VR effect.

Simulators: These are used for everything from learning how to fly virtual airplanes and operate locomotives to staging "virtual" military exercises. They must follow the same guidelines to make the experience as real as possible. It may seem insignificant to mention, but the color of sand or dirt can change tremendously with slightly different levels of yellow in the mix. So can camouflage, identifying marks, and terrain.

CONCLUSION

Sanyo's QuaDrive projection technology truly is the next step in advancing LCD imaging. It enhances existing LCD technology by providing both a wider range of usable colors and a higher level of color shading accuracy. Combined with high dynamic range and accurate grayscale reproduction, Sanyo's QuaDrive technology produces more photorealistic images across all projection applications and markets.

Presentation Technologies

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