Evaluating Video Wall Solutions in Retail and Collaboration Applications

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Introduction

In this white paper, we look at some video wall options from the perspective of the buyer for retail and collaboration room applications (such as a briefing center, board room, or large conference room). Typically, such a buyer would have a choice of an LCD-based or LED-based video wall solution. In this paper we explore these options, as well as the Laser Phosphor Display (LPD) solution from Prysm. The latter is included as it offers a number of advantages and is not as well-known as the former.

A buyer for a retail or collaboration room solution typically works with a system integrator to help detail the requirements, evaluate the options, select a technology, and then focus on suppliers, integration issues, and installation. Maintenance, content creation, and warranty issues may be part of the discussion, as well.

Describing this process in detail is complex and can be so varied that a customized evaluation and solution is often the end result. However, to facilitate the discussion, we will try to eliminate some items from consideration, like integration with IT elements, control systems, content creation, audio solutions, vendor selection and installation. Instead, we will focus exclusively on the display, calibration and interactive touch solution selection.

The Basics

For our target retail and collaboration room applications, we will analyze three display solutions: LCD, LED and LPD.

LCD video walls feature LCDs that are arranged side-by-side to form a wall. Key advantages include a mature and relatively cost-effective display solution with the highest possible pixel density (e.g., 4K panels). Disadvantages include the noticeable bezel between panels, as well as uniformity challenges.

LED video walls consist of a series of cabinets, with each cabinet containing a number of LED modules (the smallest replaceable element). Advantages include high pixel density (i.e., small pixel pitch, or distance between pixels, approaching sub 0.7 mm), a wide range of luminance levels, no bezel, and wide viewing angles. The main disadvantages are inherent fragility and price, which increases sharply as pixel pitch decreases. Uniformity over time is a concern as well.

The latest Laser Phosphor Displays (LPDs) product release consists of modular light engines installed behind a common integrated screen. Each module consists of a laser engine that scans its small area of the RGB phosphor sheet covering the entire screen. In essence, the latest LPD product offerings perform image blending of multiple laser illumination engines onto a common phosphor RGB panel. Key advantages include good luminance levels, extremely wide viewing angles, excellent color rendition, outstanding wall uniformity that auto-adjusts itself in real time, low power consumption, high contrast ratio (in excess of **1,000,000:1**), ability to install in existing buildings through standard doorways, and low cost. The key disadvantages may be that it is offered by a single provider and does not have the technology recognition of its competitors.

Figure 1: Prysm 190" 6K Solution

LCD and LED solutions can be configured in a variety of sizes, shapes, and resolutions that offers a lot of flexibility in choosing a display offering. Prysm offers two turnkey systems: a 135” (4K) and a 190” (6K) product offering that also include integrated multi-touch screen and collaboration software licenses. Prysm suggests they will likely introduce more configurations.

Executive Summary

To evaluate the display solution options, we should first start by stating the mock requirements of our two applications. (Remember, these are simplified baseline requirements. Any real job would likely require some modification.) These are shown below along with our summary of the ratings for the three compared solutions. Like the requirements, these ratings should not be viewed as absolutes – just a guide to comparing the three technologies as there are many variations of these specifications and features among suppliers. And, each installation and use case is different. We have done these ratings based on two “typical” use cases.

In the rest of the paper, we explore how each of the three solutions can meet these requirements in much greater detail discussing the requirements and the ins and outs of each display solution.

Buying a video wall solution can be a daunting process. We hope this paper can provide some guidance in helping you understand all the factors, features, and specifications that should be considered in the purchase decision for large format video walls.

⊙	exceeds requirement	○	meets requirement	●	does not meet requirement

Retail Application

Feature	**Requirement**	**LCD**	LED	LPD
>100"	Not necessary, but bigger has more impact	⊙	⊙	⊙
No seams/bezels	Certainly desireable from an engagement and impact point of view	○	⊙	⊙
Luminance uniformity over time	desired to minimize service, replacement or calibration calls	○	○	⊙
Luminance shift with viewing angle	desired to minimize service, replacement or calibration calls	○	⊙	⊙
Color uniformity over time	critical to maintain color fidelity of brand colors	○	○	⊙
Color shift with viewing angle	critical to maintain color fidelity of brand colors	○	⊙	⊙
Peak Luminance & Contrast	Has sufficient luminance and contrast in ambient environment so as not to impact application needs	○	⊙	○
Contrast decrease with viewing angle	small decrease ok if not impacting color	○	⊙	⊙
Low luminance control	generally not needed for retail	○	○	○
Color Bit Depth	10 bit desired to avoid visible contouring artifacts	○	●	⊙
Fill Factor and Pixel Pitch	No artifacts or pixel structure desired for close viewing or touch interaction	⊙	○	⊙
Motion artifacts	No obvious artifacts	○	○	⊙
Image Retention/Burn-in	Not acceptable	○	○	⊙
Power Consumption / Efficiency	Desired to lower any needed CAPEX and operating costs	○	○	⊙
Wide Color Gamut	Rec. 709 minimum	○	○	○
Touch Performance	at least 10 finger with fast response	●	○	⊙
Lifetime	10 years to 50% brightness operated 12/7	⊙	⊙	⊙

🔴	exceeds requirement	○	meets requirement	●	does not meet requirement

Collaboration Application

Feature	Requirement	LCD	LED	LPD
>100"	ideal for group collaboration	🔴	🔴	🔴
No seams/bezels	needed to avoid missing or distorted information	●	🔴	🔴
Luminance uniformity over time	desired to minimize service, replacement or calibration calls	○	○	🔴
Luminance shift with viewing angle	desired to minimize service, replacement or calibration calls	●	🔴	🔴
Color uniformity over time	Needed for color critical applications (textiles, automotive, etc.)	○	○	🔴
Color shift with viewing angle	Needed for color critical applications (textiles, automotive, etc.)	○	🔴	🔴
Peak Luminance & Contrast	Has sufficient luminance and contrast in ambient environment so as not to impact application needs	🔴	🔴	🔴
Contrast decrease with viewing angle	small decrease ok if not impacting color	○	🔴	🔴
Low luminance control	needed if looking for details in darker parts of images or graphics	●	●	○
Color Bit Depth	10 bit desired to avoid visible contouring artifacts	○	●	🔴
Fill Factor and Pixel Pitch	No artifacts or pixel structure desired for close viewing or touch interaction	🔴	○	🔴
Motion artifacts	No obvious artifacts	○	○	🔴
Image Retention/Burn-in	Not acceptable	○	○	🔴
Power Consumption / Efficiency	Desired to lower any needed CAPEX and operating costs	○	○	🔴
Wide Color Gamut	Rec. 709 minimum	○	○	○
Touch Performance	at least 10 finger with fast response	●	○	🔴
Lifetime	10 years to 50% brightness operated 10/5	🔴	🔴	🔴

>100" Screen

Single LCD screens are now available up to 98" in size. While this sounds attractive, the size, weight, and cost of this panel is significant. Also, if an elevator is required for the install, it is not likely to fit.

LCD, LED, and LPD tiled solutions can easily be assembled in sizes of greater than 100". Are screens larger than 100" needed for retail and collaboration applications? It depends. In retail, impact is all about image quality, and a large display does this – but you must have the space and budget for it. Boardrooms and customer experience centers are common locations for screens >100". Smaller collaboration rooms with 1-2 people can probably use a smaller screen, but with multiple collaborators, or for complex projects that require a large working canvas with lots of open documents or applications, a large screen is best.

Rating: LED, LCD, and LPD screens exceed the requirement to be assembled into large formats.

No Seams/Bezels

Clearly, the LCD video wall solution has some visible bezels, even if some vendors claim to have "bezel-free and seamless" solutions. While this is never desirable, it has been acceptable to date as the cost of a seamless LED solution can be much higher. The much more attractive price point of the LPD seamless solution means buyers do not have to settle for visible seams and bezels.

Seams can be visible between LED modules or between LED cabinets when alignment is not done to a high degree. Certain images make these seams stand out more, as does off-axis viewing. Be sure to require a high degree of precision in the alignment of the LED modules and cabinets, as well as overall planarity.

For a retail application, while not desirable, bezels can be acceptable as such displays generally do not show fine-detailed information. In a collaboration room, display of fine details is likely to be required, and bezels often cut off critical information, so bezels and poor alignment are not acceptable.

For this category, we rate LED and LPD as exceeds the requirement with LCD getting a meets requirement for retail and does not meet for the collaboration application.

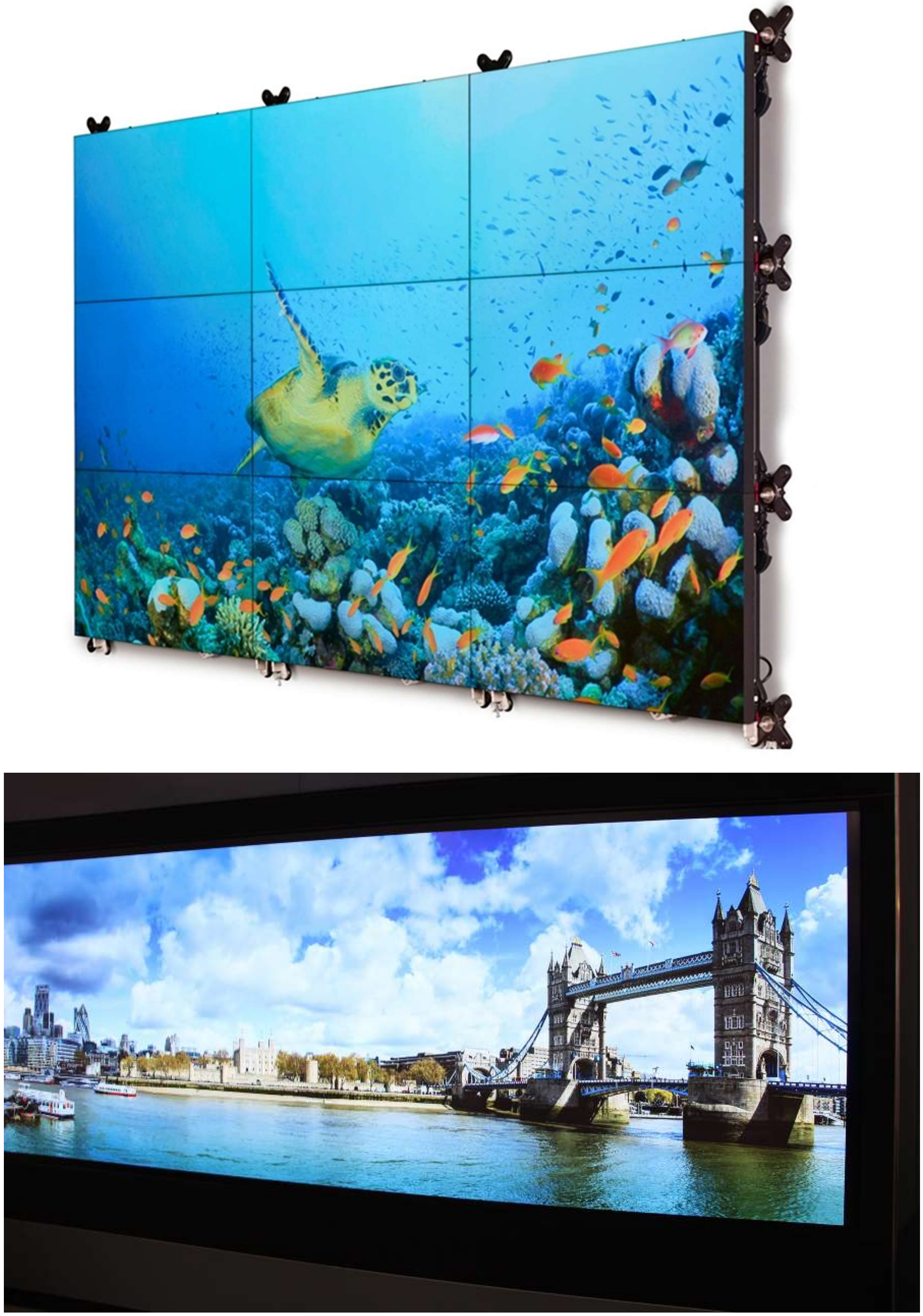


Figure 2: Top: LCD Video Wall with Bezels that Create Visible Seams (image: Barco)
Bottom: Prysm Video Wall with no Visible Seams

Luminance Uniformity Over Time

Luminance of the display is measured typically in nits or Cd/m^2. Brightness is our perception of luminance, which can be affected by the white point, the saturation of the colors, and the ambient illumination in the room. It is possible for two displays to be perceived to have the same brightness, but with different measured luminance. Having luminance uniformity is required because brightness uniformity cannot be measured.

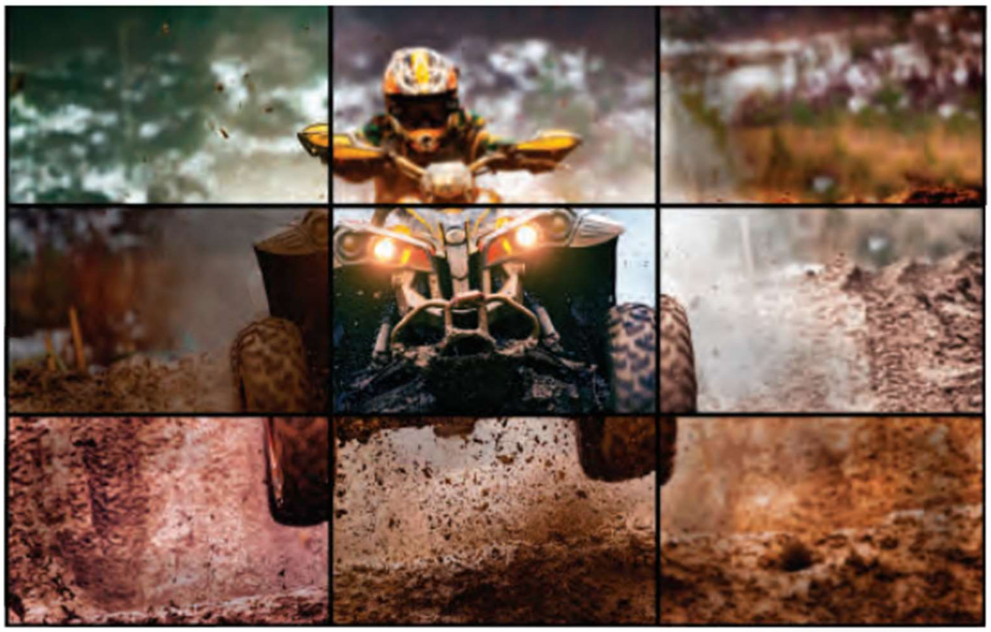


Figure 3: A particularly bad example of non-uniformity (image: Samsung)

All displays lose luminance over time. For LCD, LED, and LPD tiled solutions, each module can have a different luminance level at the beginning. If each module or cabinet ages at a different rate, the non-uniformity of the image can become quite noticeable. The eye is very sensitive to small variations in luminance. Specifically, as low as 1-2% differences between neighboring modules are easily discernable when full flat fields are displayed. Minimizing such variations is critical to a video solution that is not distracting to users.

The aging of LED modules is different because of the difference in materials and driving structure. Green and blue LEDs are made from GaN, whereas red LEDs are made from InP. These materials require different driving circuits and, as a result, age at different rates. Since it is very difficult to monitor real-time performance of LEDs, camera-based calibration is the best way of maintaining uniform luminance over time.

In LCDs, red, green, and blue light is achieved through color filters from a white backlight source. LCD manufacturing is quite mature, and uniformity has become very good within any given LCD panel, but the white point of the backlight changes with time. In addition, panel to panel variations are bound to be present due to difference in aging and factory calibration. Again, this is very difficult to monitor and manage in real time, so external camera-based calibration is needed, but not as often as in an LED display.

LPD displays use a common UV laser to excite red, green, and blue phosphors. Phosphor materials are very mature and stable over time, with predictable decay in efficiency. This means the uniformity of a module will be good, but there can be module-to-module variations. As a result, camera-based calibration is required during installation. However, LPD technology has the added advantage of real-time luminance decay tracking over time, so the re-calibration frequency is the lowest among the solutions under consideration.

For retail applications, eliminating luminance non-uniformity at install and auto-tracking uniformity over time are clearly desirable as they can dramatically reduce the frequency of service and calibration calls – a key component to the Total Cost of Ownership calculation.

Since all three displays can look uniform after proper calibration, we focus on the frequency of calibration to do our rating. Using this criteria, we rate the LED and LCD as meeting and the LPD as exceeding the requirement for both applications

Luminance Shift with Viewing Angle

The luminance of a display can often change as the viewing angle becomes more oblique. LCDs have two main types of liquid crystal materials: IPS (In Plane Switching) and VA (Vertical Alignment). In general, IPS panels maintain luminance at oblique angles better than do VA panels. Off-angle luminance can be improved with the addition of special films, but not all displays use them due to the greater cost. As a result, off-angle luminance performance varies based upon the technology and brand of display; however, all suffer some luminance loss.

LEDs generally offer good off-angle luminance. Only the newer Chip on Board (COB) type may suffer a bit more in the off-angle luminance category.

LPD offers the best off-angle luminance variation because phosphors are Lambertian (i.e. omnidirectional) emitters. Basically, the viewer doesn't perceive a luminance reduction until they reach 178 degrees off the normal axis.

For retail applications, the fall-off in luminance is not desirable, but not critical, so we rate LCDs as meeting this requirement, while LEDs and LPD are exceeding it.

For collaboration, users often are close to the screen, interacting with it at very oblique angles, so it is more critical here. Thus, we drop the LCD rating to does not meet.

Color Uniformity Over Time

One also must consider the color uniformity over the module or cabinet, in addition to the entire display wall. Variations in color can make a sky look blotchy, for example, or uniform color fields may have a mottled look. Clearly, this is undesirable.

A key component of color uniformity is the white point, typically measured in degrees Kelvin. As with luminance uniformity, small variations (e.g., a few hundred degrees Kelvin) in white point are readily detectable to the human eye and measurable with instrumentation.

LED screens are manufactured by "binning" red, green, and blue LEDs into buckets, so that the peak wavelength varies by a set amount. Higher-quality providers have a narrow +/- 2 nm range, while others expand the range to lower costs. This is what initially determines the color uniformity of the display; so, for color critical applications, a smaller range is better.

As discussed with luminance uniformity, red LEDs are from a different material system than green and blue, so they are driven differently and age differently. Aging primarily impacts light output, not color hue. However, it's the mixing of primary colors that yields cyan, magenta, yellow, and white point. As a result, variations in light output will alter how these colors are rendered. Under these conditions it becomes very easy for the eye to notice those variations across modules, especially with off-axis viewing. Calibration is the answer.

The color in an LCD is defined by the dyes in the color filters and the aging of the backlight. The color filters are very stable, but the backlight is known to lose blue light output, which results in an overall yellowing of the white point over time. Also, since most LCD backlights nowadays employ LEDs, these too may will age differently, resulting in discernable shifts in white point from display to display. Recalibration is key at regular intervals, using a colorimeter and software to color correct at the expense of reducing overall light output.

For LED and LCD video walls, it is often recommended that calibration be done every six months. This can impact operational time and the total cost of ownership (TCO).

LPD technology is unique in many respects, but especially in its ability to self-correct itself over time. Specifically:

- It uses a single UV (408 nm) laser diode (LD) to excite all three of its RGB phosphor stripes. The advantage of this is that even as the LD ages (i.e. its output diminishes over time), the white point created by the mix of RGB phosphors stays exactly the same.
- The phosphor chemistry has been shown to resist chemical modification for the duration of the display's stated lifetime. This means that the emissive spectra of each phosphor stripe stays the same, so color hue, saturation, and white point also remain unchanged.
- Each LPD module that illuminates the common phosphor panel uses real-time monitoring of the light output from all its UV LDs via a photodiode sensor. This allows the LPD electronics to track the dimmest LD continuously, adjusting the overall video wall luminance for uniformity without any user intervention.

The combination of stable phosphor chemistry and real-time tracking eliminates the need for regularly scheduled re-calibrations, which reduces the overall TCO for the client while maintaining very high levels of image quality.

It should also be noted that color shifts in very dark images can be visible as well. This may be apparent as slight green or blue or magenta hue changes, especially when changing the viewing angle. However, this mostly applies to LCD displays.

For retail applications, color uniformity is desirable, but not a key requirement. We rate LEDs and LCDs as meeting the requirement because they need periodic calibration with LPD exceeding the requirement.

For collaboration, there can be color-critical applications, but we apply the same rating here for the same reasons.

Color Shift with Viewing Angle

Moving off-angle can create some color shifts in some display solutions. In general, LCDs are the worst with respect to colors shifting and luminance decrease with angle. As stated previously, luminance decreases with angle and the color shift depends on the type of LCD panel and any compensation films applied. There are no perfect solutions for this problem.

The off-angle color performance of LEDs is next best, with only slight shifts. As discussed in the uniformity section, off-angle performance is determined by the tolerance in the manufacturing binning process and proper calibration over time.

The phosphors in LPDs are omnidirectional self-emissive elements, which means that the colors produced stay virtually unchanged at any angle.

For retail applications, any color shift is undesirable, but not critical unless it is particularly bad. The exception is the display of brand logos or colors where color accuracy is very important. Buyers need to check this aspect of the chosen display solution to see if it can meet the requirement. We rate LCDs as meets the requirement, and LED and LPD as exceeds.

For collaboration, we apply the same rating. Again, certain applications in textiles or automotive, for example, can require high color-accuracy even with off-axis viewing. The display technology should be checked for color shifts if such color critical applications are used.

Peak Luminance & Contrast

When contrast is measured as the ratio of peak luminance to the black level of the display, this is called sequential contrast (typically shown on a specification sheet). This is determined by measuring the luminance with a full white screen and then with a full black screen viewed normal to the display surface.

Contrast is a key indicator of image quality – the higher the better. Contrast can be affected by the ambient light in the room. We all know what happens with the contrast on a projection system when you turn on the lights – the image looks washed out. There's also another type of contrast, referred to as simultaneous/intraframe or ANSI contrast. This is typically measured by displaying a 3x3 or 4x4 black and white checkerboard pattern in the actual application environment and taking the ratio of the white over the black squares. This is a much better indicator of real usable contrast, but it's rarely, if ever, quoted by display manufacturers as it can be orders of magnitude lower in value than the sequential contrast.

LCD, LED, and LPD do not degrade in checkerboard contrast nearly as badly as projection solutions, but they still can be affected. To maintain good checkerboard contrast in the application environment, one method is to increase the peak luminance of the display to "overpower" any background ambient light that illuminates the screen. Another trick is to add black or dark coatings, or anti-reflection films, to absorb or reject ambient light. Some LED screen add elements that are like Venetian blinds – they block light coming typically from overhead office lighting from getting to the display with the trade-off that the vertical viewing angle is limited.

The LPD solution has a very high sequential contrast, 1,000,000:1, but a modest (300-500 nits) peak luminance level. LEDs also have extremely high sequential contrast with luminance levels that run from 750 nits to thousands of nits. LCDs typically have modest sequential contrast levels of 1000:1 to 2000:1, and luminance levels of 500 to 1500 nits.

Our discussion of contrast has shown that checkerboard contrast is the best measure of in-application image quality. High sequential contrast, driven by bright displays, is helpful in very bright ambient environments, and it does reduce the impact of ambient lights washing out the image.

So how should we rate the LCD, LED, and LPD solutions in our retail and collaboration room applications? First, let's consider the ambient illumination. Collaboration rooms generally have office-like, or subdued, lighting; so, high luminance is not necessarily an advantage. In retail, the need for high luminance can clearly vary. If the display is in an area where natural lighting is used, high luminance is an advantage. In a more typical in-store application, lighting that is office-like or a bit brighter seems more typical.

As a result, for the collaboration application, we rate all systems as exceeding requirements as the ambient is controlled and modest, and these solutions should deliver quite acceptable checkerboard contrast. For the retail application, because the ambient can vary widely, we rate LCDs and LPDs as meets expectations, with LEDs as exceeding them because of the luminance upside they offer.

Contrast Decrease with Viewing Angle

The decrease in contrast with viewing angle is related to the decrease in luminance with viewing angle (as discussed above), as well as with an increase in the black level with viewing angle (LCDs only).

Most LCD display specs quote the viewing angle as the angle at which the contrast falls to 10:1 – a very low threshold to pass, such that most LCDs can claim 178-degree viewing angles. Be wary of such specifications. A more realistic way to measure contrast reduction is the angle at which the contrast falls to 50% of its peak value. Unfortunately, few, if any, display makers provide such a spec, so it may be wise to consider asking the system integrator to do this measurement if off-angle viewing is an important use case for you.

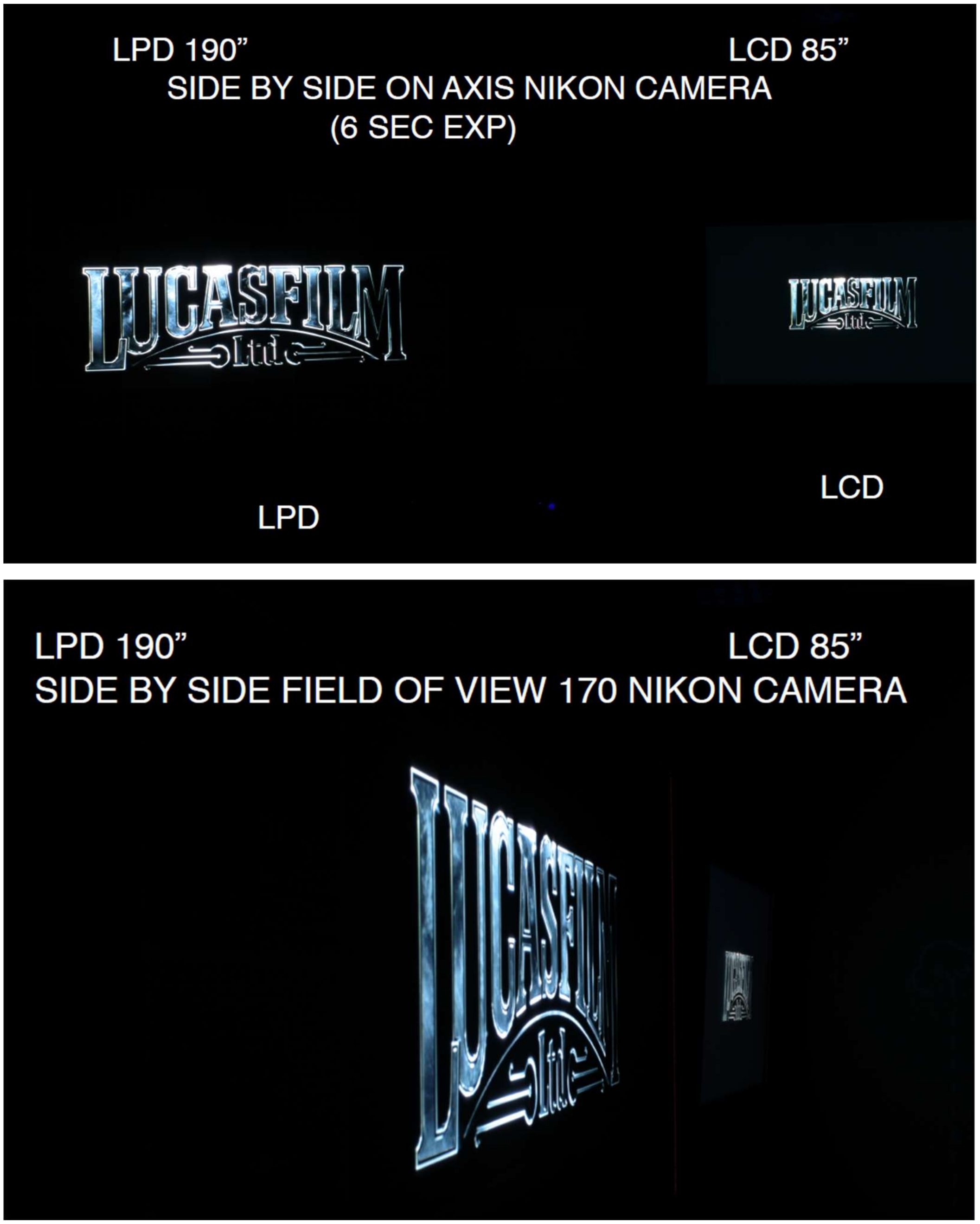


Figure 4: On-axis vs. Off-axis Contrast Example

As discussed, LCDs have a fairly rapid fall-off in contrast with viewing angle, while LEDs and LPDs offer much better results. LCDs also exhibit more color shifts with off-axis viewing than LEDs or LPDs. The ratings reflect this assessment.

Low Luminance Control

This metric refers to the ability of the display to accurately show darker parts of the image. For example, some displays will “crush the blacks,” meaning that the display is not able to show subtle changes in darker tones – they all look the same. This might be important, for example, when looking at the texture in a dark jacket or car interior. If subtle changes are not discernible, the ability to judge the visual look is negatively impacted.

LED screens can have a hard time displaying these darker tones. This is a result of the way they are driven (pulse width modulation). While the pulse can be very short, capacitance in the system can elongate the pulse, so fine control of very low light levels becomes nearly impossible for most LED solutions aimed at retail and collaboration application.

LPD screens can control the pulse in the laser very accurately, and since light is produced optically, there are no electrical capacitance issues to worry about. This should allow for fine control of darker tones.

The ability to control low light levels on LCD screens depends very much upon the backlight architecture and the dynamic backlight control algorithms that are implemented. For example, a backlight that is always on will not have very good control of these darker light levels.

The next level up would be what is called global dimming. This means that for darker scenes the light output of the entire backlight is lowered, so that the control of light levels by the LCD panel is shifted down. For brighter scenes, the backlight luminance increases, shifting the dynamic range upwards. This can happen quite rapidly.

Even finer control can be obtained with a zoned backlight. In this case, the picture area is divided into zones, with the backlight luminance controllable in each zone. This allows a zone with a bright image element to have the backlight bright, and a nearby darker part of the screen can have the backlight dimmed. Such techniques are now common on UHD TVs, but they are less common on LCD displays geared for commercial applications like retail and collaboration. Top brands like Samsung now offer commercial displays with zoned backlights, but most brands do not.

For retail applications, there is not likely to be a need for high fidelity in the darker tones, but for collaboration, such a need could very well exist. As a result, for retail, we rate all as meets requirements. For collaboration, we drop the LCD and LED rating to does not meet.

Color Bit Depth

Color bit depth refers to the number of bits allocated to rendering each shade of gray or color. Displays that have 8 bits-per-color (24 bits in total for red, green, and blue) can render 16 million shades, while panels that have 10-bits-per-color can render over a billion shades.

While both options sound like plenty of colors, issues can come up. The most significant problem is what is called contouring or banding. This is most noticeable on a blue sky or a very dark scene. The sky and the dark background do not appear uniform. Instead, clear bands are visible with sharp transitions. Obviously, the sky does not look like that in real life, so this is an unwanted visual artifact. This can result from video compression but it can also be a problem in the display as well

Contouring is most likely to occur in displays that support only 8 bits per color. However, panels with 10-bits-per-color may not always perform better. That’s because some manufacturers claim 10- bits but may actually drive the panel with 8 bits plus dithering. Dithering is a technique commonly employed to change the state of pixels over time to provide finer control of the light level. For example, suppose you want to display 1 nit of light. If the digital code value N displays 0.9 nits, and code value N+1 display 1.1 nits, there is no way to directly show 1 nit. Dither flashes the pixel between code value N and N+1 to average the light and display 1 nit. This clearly helps to reduce contouring, but it also can introduce some temporal artifacts.

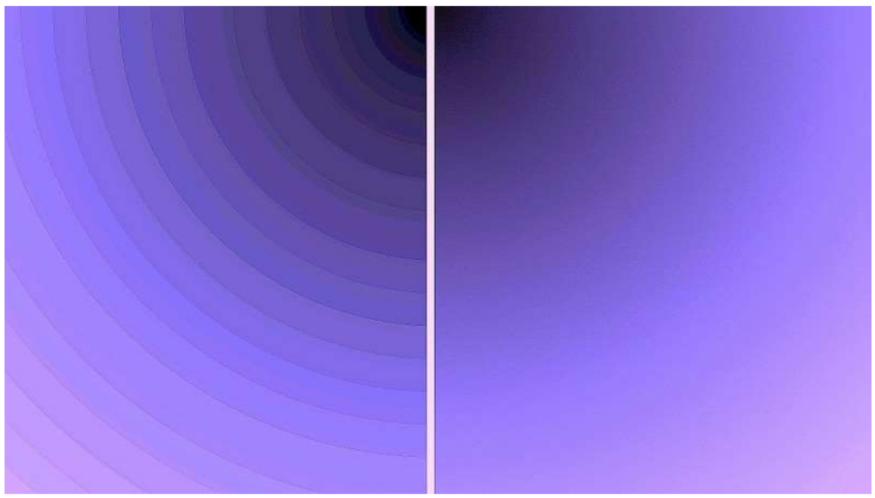


Figure 5: Contouring or Banding (left)

LCD panels are the technology where 8-bit and 8 bits plus dithering apply the most. LPD solutions are native 10 bit. The bit depth on LED displays can be very misleading. For example, many LED manufacturers quote 16-bit depth, which sounds like it is more than 8 or 10-bits. Unfortunately, this 16-bit spec sometimes refers to all three colors, so, for instance, it might mean 6 bits for green, and 5 for red and blue. This means such displays are much more prone to contouring than LCD or LPD displays.

For retail and collaboration applications, it is certainly desirable to not see any contouring. The reality is that many LED screens show a great deal of contouring, yet they are widely deployed. For both applications, 8 bits per color is generally quite acceptable because there are not that many images where contouring will be visible. Only more image-intense applications will demand 10 bit to avoid any contouring.

As a result, for both applications we rate LED as does not meet (even if currently accepted); LCDs as meets, and LPD as exceeds.

High Fill Factor

Fill factor refers to the percentage of display area that is light emitting vs. inactive. High fill factor means that a lot of the display area is devoted to emitting light. For applications where there is touch interaction or close-up viewing of the display, high fill factor is desirable.

Low fill factor means there is a lot of dark area surrounding the light emitting areas. This has the benefit of creating a black background which can increase the apparent contrast of the image when a lot of ambient light is present. The downside is that this black area and the pixel structure becomes easily visible for close-up use, which can seriously degrade image fidelity.

Fill factor is different from pixel pitch, which refers to the spacing between full-color pixels. Different displays technologies can quote the same pixel pitch, but can have very different fill factors so their close-up viewing experience is profoundly impacted.

LCDs have small pixel pitch and decent fill factors depending upon the type of backplane – i.e. a-Si backplane technology makes larger transistors so lower fill factors while ZnO can make smaller transistors allowing for higher fill factors. A-Si will be typical for FHD panels with ZnO being used on some UHD panels, but rarely today in slim-bezel video-wall type panels). A 55-in. LCD panel with FHD resolution has a pixel pitch of 0.63 mm and a decent fill factor, while a 55-in. panel with UHD resolution has a pixel pitch of 0.32 mm and a lower fill factor. FHD resolution is common today, with the trend being toward UHD. Such displays are quite good for close-up viewing and touch screen applications.

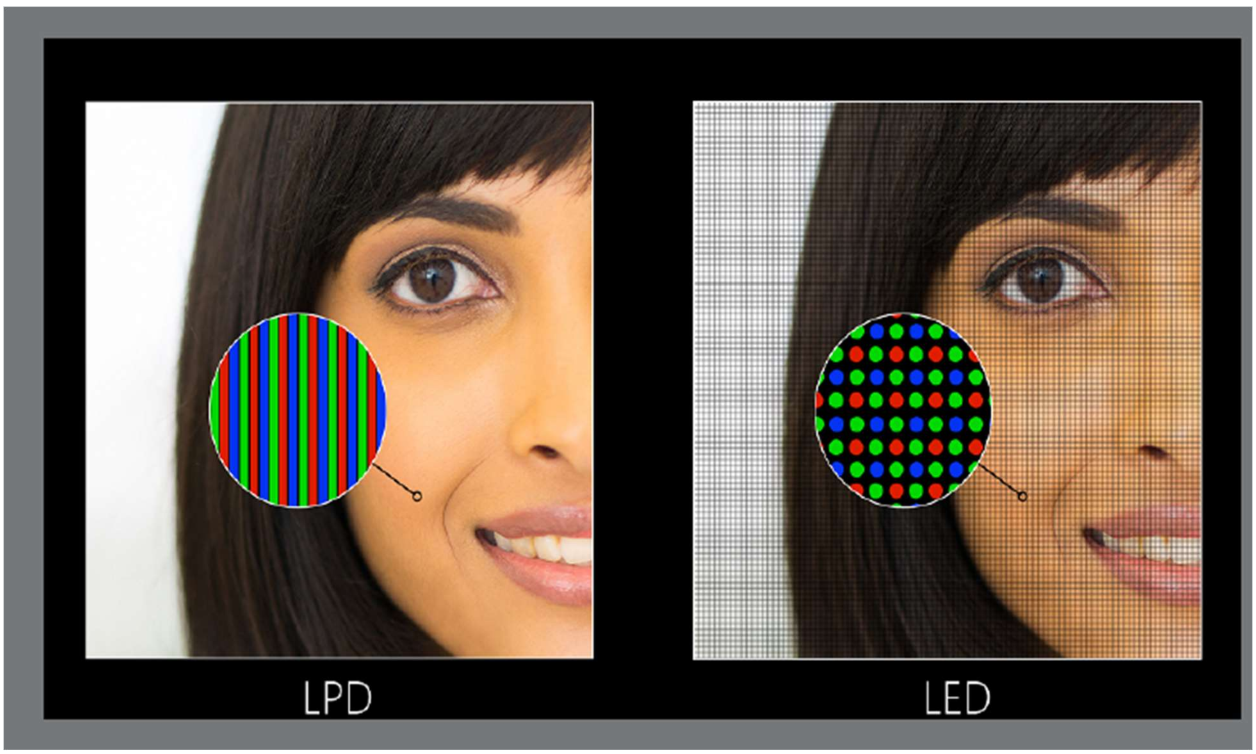


Figure 6: High Fill Factor Means a Smoother Image

LEDs are offered in a variety of pixel pitches, but for close-up viewing, pixel pitches under 1.2 mm are generally recommended. Some vendors can now offer pixel pitches of 0.7 mm, with 0.5 mm probably coming within the year. All that said, LEDs are true light-emitting point sources, so their fill factor is typically quite poor (<10%) even at very small pixel pitches of < 1.00 mm. In addition, these smaller pixel pitch LED displays have much lower luminance capabilities due to heat dissipation challenges as pixel density increases.

LPD displays employ an RGB phosphor screen with a high fill factor. Specifically, LPD screens are currently offered with a 1.2 mm horizontal by 0.8 mm vertical pixel pitch, and their fill factor is at 90%, exceeding that of LCDs.

Pixel pitch and fill factor say a lot about the image quality, but not everything. Sometimes there are optical structures that are part of the display architecture that can improve or degrade image quality – which will be especially noticeable with close-up viewing. LEDs for example, have dome-like lenses over the emitting surface, which adds structure. This is noticeable and sometimes distracting when viewed up close. The LCD color filters and the LPD phosphor screen are quite flat and homogeneous. As a result, they create a much smoother-looking image.

For both retail and collaboration, the requirement is for no artifacts or pixel structure to be visible during close-up viewing or touch interaction. Because LEDs do show more structure than LCD or LPD, we rate them as meets requirement, with the other two as exceeds requirement.

Motion Artifacts

Motion artifacts can be a limitation of the image processing electronics or the display itself. The image processing electronics accept signals in various formats and frame rates; they scale the resolution of the signal to the resolution of the video wall and adjust the signal frame rate to that needed to drive the display. There can be huge variability in the sophistication of these image processing electronics from different vendors. There is also a wide range of input sources that may cause problems, so this aspect also needs to be considered.

For example, if all content is computer generated at the resolution and frame rate of the native mode of the display, the image processing electronics don't have to do much. Video content is far more variable with respect to frame rate, resolution, and color gamut so much more processing is needed.

At the display level, pixel response time is a key metric in reducing display-related motion artifacts. LPD displays employ phosphors with extremely fast response times (as fast as 0.003 ms), and the laser pulses driving the signal are even faster by orders of magnitude. This means there is virtually zero display-related motion artifacts with an LPD display.

LED displays can also be driven very quickly with current pulses, but as discussed previously, system capacitance may limit how quickly the signal can ramp up and down. The LED elements however, faithfully follow this drive signal without delay.

LCDs have the slowest response time. This varies with the LCD material and cell thickness, but is on the order of 1-8 ms. This can make a fast-moving object exhibit ghost images trailing behind it, a very objectionable artifact.

LCD makers can employ a number of tricks to reduce motion artifacts, such as increasing the frame rate to 120 or 240 Hz. An informed buyer should be aware that most of these claims do not typically reflect how fast the LCD material can switch. For example, an LCD material with a 8 ms response time cannot switch faster than 125 frames per second. Moreover, most LCDs employ switching electronics that are capable of only switching at 60 Hz as that is the most cost-effective option of building a LCD module. Marketing claims of 120-240 Hz frame rates usually come with an asterisk and fine print to go along with them. Specifically, image processing can be used to create video frames that are in-between the original video frames to run at these higher frame rates. These techniques, commonly referred to as motion estimation/motion compensation algorithms, are used to calculate the position of the object between the original frames 1 and 2 to create an intermediate frame. Other techniques include over-driving the LCD to force a faster response, black frame insertion, and scanning/blinking backlights. Such techniques are often employed in TVs at various price points with varying success. However, such techniques are less common in commercial video wall panels.

The requirement for our application cases is no visible motion artifacts. It is difficult to rate solutions accurately as so much depends on the signal sources and image processing electronics, in addition to the native display capabilities. As a result, we only try to rate the native display motion capabilities. Therefore, we rate LCD as meets the requirement, since not all solutions have the additional image processing horsepower required to improve native panel response, and LED and LPD as exceeds the requirement.

Image Retention / Burn-in

Burn-in and image sticking refer to an effect where part of a static image displayed for an extended period of time is still visible on a new image. Residual image, image sticking, image persistence, ghosting, or image retention all refer to a temporary effect. That is to say, the effect of the image retention is reversible over time, sometimes very quickly or by simply turning off the display. Screen burn-in is an extreme case of image sticking, where the damage becomes irreversible.

There are a few scenarios where image sticking becomes a showstopper:

- Watching sports or news channels for a long time. Here the station logo or graphics is displayed in the exact same spot on the screen for extended periods, leading to image retention when changing channels.
- Gaming for long periods of time. Menu items and head-up graphics may be displayed continuously and in the exact same location, leading to image retention when switching to non-game applications.
- Commercial applications with static content. These displays can be on for many hours per day, so any static content may be problematic. These applications can be particularly troubling because the luminance levels are often quite high, which can exacerbate image sticking.

OLED displays have been shown to exhibit image retention and burn-in issues that have been documented over the last 12 months by various outlets. LED displays are not known to have any issues. For the most part, LCDs have few problems as well, but for high-luminance displays, there can be some issues, as outlined above. LPDs are phosphor-based, and some phosphors from CRTs were known to burn in. That said, the phosphor chemistry used in LPD displays is unique and quite a different chemical composition than the phosphors used in CRTs and plasma TVs. In addition, each phosphor element gets illuminated once per frame and stays on for only 0.003 ms (i.e., it is OFF for the rest of a 16.67 ms frame). As a result, even if an LPD display were to display a white background 24/7 for the life of the display, 60,000 hrs, each phosphor element would only be active for a total of 10.8 hrs. One can readily see that LPD displays are extremely resilient against image retention/burn-in.

Figure 7: Example of Image Retention in an LCD (Source: Rtings)

We rate LCDs and LEDs as meets, while LPDs exceed the requirement.

Power Consumption / Efficiency

The energy usage of the display solution should be a consideration when evaluating a purchase. Not only is there the direct operating expense of the electricity to run the display and controller, but one also must consider the secondary effects of an inefficient display. For example, if the electronics and display screen emit a lot of heat (a sign of inefficiency), then there will be increased air conditioning expenses. If this heat is significant, it could require an upgrade to the HVAC system in the application space.

The most accurate way to judge the efficiency of the solution is the wall plug efficiency (WPE). However, few manufacturers publish that data. A more practical way to judge electrical efficiency and impact to HVAC systems is by using the normalized power consumption expressed in Watts/m^2, where the wall plug power consumption is normalized with respect to display active area. Most manufacturers publish those numbers. Large diagonal LCDs, 85-98", are at the 250 W/m^2 range. By comparison, LEDs are in the 360 W/m^2 range, and LPDs are in the 200 W/m^2 range under "typical" usage. Note that the definition of "typical" varies from manufacturer to manufacturer and may not meet the guidelines set forth in the IEC-62087 standard that was designed to quantify TV usage under standardized broadcast TV (mostly movie/dark content) and computer usage (entailing frequent use of white backgrounds).

Based on the above figures LPD is among the most efficient display technologies in the market. As a result, it enjoys the lowest impact on HVAC facility requirements and is very cool to the touch. It also can operate on 110V AC power, so no electrical upgrades are likely to be needed. On the other hand, it can only generate 300-500 nits.

LCDs can generate 400-1500 nits, are generally slightly warm to the touch, but usually don't have much of an impact on HVAC.

Early LED devices were known to be very inefficient because of the amount of direct driven electronics required. The inefficiency is further exacerbated at smaller pixel pitches as heat dissipation from the backplane becomes quite challenging at high luminance outputs. They are often run quite bright in the 700 to 2000 nit range, so they can often have LED screens that are warm to the touch. In these luminance ranges, the integrator is expected to design in additional HVAC infrastructure dedicated to the LED solution.

LEDs consume more power generally than LCDs and LPDs while generating higher luminance levels. As a result, they require additional HVAC infrastructure to be installed. Therefore, we rate LED as meeting the need, with LPD and LCD as exceeding the requirement for both collaboration and retail.

Color Gamut

Color gamut refers to the range of colors the display is capable of producing. The color gamut is determined by the chromaticity coordinates of the red, green, and blue primaries. These coordinates are typically specified in the CIExy color space, but the color gamut coverage is meant to be expressed in the CIEuv color space. Alternatively, some display makers reference the display's color capabilities relative to a specific color gamut standard.

For example, the Rec. 709 color standard is the one specified for HDTV. The similar sRGB gamut is primarily used for printing and web-based images. The Adobe color gamut is popular in the printing and graphic industry, while Hollywood movies and some UHD TV content uses the DCI-P3 color gamut.

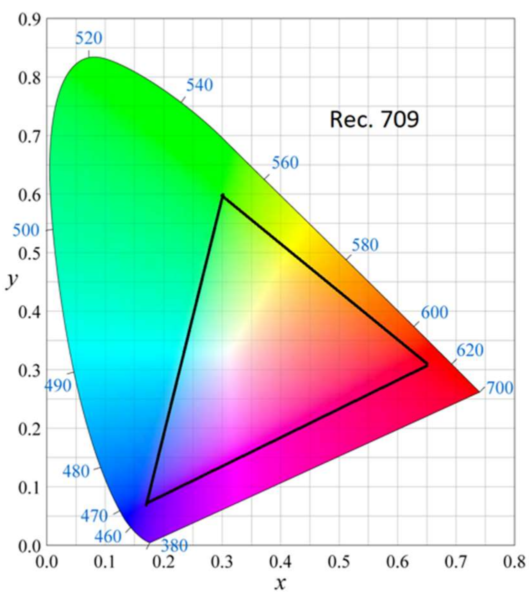


Figure 8: Rec 709 Gamut is the Minimum for Video Walls

The display manufacturer chooses the RGB primaries – and appropriate materials to achieve these primaries – based on the intended use and color gamut standard the application will use. Mid-tier TVs typically are built to cover the Rec 709 gamut, while higher-end TVs will cover the bigger DCI-P3 gamut. Display monitors for consumers are usually sRGB. For color critical applications professionals may choose Rec. 709, DCI-P3, or Adobe. Professional grade displays, such as would be used in a retail or collaboration room applications, are generally offered with support for the Rec. 709 or sRGB color gamut.

LCD displays can easily meet the Rec. 709 requirement, but Samsung now offers a commercial LCD with a DCI-P3 color gamut using quantum dot technology. LEDs can meet the Rec. 709 requirement or can offer an expanded color gamut with tighter binning of the RGB LEDs. The phosphors in the LPD display were chosen to meet the Rec. 709 gamut, but development is underway to offer DCI-P3 coverage as well. Since the expanded color gamut often comes at a higher cost and is optional, we rate all three technologies as meets the requirement.

Touch Performance

The ability to interact with the video wall for a collaboration application is a clear requirement. For retail, this requirement will vary for various applications. In both retail and collaboration applications, it is necessary to support interaction by at least three people. While most interaction will be the two-finger type, the ability to support five-finger tasks may be needed, too. As a result, we set the requirement at 10 fingers minimum, which could be one to multiple persons.

LCD screens can support capacitive touch screens that are built into the screen, but the bezels can make interaction very cumbersome and ineffective.

The most widely used touch technology for LED screens and for the LPD screen is Infrared (IR) touch. This requires a frame to be built around the display that houses the IR LED emitter and sensors. When a finger touches the surface, it interrupts multiple IR beams, allowing the location of the touch point to be determined with high precision. The touch controller and sensor array determine the accuracy, as well as the number of simultaneous touch points that can be supported. This will vary depending on the IR touch frame used.

Implementing a touch screen on LEDs has not been easy because traditional LED screens do not have a smooth or touch-friendly surface. Just a few companies have been able to implement a special overlay material that allows for touching the surface. However, this material deflects upon pressure, so the touch experience is not what most people have come to expect by interacting with their smartphones and tablets. In addition, every time the LED screen needs to be serviced at the module level, because of a dead pixel, the entire overlay must be removed and then re-applied after the new module is installed. This is certainly not ideal.

The LPD touch solution is also IR based, but it has a much more rigid surface for a more natural interaction experience. It also comes with a limited lifetime warranty since the phosphor screen employs an unbreakable plastic overlay and will not need to be serviced for the life of the display.

Consequently, we rate LCD as not meeting the requirement, LED as meeting, and LPD as exceeding.

Lifetime

Lifetime of display products is typically given as hours to 50% of the initial luminance. Clearly, longer lifetimes are desirable.

For the retail application, the display is likely to be operated 12 hours a day for 7 days per week. For the collaboration application, operation at up to 10 hours per day, 5 days per week seems more typical. In both applications, we specify a display lifetime of 10 years.

While the display may dim by half in 10 years, other components, such as power supplies, are likely to fail before this time period, which should be considered in the warranty evaluation.

For either retail or collaboration applications, end users have the option to source thin-bezel LCDs to make a thin bezel video wall. Consumer-level LCDs are not designed for such use and will likely fail well before the required 10 years of use. Therefore, we will not consider this solution, but only professional-grade LCD panels with high-reliability components.

LCD, LED, and LPD lifetimes can vary, but are in the 60-100K hour range. Ten years of operation at 12/7 equates to 43,800 hours of operational time. Ten years of operation at 10/5 is 26,000 hours of operational time. Therefore, all three technologies exceed the requirement.

Other Desired Features

There are a number of additional features that are desirable but are not easily specified or rated. These features are mostly independent of the display technology, but clearly vary from supplier to supplier. They are discussed below.

Reliability & Warranty

Reliability is often measured as Mean Time Between Failure (MTBF), with longer MTBF being better. MTBF for video walls is not an often-quoted specification, so end-users should ask about this number. If the vendor has no data, that may mean they have a low MTBF, or they don't value this parameter enough to measure it.

Warranty will cover the display system from the initial purchase for a certain period of time. We recommend that end users seek a warranty of a minimum of 2 years on all display-related parts.

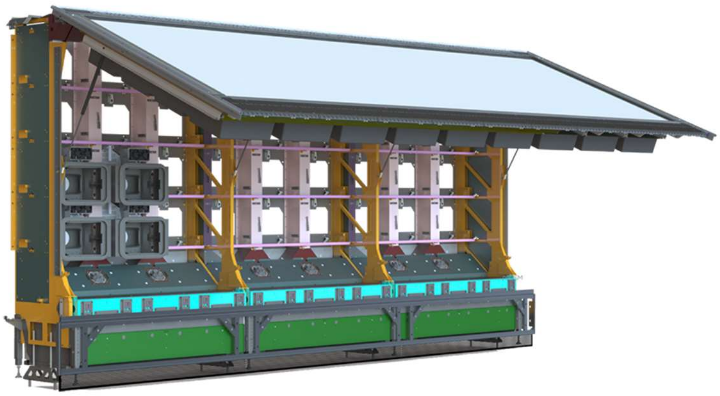
Easy to Calibrate

All display systems need periodic calibration to maintain accurate image reproduction. Unfortunately, not every end user values this aspect highly, which is why many video walls in the wild often look highly non-uniform. While some viewers may not notice, nor care about such non-uniformities, many people will notice. If those that notice are your customers, prospects, superiors or suppliers, you can create a poor impression with them – something to be avoided.

Most calibration workflows are camera-based. The procedure can take minutes or hours, depending upon the supplier and the display technology. Such downtime and the frequency of calibration should be considered when making a purchase decision.

Transport, Install and Service

Where the video wall is to be placed can also drive a purchase decision. Do components need to fit inside a service elevator? Are any structural or facilities upgrades needed? How long will the install take, and how disruptive will it be for adjacent areas? When servicing is needed, can it be serviced from the front, or is rear access needed? Are broken parts field-replaceable for minimal downtime? These are all questions that should be asked of the system integrator



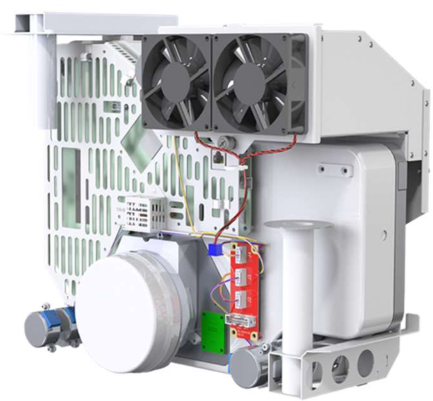


Figure 9: The Prysm system has a lift-up touch panel and can front service to remove and replace the LPD Modules

Environmentally Friendly

Some firms are concerned about the environmental impact of their video wall. This has two components: the manufacturing, shipping, and installation impact, as well as the operational impact. If this is a concern for your organization, ask your integrator to provide some information on potential solution to better judge the impact of each technology in these two areas.

Durability

Durability refers to the ability of the display to survive spills, bangs, and knocks. Bad things sometimes happen to the display, and you should want to know how durable the potential solutions are. And if something bad happens, how does that impact the warranty?

Design Flexibility

Design flexibility is generally desired, so that the customer can configure a screen in the size, resolution, aspect ratio, and other parameters that are desired to fit the space, application, and budget. Sometimes, this can include flat or curved, irregular shapes or aspect ratios, touch interfaces, remote power supplies, and many other factors.

LCD, LPD, and LED are all modular solutions, but some technologies and some manufactures may offer a greater range of modules sizes, resolutions, luminance levels, etc. to offer more design flexibility. End-users should understand what they want and then try to find the technology to fit their needs.

Total Cost of Ownership

Obviously, the cost of the display system and associated controller is always a factor in the buying decision. But there may be additional factors, such as equipment, installation costs, infrastructure upgrades, and optional warranty or service plans to consider.

The total cost of ownership calculation should include these factors, as well as the operational costs over the projected lifetime of the solution. This means electricity, air conditioning, service, and repair estimates. Be careful to not fall into the trap of buying the lowest initial cost solution only to find the system requires frequent repair or calibration, and the operating costs are higher than alternatives. The result may be a higher total cost of ownership and more headaches.

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