SONY

4K Home Cinema Projectors

Technical Background

4K HDR Z-Phosphor LASER LIGHT SOURCE SXRD

Welcome

With the emergence of 4K Ultra HD, High Dynamic Range and ATSC 3.0 TV transmission, home cinema is undergoing a transformation as dramatic as the change from standard definition to high definition 20 years ago. And Sony's projectors are uniquely qualified to bring out the best in this new era.

These six projectors – the VPL-VW5000ES, VW870ES, VW760ES, VW570ES, VW270ES and VZ1000ES – are distinguished by a suite of key technologies:

1. Sony's proprietary SXRD® microdisplays
2. True 4K resolution: native 4096 x 2160 microdisplays
3. The 100% stability of three-chip colour
4. High Dynamic Range and associated advances
    - BT.2020 wide colour gamut emulation
    - 10-bit encoding
    - High Frame Rates
5. Z-Phosphor™ laser light source (VPL-VW5000ES, VW870ES, VW760ES and VZ1000ES)
6. ARC-F lens (VPL-VW5000ES, VW870ES)

As a result of these advances, the projectors deliver a more "organic" picture, with resolution, dynamic range, colour and brightness merging to form a seamless whole. Viewing is more immersive, more emotionally compelling and closer to the experience of actually being there than ever before.

It's no surprise that the company behind these products is Sony. We build our projectors on a foundation of Total System Technology – innovating the essential sub-components, which we design in-house. Unlike so many other companies, we use our own projection microdisplays, digital processors, light engines and projection lenses. This enables Sony to do what others don't. The difference is dramatic.

Contents

Sony’s heritage in projectors and displays

Sony’s leadership in home cinema technology is not recent. Nor is it an accident. It’s the natural consequence of decades spent advancing technology in projection and high-end displays.

1973 **VPP-2100.** Sony’s first colour video projection system

1982 **VPH-1020Q.** “Universal” PAL/NTSC/RGB projector

1989 **HDIH-2000**. Sony’s first commercial high definition projector

1993 **LPH-350J and VPL-350Q.** Sony’s first 3LCD projectors

2003 **QUALIA™ 004.** World’s first microdisplay Full HD projector and the first with Sony’s SXRD® panels

2005 **SRX-R110 and R105.** World’s first commercial projectors with 4K (4096 x 2160) resolution

2006 **SRX-R220.** World’s first 4K projector purpose built for Digital Cinema

2011 **VPL-VW1000ES.** World's first 4K home cinema projector

2012 **XBR-84X900.** Sony's first 4K Ultra HD television

2013 **VPL-FHZ55.** World's first 3LCD laser phosphor projector and the first with Sony's Z-Phosphor™ laser light source

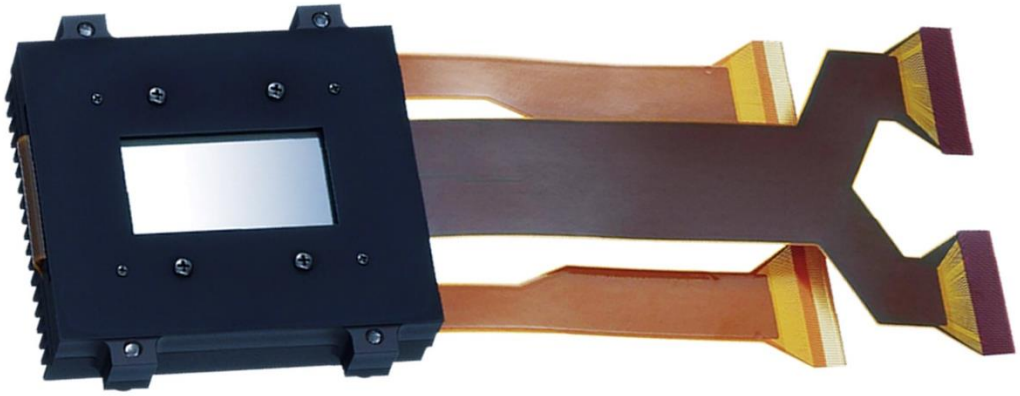
2015 **BVM-X300.** Emmy® Award winning professional evaluation monitor with Sony's TRIMASTER EL® OLED technology providing native 4K resolution, High Dynamic Range and Wide Colour Gamut

2015 **VPL-GTZ1.** World's first 4K laser light source home cinema projector, also featuring ultra-short throw design

2016 **VPL-VW5000ES.** Sony's first 4K HDR home cinema projector

Key technology #1:
The SXRD microdisplay (all models)

Sony's own Silicon X-tal (crystal) Reflective Display (SXRD®) chip has proven to be a foundational advance in projection technology. A proprietary version of liquid crystal on silicon (LCoS) technology, the SXRD chip has underpinned Sony's repeated breakthroughs in projector resolution for nearly 14 years. Today, no other company can match Sony's expertise with LCoS, encompassing SXRD projection everywhere from cinema auditoriums to flight simulators, planetariums, oil & gas exploration, home cinemas and even compact, portable projectors. To appreciate Sony's SXRD microdisplays, it helps to consider the world before microdisplays, the age of Cathode Ray Tube (CRT) projection.



From the beginning, advances in SXRD technology have led to breakthroughs in projector performance. For example in 2005, our first 4K SXRD microdisplay made possible the world's first commercial 4K projectors, Sony's SRX-R110 and R105.

The limitations of CRT projection

From the dawn of home video projectors in the 1970s through the end of the last century, the dominant technology was the CRT. Projectors typically used three CRTs: one each for Red, Green and Blue. In this system, the CRTs were responsible for providing both resolution and brightness. Unfortunately, it was very difficult for a CRT to do both.

To achieve higher performance, designers were forced to employ larger and larger CRTs, like the 9-inch tubes of Sony's well-loved VPH-G90U of 1999. While that projector was capable of gorgeous images and 2500 x 2000 resolution, it could only output 350 ANSI lumens. Considered paltry by today's standards, this output limited the G90U to relatively small screens or rooms with carefully controlled ambient lighting.

Microdisplay projection overcomes this bottleneck through division of labor. Resolution is determined only by the microdisplay, while brightness is primarily determined by an external light source.

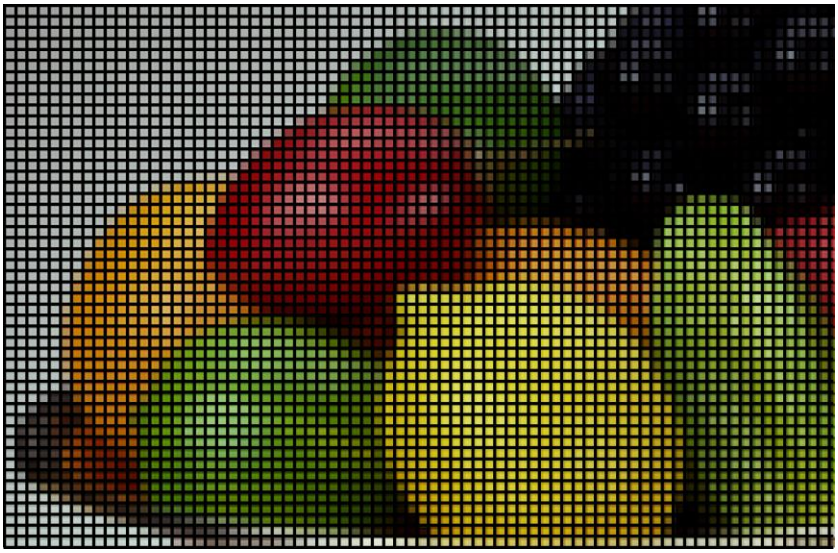
Sony and microdisplay projection

Sony was quick to recognize the enormous potential of microdisplays. That's why we've been building microdisplay projectors since 1993. And we don't just build the projectors; we build the microdisplays inside. In fact, while there are dozens and dozens of projector brands, Sony is among the very few that builds microdisplays in-house. We manufacture both our SXRD and our transmissive LCD BrightEra® panels in our Kokubu and Kumamoto Technology Centers. In-house panel manufacturing has enabled Sony to innovate, decade after decade.

The issue of inter-pixel gaps

When Sony developed the SXRD panel, the dominant microdisplay technology was transmissive LCD. As the name implies, transmissive LCD requires the light to shine through. Because the pixel transistors are transparent, they don't cause a problem. Unfortunately, the addressing wires that drive and control the pixels are not transparent. They must run alongside the pixels, creating substantial

“inter-pixel gaps” that block the light. These gaps were so big that they occupied as much as 50% of the screen. This left an active picture area (or “fill factor”) of just 50%.

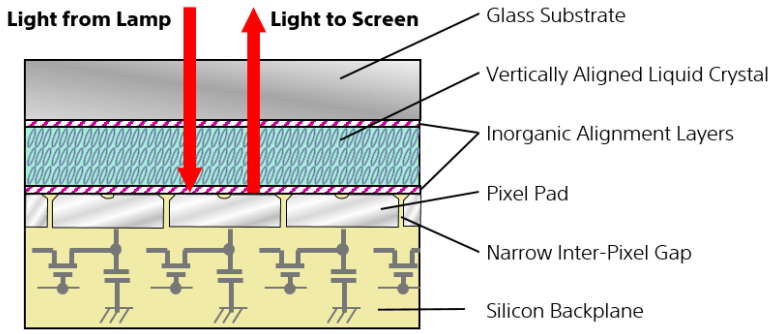


Wide inter-pixel gaps can make it seem as though you’re looking at the image through a screen door. Hence the name “screen-door effect.”

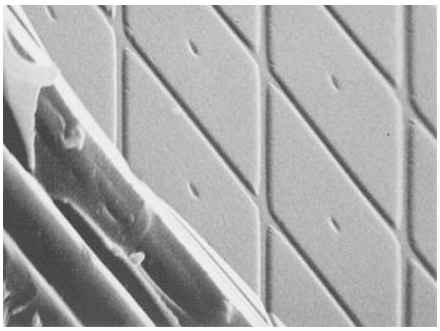
A fill factor of 50% creates issues in projector design. It lowers image brightness, because so much of the projector’s lamp light is blocked. It creates “screen door effect” in the projected image, giving each pixel an individual outline. And in terms of system design, large inter-pixel gaps also require large pixels, which make high-resolution chips relatively expensive. Sony recognized that the transition to HD projection demanded a smarter approach.

The SXRD solution

Sony’s answer was the SXRD chip. Instead of light shining through the chip, the light reflects off a polished aluminum surface, behind which we can hide the transistors and all the pixel address wires. The benefits are profound.

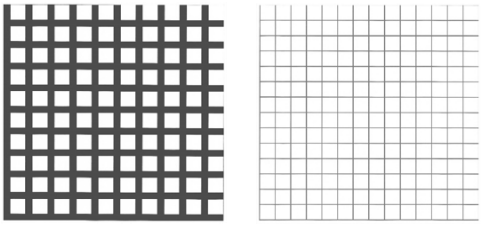


The SXRD panel in cross section. Light from the projection lamp enters through the glass substrate at the top, reflects off the mirrored surface and passes back out through the Liquid Crystal, toward the screen.



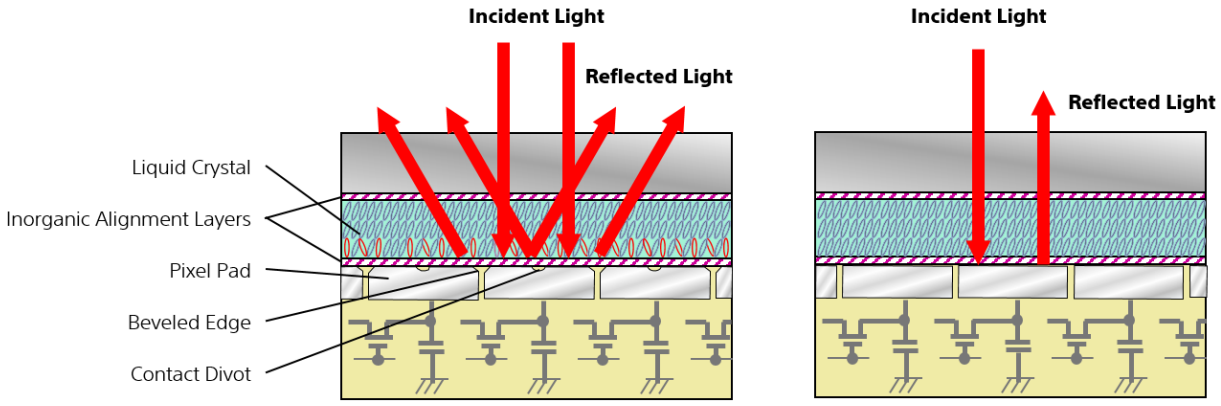
Photomicrograph of the first-generation SXRD panel. You can see that the inter-pixel gaps are quite narrow in comparison to the live picture area. Each pixel has a beveled edge and a "contact divot" in the center.

- **High fill factor.** Hiding the pixel address wires enables the inter-pixel gaps to be quite small. So the proportion of the chip surface devoted to active picture area can be quite high: 92% in our first-generation chips, compared to the 50% fill factor for the transmissive LCDs of the time. This enables Sony to deliver high resolution without sacrificing brightness.



Compared to the typical transmissive LCDs of the time, Sony's first SXRD panel delivered thinner inter-pixel gaps, which translate to higher fill factor and higher pixel density. These are crucial advantages for achieving brightness and resolution.

- **Superb contrast.** From the outset, the SXRD panel achieved very high native contrast. Previous LCD projectors had used Twisted Nematic (TN) liquid crystal, which normally displays white. The SXRD panel uses a proprietary Vertically Aligned Nematic (VAN) liquid crystal, which normally displays black. The normally black state helps prevent stray light from washing out the image. This improves black levels and increases contrast. With succeeding generations of chips, Sony upgraded the chip-making process to drive contrast higher still. We refined the pixel surface, eliminating the center "contact divot" and beveled edges. We also improved the liquid crystal alignment. These upgrades dramatically reduced light scatter, optimizing black levels and maximizing contrast.



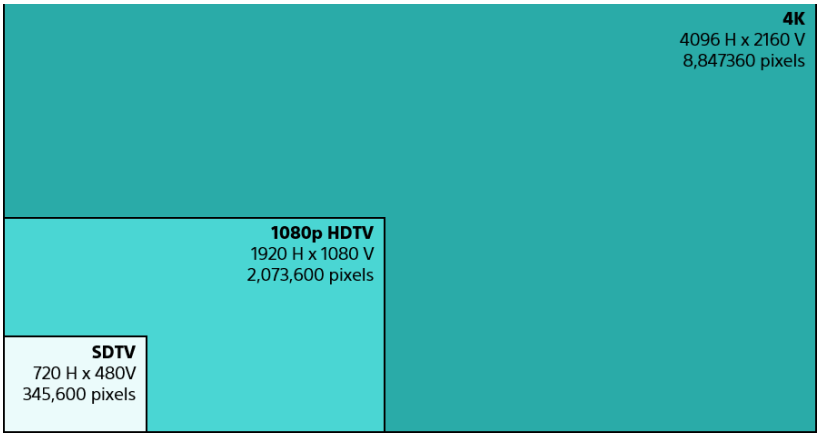
Improving liquid crystal alignment and eliminating both the contact divot and the beveled edge minimize stray reflections. The result: a substantial improvement in black levels.

- **High pixel density.** There are two ways to increase the native resolution of a microdisplay projector. You can take an existing chip technology and build larger chips. Unfortunately, large chips are expensive; and they require larger, more expensive light engines, optical blocks and lenses. That's why Sony went the other route, shrinking the pixels and increasing pixel density. Sony's first generation SXRD chip was a Full HD 0.78-inch diagonal panel that achieved an astonishing 12,400 pixels per square millimeter. These pixels were so microscopically small that it would have taken about 29,000 of them to form a rectangle to cover the "E" in the word "LIBERTY" in the US quarter dollar. In comparison, our current 4K home cinema projectors incorporate slightly smaller, 0.74-inch chips with *more than four times* the pixels per square mm. The phenomenal pixel density of Sony's SXRD chips enabled us to create the world's first Full HD microdisplay projector, world's first commercial 4K projector and world's first 4K home cinema projector. None of these achievements would have been possible without the SXRD microdisplay.

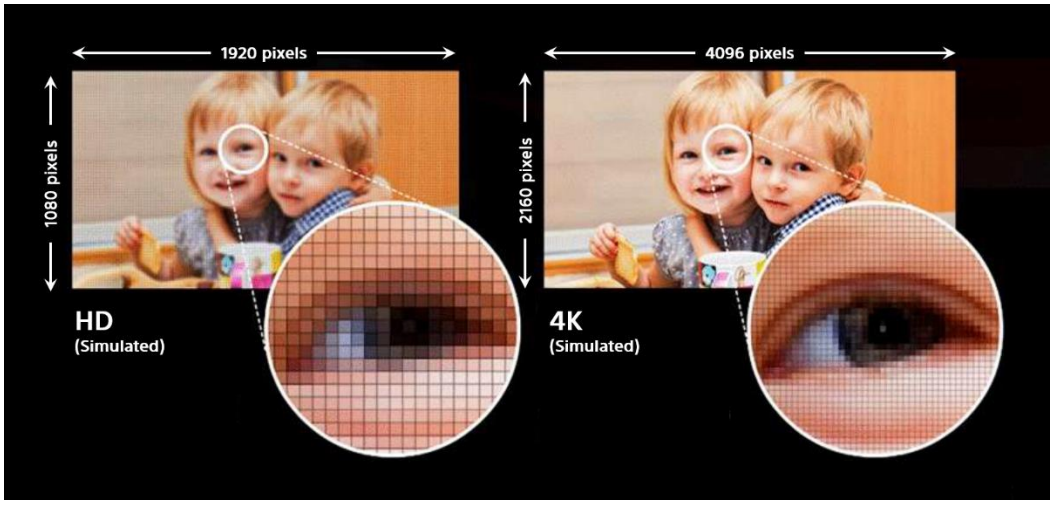
A US quarter dollar, shown actual size (for letter size printout). The pixels of Sony's first generation SXRD chip were so microscopically small that it would have taken about 29,000 pixels to form a rectangle covering the letter "E" in the word "LIBERTY." For our current 4K home cinema projectors, the pixels are even smaller. It takes about 142,000 pixels to cover the same area.

Key technology #2:
True 4K resolution (all models)

In home cinema projection, resolution is not some purely academic pursuit. It's a powerful tool to achieve viewer "engagement," a more exciting, more emotionally compelling entertainment experience. Viewing becomes more engaging when you sit closer (for a given screen size) or use a larger screen (for a given viewing distance). Either way, the screen fills more of your field of view.



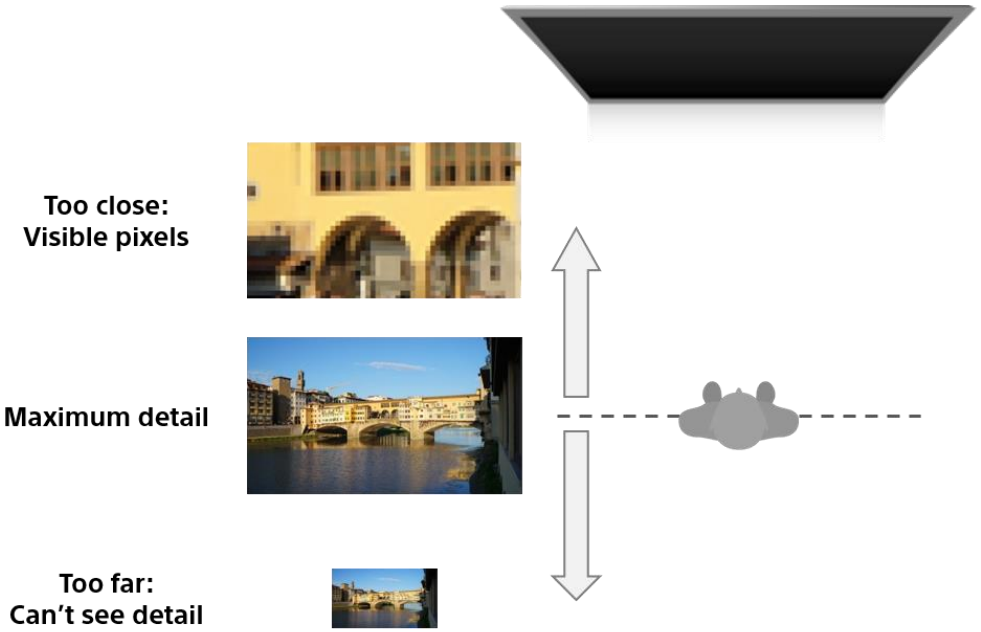
True 4K delivers slightly more than four times the pixels of Full HD. But it's not about numbers. It's about a larger canvas for a more engaging viewing experience.



Compared to HD, 4K Ultra HD images are smoother, more lifelike and more natural.

Greater viewer engagement

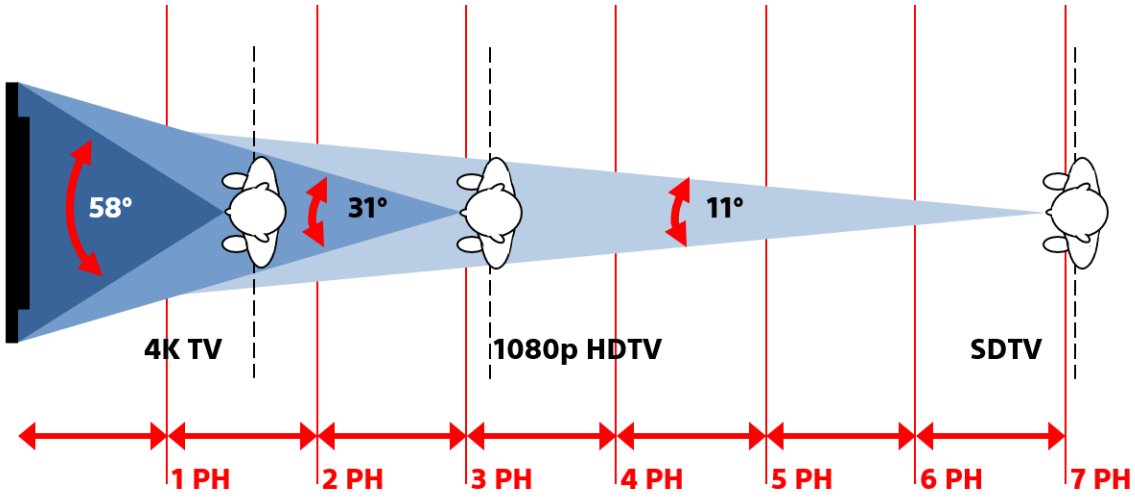
If you like the idea of a more engaging experience and you try to sit closer to a 1080p HD screen, at some point you'll start to see the individual pixels. On-screen objects will become visibly jagged around the edges. The illusion of a seamless picture will begin to fall apart.



The "threshold point" is the seating distance at which you're close enough to see the maximum picture detail, but not so close as to discern individual pixels.

If sitting too close poses a problem, so does sitting too far away. As an extreme example, if we were to watch a typical home cinema from a distance of 100 feet, our eyes would certainly not be able to resolve the picture's fine details. The same holds true at less extreme distances. This suggests that there's some "threshold point" at which we can perceive maximum detail, without detecting individual pixels.

Studies of human visual acuity confirm that we can perceive details as small as 1/60 degree (one arc-minute) in the visual field. This works out to 60 pixels per degree. Using this measure and some high-school trigonometry, we can calculate the threshold distance for a given on-screen resolution. We measure this in multiples of the Picture Height (PH).



SDTV was designed to be viewed from a distance of 7 Picture Heights (PH). HDTV enables you to sit closer and/or watch a bigger screen than SDTV. 4K is even more compelling.

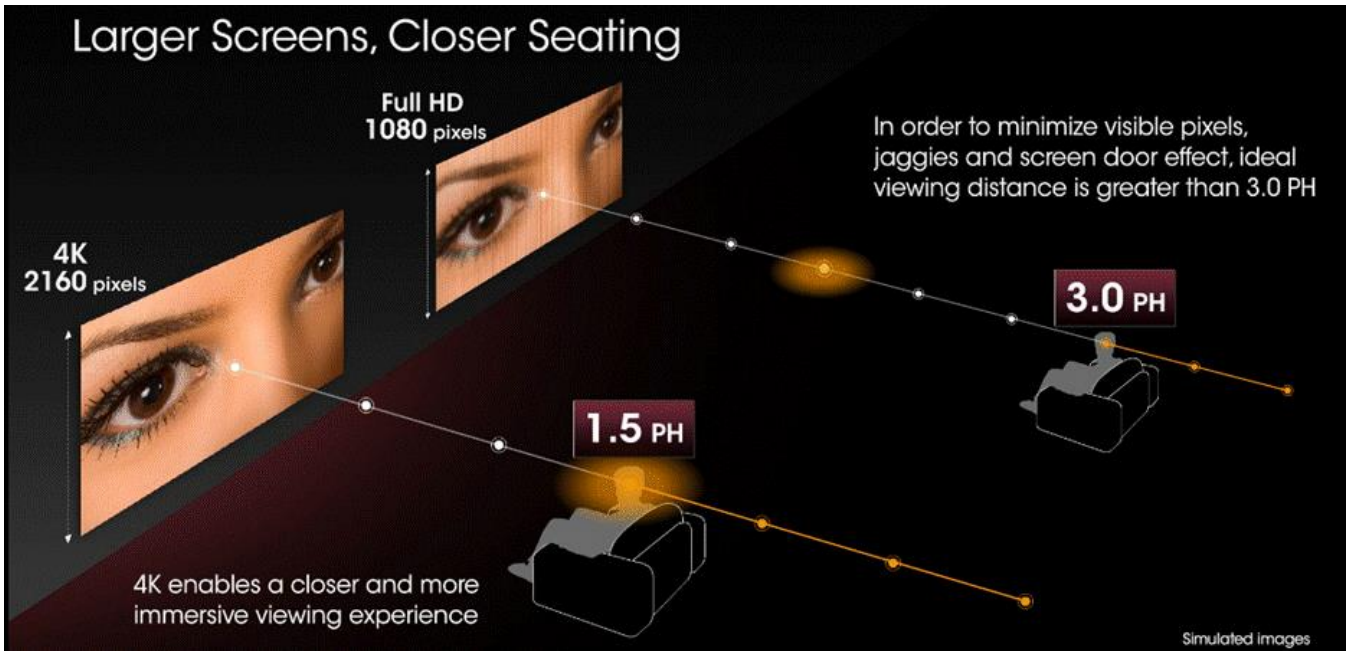
For SDTV, the threshold distance is 7 Picture Heights (7 PH). This corresponds closely to a 25-inch diagonal screen viewed from 9 feet away. For decades, 25 inches was a best-selling screen size for

living room TVs. And studies showed that 9 feet (the “Lechner distance”) was the default distance for living room viewing. So the theory matched very well with actual home viewing.

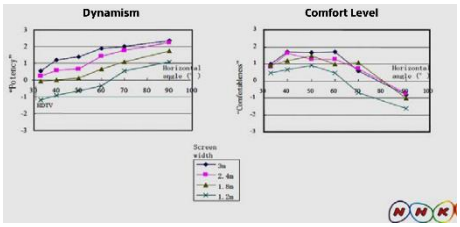
For HDTV, the threshold distance is reduced to 3 PH, a distance at which your entertainment becomes much more immersive. While SDTV occupied a horizontal angle of 11° when seen from the threshold distance, HDTV occupies an angle of 31°.

HDTV viewing at 3 PH was designed to replicate the immersive experience of classic cinema auditoriums. However, modern “stadium seating” auditoriums have moved ahead. In stadium seating, 3 PH is near the back row of the auditorium – or even in the projection booth! You need to sit closer than 3 PH for your home cinema to reproduce the immersive effect of stadium seating. To avoid visible pixels and screen door effect when you do sit closer, you need higher-than-HD resolution. That’s the logic behind 4K Ultra HD home cinema.

With 4K Ultra HD, the threshold distance is now 1.5 PH, from which the screen occupies 58° of your visual field. In this way, 4K frees you to sit closer, without visible artifacts. You’re more immersed in the entertainment experience, just as in a stadium seating cinema auditorium.



This 1.5 PH number is more than just a back-of-the-envelope calculation. It’s been tested by the Science & Technology Research Laboratories of NHK, Japan’s national broadcaster. Conducting research with real-world viewers across a range of seating distances and screen sizes, they found the qualities of “dynamism” and “comfort level” were well served at a horizontal viewing angle of 60° -- quite close to our calculated value of 58°. The viewing distance of 1.5 PH is also supported by reports from a global standard-setting body, the International Telecommunication Union (ITU).



NHK research findings on variation in perceived “dynamism” and “comfort level” across different horizontal viewing angles.

Growing momentum for 4K

When Sony built the world's first commercial 4K projector back in 2005, we had to explain that a "K" was 1024 horizontal pixels. We had to detail the interfaces and explain the applications. Today, 4K is a burgeoning standard everywhere from the sound stages of Hollywood to professional sports stadiums to an ever-growing proportion of big-screen televisions and home cinemas.

- **Digital Cinema 4K.** In the context of cinema, 4K refers to a container of 4096 x 2160, about 8.8 million pixels. While movie aspect ratios inside the container vary, the container itself has an aspect ratio of roughly 17:9.
- **4K Ultra HD.** In the context of home entertainment, 4K Ultra HD maintains the 16:9 aspect ratio of HDTV. This is 6% narrower than Digital Cinema 4K, with 3840 x 2160, about 8.3 million pixels.

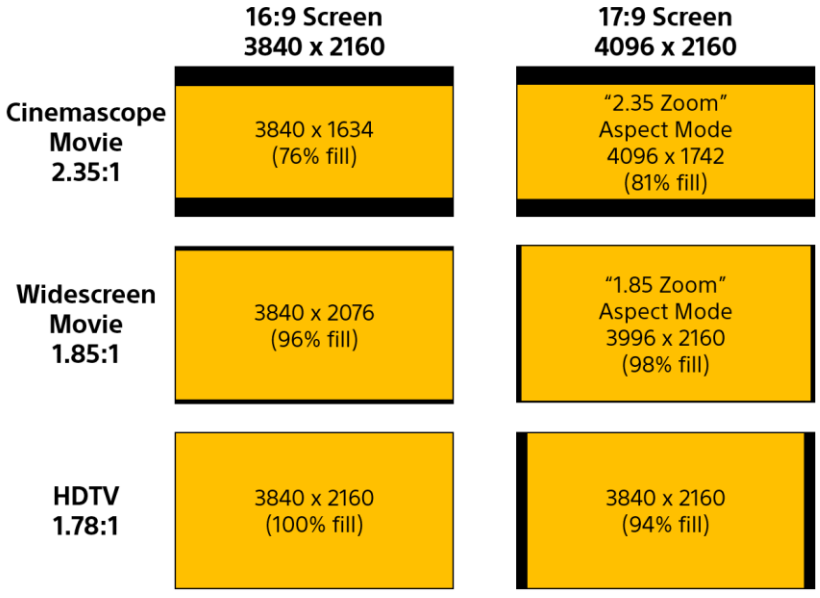
Sony's 4K home cinema projectors support both resolutions, with native 4096 x 2160 chips.

4K is supported by internationally accepted standards documents, including the International Telecommunication Union's ITU-R BT.2020 recommendation and the corresponding Society of Motion Picture and Television Engineers standard SMPTE ST 2036-1. In the movie theater, 4K is enshrined in the Digital Cinema Initiatives (DCI) specification. 4K Ultra HD is also supported by the Consumer Technology Association, the Blu-Ray Disc Association, the UHD Alliance, High-Definition Multimedia Interface (HDMI) Founders and the ATSC 3.0 TV transmission standard.

Superior presentation of movies

Mirroring the Digital Cinema Initiatives 17:9 container, these projectors are optimized for movie presentation. To take maximum advantage of the 17:9 screen, the projectors include "Reality Creation" 4K upscaling and two special aspect ratio accommodation modes. For panoramic movies with the ultra-widescreen Cinemascope® aspect ratio, Sony provides a "2.35 Zoom." This enables the movie to fill more of the screen. The black letterbox bars at top and bottom are smaller.

For the 1.85:1 widescreen aspect ratio that is the default for modern movies, the "1.85 Zoom" setting nearly fills the screen, with very narrow pillar-box bars on the left and right. Conventional HDTV programming also comes close to filling the screen.



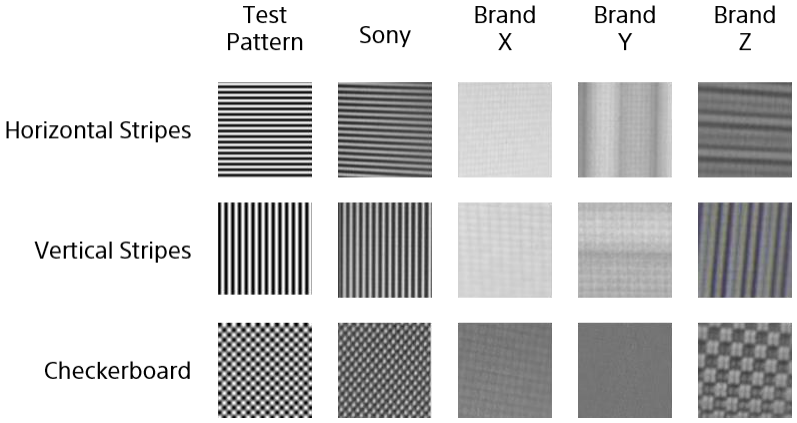
Sony maximizes the use of the 17:9 cinema screen with a choice of Aspect Mode settings and "Reality Creation" 4K upscaling.

Sony and 4K

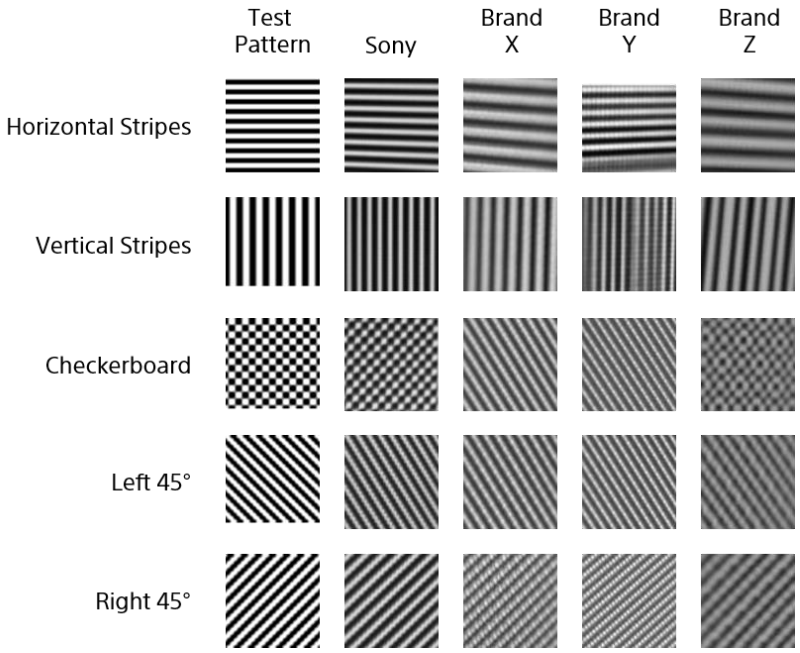
From broadcast and motion picture cameras to monitors, instant replay servers, broadcast switchers and projectors, Sony is a leader in professional 4K. Over 21,000 digital cinema screens use 4K SXRD projectors from Sony. We have more digital cinema installations in the US than any other brand. We're also a force in consumer 4K with camcorders, 4K-capable still cameras, televisions, home cinema projectors, the PLAYSTATION® 4 Pro entertainment console, Sony's UBP-X1000ES, X800 and X700 Ultra HD Blu-ray players and the FMP-X10 home media player, with access to over 200 titles in 4K.

True 4K, not "faux K"

Enabled, as we have seen, by Sony's proprietary SXRD technology, these projectors incorporate three microdisplays, each with native 4096 x 2160. This means you get a true 4K picture with full image integrity. There's no pixel shifting, no interlacing, no so-called "enhancement." The same cannot be said for some home cinema projectors that may have 4K inputs but must somehow downconvert the signal because they don't have native 4K microdisplays. Dubbed "faux K" by some observers, these projectors may claim "4K-ness." But look carefully, as we did, and you'll see that some of these solutions fall short.



We input test images of alternating white and black stripes one pixel wide, plus a one-pixel checkerboard to one of our 4K home cinema projectors and three competitors. These are all projectors from major global brands that can input 4K and thereby make some claim of "4K-ness." Then we took high-resolution still images of the projected results. It's no surprise that the Sony projector reproduces the test patterns faithfully, a feat the other projectors can't match.



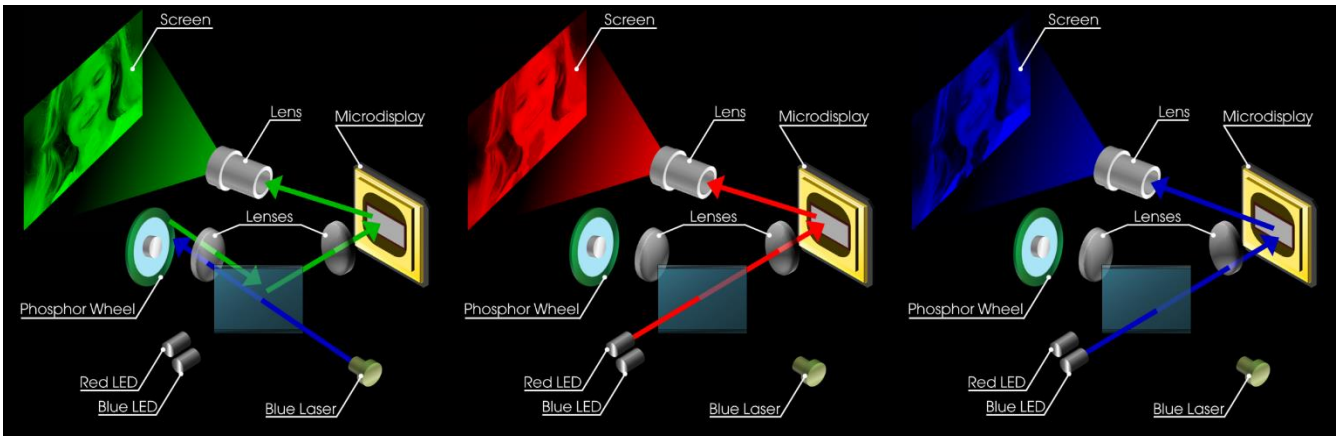
We then repeated the tests with the same projectors and test signals that are two pixels wide, and checkerboard squares that are 2x2 pixels, adding diagonal stripe test patterns for good measure. Even here, on these much less demanding tests, the other projectors had issues.

Some brands are now marketing projectors designated as “4K” at surprisingly low prices. However, under the hood, many of these projectors are pixel shifting with a single microdisplay having native resolution of just 2716 x 1528. Obviously, these projectors can only present half the pixels at any given instant. In addition, these projectors are limited by one-chip colour reproduction. As we will see in the next section, one-chip systems can only generate one colour at a time. So these projectors cannot display all the pixels – or all the colours – all the time.

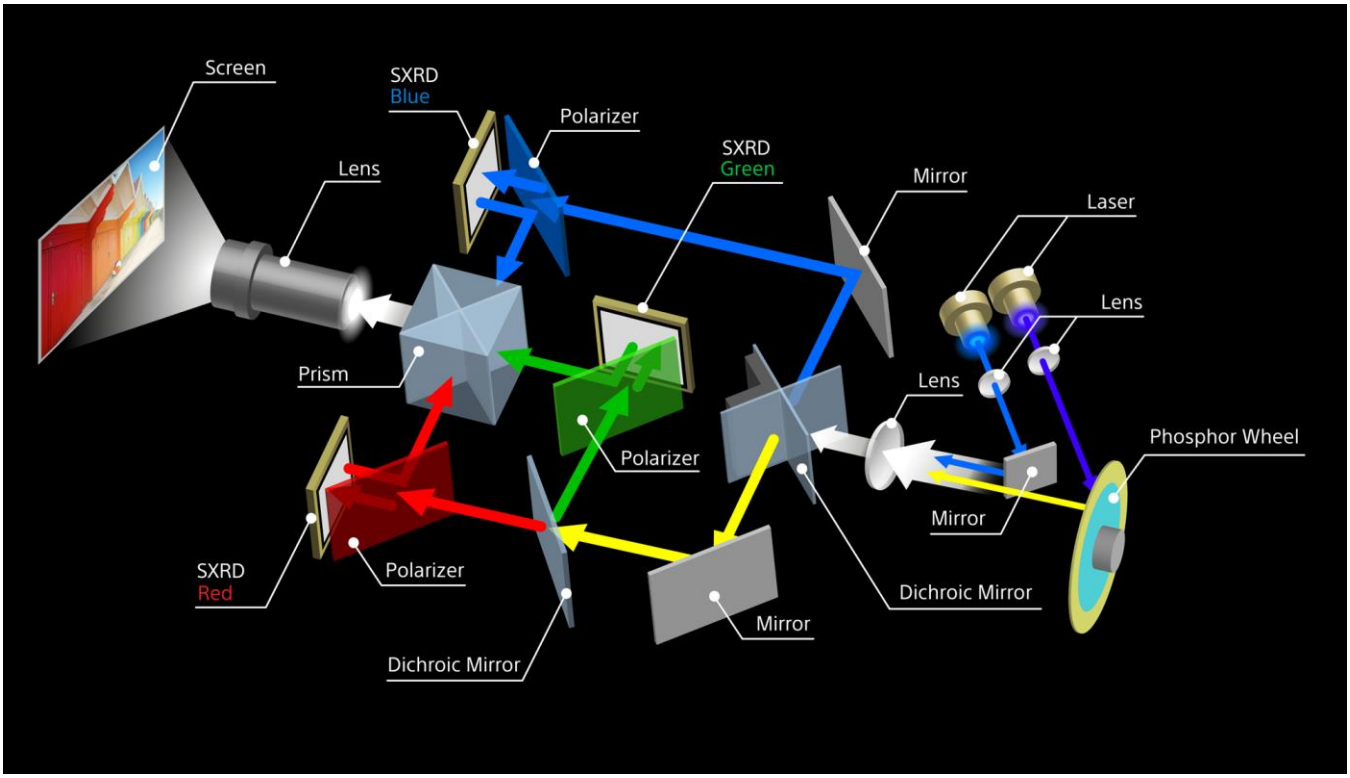
The simple fact remains: to project a true 4K image, you need a true 4K projector. While projectors with “shift” and “enhancement” technologies may provide 4K inputs, they are simply not capable of persistent 4K presentation. And if you’re asking how Sony can offer true 4K where prominent competing brands do not, the answer is our proprietary 4K SXRD microdisplay. Only Sony manufactures these chips.

Key technology #3:
The 100% stability of 3-chip colour (all models)

Entry-level 4K projectors from other brands use a single chip to produce all the on-screen colours. The chip itself can only modulate light intensity. It is essentially monochromatic. The projector creates colours one at a time via external control of light. Traditional lamp projectors use a rotating colour wheel with three or more segments that filter the light to create Red, Green and Blue. These sync with the projection chip's Red, Green and Blue sub-frames. Laser and LED/laser hybrid projectors use different methods of generating Red, Green and Blue. No matter what the approach, only one colour reaches the screen at a time. Unlike real life, the projector relies on the human visual system to blend all the colours together. The colour is unstable across time, always cycling between Red, Green and Blue.



Single-chip 4K projectors can only display one colour at a time, typically Red, Green or Blue. Approaches vary. This illustration shows a representative LED/laser hybrid light engine.

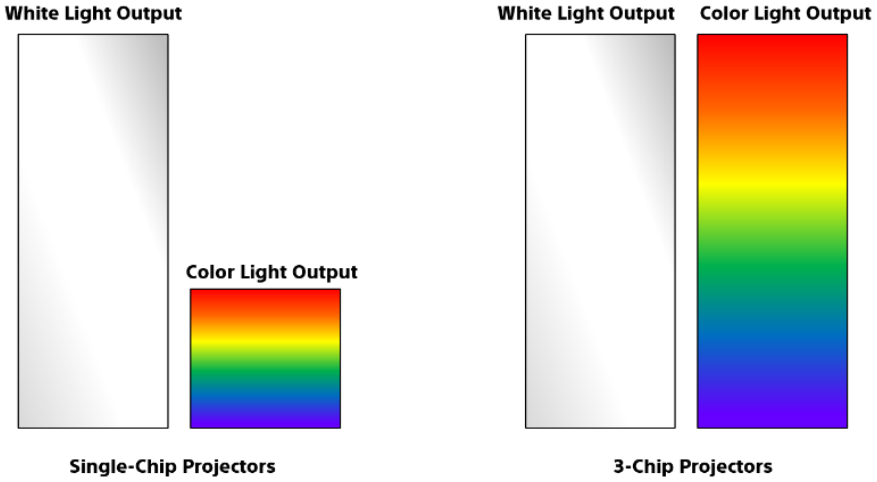


Conceptual view of the 3 SXRD projection system, shown with the Z-Phosphor laser light source of the VPL-VW5000ES. All of Sony's 4K projectors display all the colours, all the time.

In dramatic contrast, nearly every projector used in digital cinema, professional postproduction and ultra-high end home cinema uses three separate chips for Red, Green and Blue. Like all of Sony's home cinema projectors, our 4K models are three-chip designs. So you see all the colours, all the time. Each pixel on the screen always shows the correct colour.

The three-chip system has powerful advantages.

- **Colour accuracy.** Projecting all the colours, all the time, 3-chip projectors achieve high colour accuracy.
- **100% colour stability.** Depending on viewing conditions and individual viewer sensitivity, single-chip projectors can reveal "colour breaking" and "rainbow" artifacts. These tend to be especially notable on scenes with high contrast and high motion. Because 3-chip projectors display all the colours all the time, they are immune to these artifacts. You get a more continuous, more organic display of colour, much closer to life itself.



Single-chip projection colour light output is just a fraction of the white light output claimed in brochures and ads. In Sony's 3-chip system, the two measures are identical.

- **Colour Brightness.** Projector light output is conventionally measured on an all-white screen – not exactly an accurate representation of home cinema viewing conditions. A more realistic (and more demanding) test is colour light output, as standardized by the Society for Information Display (SID) in 2012. Unfortunately, the colour light output of single-chip projectors is just a fraction of the white light output claimed in typical brochures. For every one of our 3-chip home cinema projectors, specified colour light output is exactly equal to the specified white light output. As we will see, High Colour Brightness is crucial for our next Key Technology: High Dynamic Range.

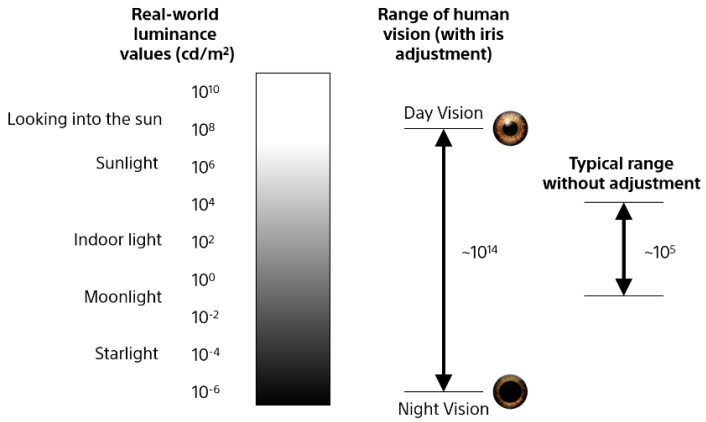
Key technology #4:
High Dynamic Range – HDR (all models)

If 4K is about *more* pixels, then HDR is about *better* pixels. In audio, "dynamic range" defines a system's breadth of reproduction from the softest possible sounds (limited by the noise floor) to the loudest (limited by the distortion ceiling). In video, it's the breadth of reproduction from the darkest possible black to the brightest possible highlight.

Compared to conventional, Standard Dynamic Range (SDR), HDR delivers home entertainment with unprecedented immersion and impact. Just as anyone who has experienced high definition is spoiled for standard definition, once you've seen a proper demonstration of HDR, you'll never want to look back.

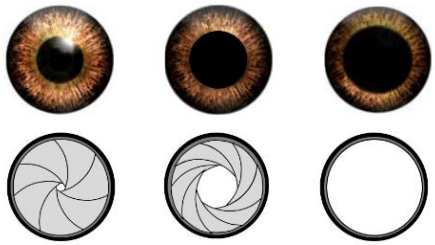
SDR falls short of human vision

The human visual system is incredibly versatile. We can perceive light values from 10^{-6} candelas per square meter (cd/m^2) for starlight all the way to 10^8 cd/m^2 for direct sun. That's a ratio of 100,000,000,000,000:1. This is essentially our "dynamic contrast ratio." However, "simultaneous contrast ratio" is another matter.



To accommodate the range from starlight to sunlight, the irises in our eyes need to adjust. At any given instant, the human visual system can "only" accommodate a luminance range of 10^5, Think of this as a "simultaneous contrast ratio" of 100,000:1.

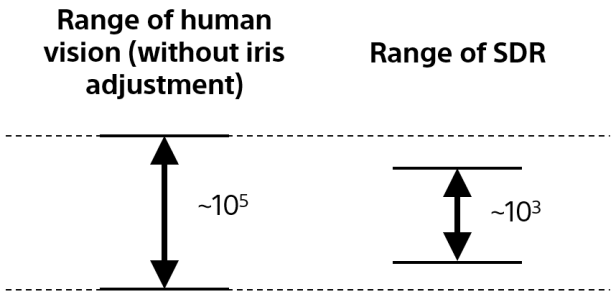
To accommodate such a broad range of light levels, the irises in your eyes need to adjust, a process that takes some time. Like the human eye, television and cinema cameras also have adjustable irises that operators use to accommodate the difference from daytime to nighttime light levels.



Like the iris in the human eye, the mechanical iris in the camera's lens adjusts to accommodate the huge variations in light levels from day to night.

Within a single scene, the human visual system's dynamic range is far more limited, on the order of 100,000:1. Even this narrower range is beyond the reach of conventional television technology. Early

television cameras couldn't capture 100,000:1. CRT televisions couldn't display 100,000:1. They were limited to a maximum brightness of just 100 nits (100 cd/m^2). Analog TV broadcasting, 8-bit digital recording and 8-bit HDTV broadcasting can't preserve all the nuances of a 100,000:1 image. For all these reasons, conventional, SDR reproduction has been stuck with a dynamic range closer to 1,000:1.

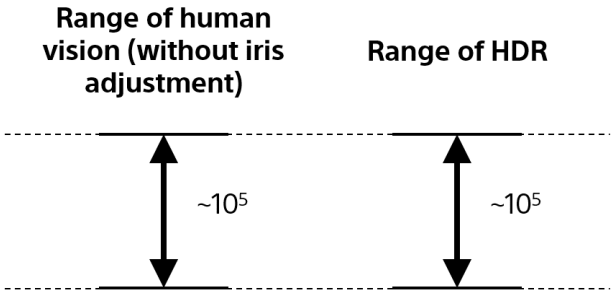


SDR television systems can't match the dynamic range of the human visual system.

The HDR opportunity

Since the 1950s, a suite of technical advances has made the limitations of SDR increasingly obsolete. For the first time, it is now practical to create an end-to-end television system that comes close to reproducing the human visual system's 100,000:1 capabilities. This is High Dynamic Range.

The current generation of digital motion picture and TV broadcast cameras can capture HDR. The current generation of professional digital recorders feature 10 bits or more of precision, capable of recording HDR. The very latest professional monitors, such as Sony's BVM-X300, enable directors and cinematographers to evaluate HDR images on-set during the shoot and also during critical postproduction processes such as colour grading. New display technologies can deliver HDR to movie theaters, home cinemas and televisions. For the first time, HDR can convey this entire 100,000:1 range all the way from the camera set through to the viewer.

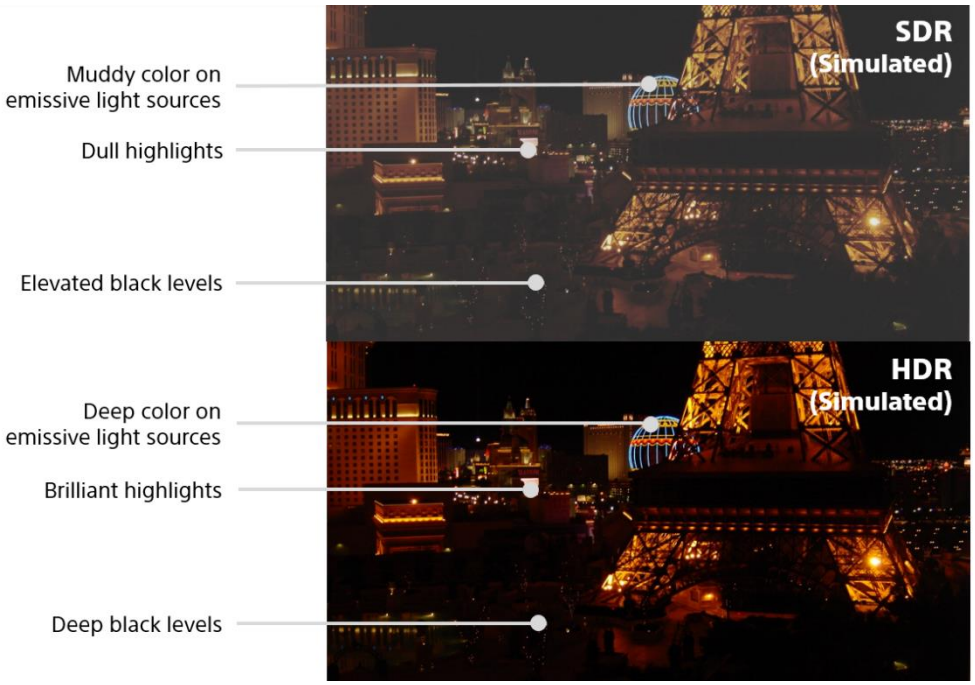


HDR preserves the 100,000:1 range of human vision.

HDR benefits

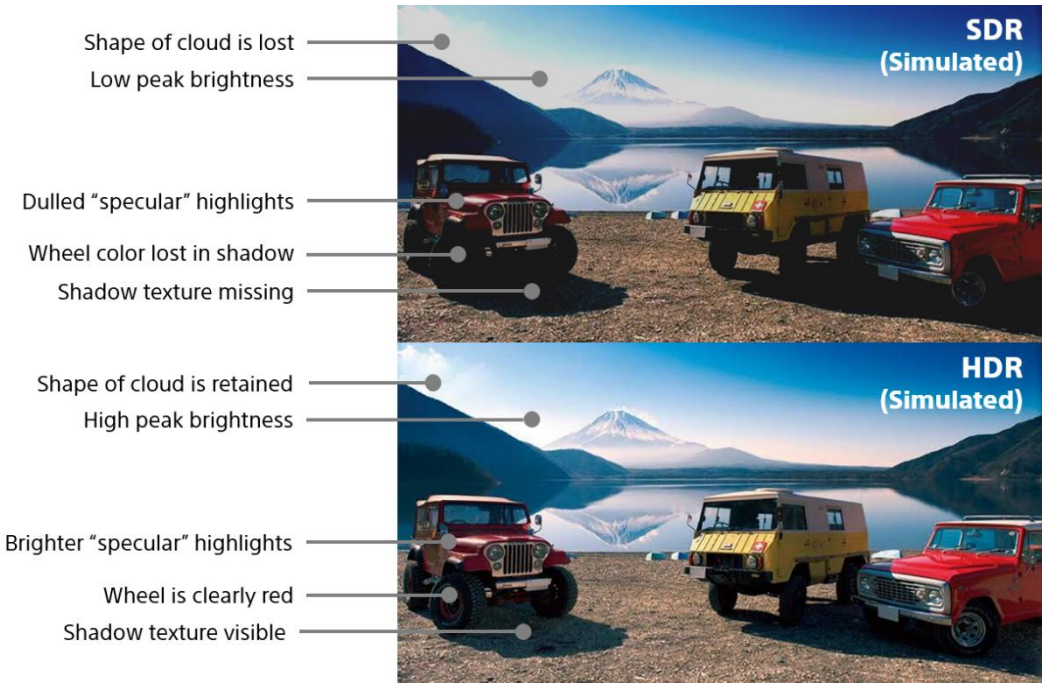
HDR can improve every type of content, from cinematic drama to TV sports.

- **Greater impact.** Compared to HDR, SDR is a pale imitation of life. We've seen that SDR falls far short of the contrast you experience in real life, while HDR can achieve that contrast. Images become more vibrant, more compelling and more involving. The advantage is most obvious in scenes with dynamic extremes: fireworks, pyrotechnics, sunsets or city skylines lit up against a deep black night sky. You see blacker blacks, higher peak brightness and better tonal gradations in between.

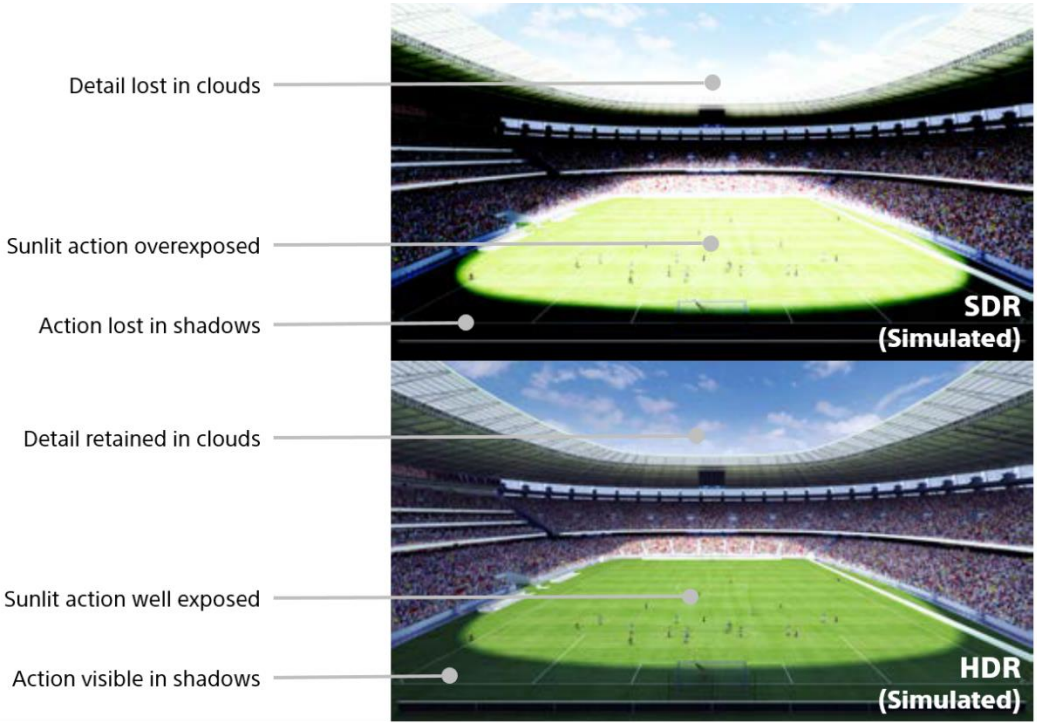


Nighttime cityscapes are a classic demonstration of HDR. A proper presentation of this effect would require HDR authoring and HDR viewing, conditions that do not apply here. The best we can provide are simulated images that only approximate the true comparison.

- **More information.** With SDR, detail is in constant danger of being lost in the darkest and brightest areas of a scene. Professionals call these losses “crushed blacks” and “clipped highlights.” The limitations of SDR force content creators to constantly squash scene dynamic range to fit into the constraints of the narrow SDR distribution pipeline. In scripted productions such as movies and episodic TV shows, the process of colour grading often squashes the range to ensure that the SDR distribution master retains important storytelling details in highlights and shadows. But live productions, such as TV sports, don’t have that luxury. When the action moves from stadium shadows into bright sunlight, the picture momentarily becomes overexposed. That’s because an SDR camera properly exposed for shadows, can’t cope with bright sunlight. We can’t follow the action until a broadcast technician adjusts the camera’s iris. With HDR, no adjustment is necessary. HDR can deliver the entire event from shadows to highlights seamlessly.

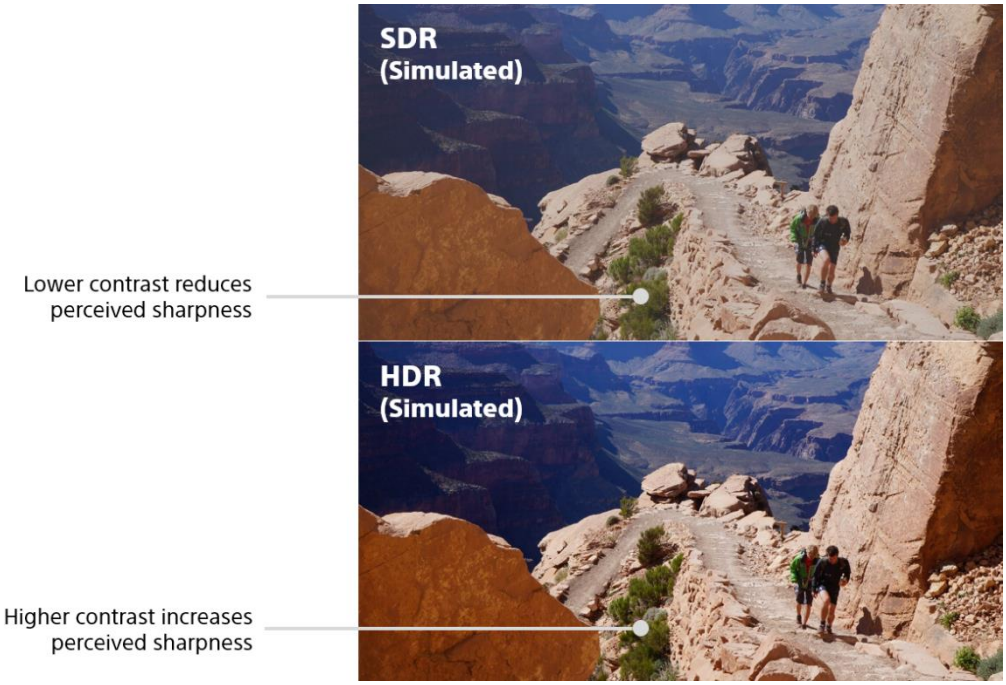


This pair of simulated images illustrates how SDR clips highlight details and crushes black details that HDR retains.



In these simulated images of live sports, the SDR broadcast can't accommodate the dynamic range from in bright sunlight to stadium shadow. The HDR broadcast can.

- **Greater sharpness.** Distinct from resolution, “sharpness” describes the subjective impression that an image creates. Achieving high sharpness requires both high resolution and high contrast. Because HDR enables a significant boost to reproduced contrast, picture details will “pop” as never before. Images will be crisper and more lifelike.



In these simulated images, the resolution is identical. Only the difference in contrast accounts for the higher perceived sharpness.

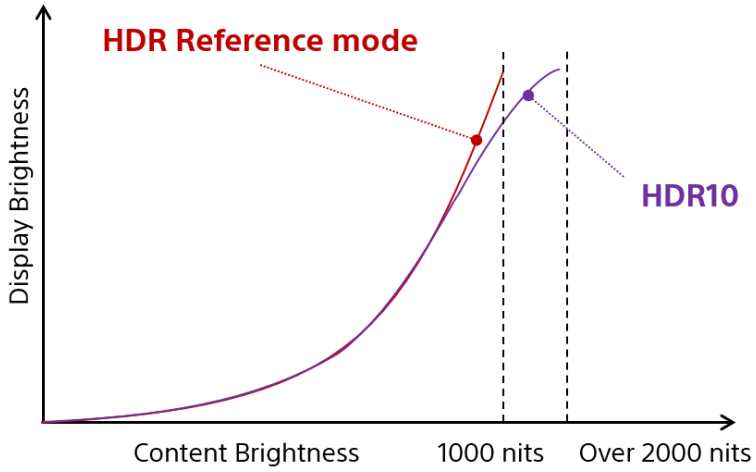
Sony built these projectors to take advantage of all these benefits. If you supply proper HDR source material and operate the projector in a proper environment, the image is staggering. The projectors support HDR10 and Hybrid Log-Gamma.

- **HDR10** combines Perceptual Quantization, 10-bit encoding and wide colour gamut. HDR10 is broadly supported by monitor and TV manufacturers as well as game consoles and set-top boxes.
- **Hybrid Log-Gamma (HLG)** was created by the national broadcasters of the United Kingdom (BBC) and Japan (NHK). Recognized as useful for live broadcasting, HLG offers 10 bits of precision. The system gets its name from a transfer function that combines the conventional gamma curve for the dark scene values with a log curve for the highlights.

The projectors also incorporate several operating refinements that make it easy to get the most out of the HDR experience.

- **HDR Auto Mode** automatically detects the digital flag that identifies HDR content (as well as the companion BT.2020 colour gamut). So you automatically get the correct settings, whether you’re watching SDR or HDR.
- **HDR Contrast** adjusts contrast level for HDR independently from your SDR setting. You get satisfying on-screen brightness and contrast for all your content.
- **On-Screen Display.** To confirm what you’re watching, we’ve also added HDR format indication to the Signal Type field in the Information page of the On-Screen Display.
- **HDR Reference Mode.** To get added colour fidelity in the brightest areas of HDR10 reproduction, Sony created HDR Reference Mode. It’s based on our experience with the Emmy® Award winning BVM-X300 monitor, the tool Hollywood professionals use for critical evaluation of HDR content. The conventional HDR10 transfer curve tends to mute colour

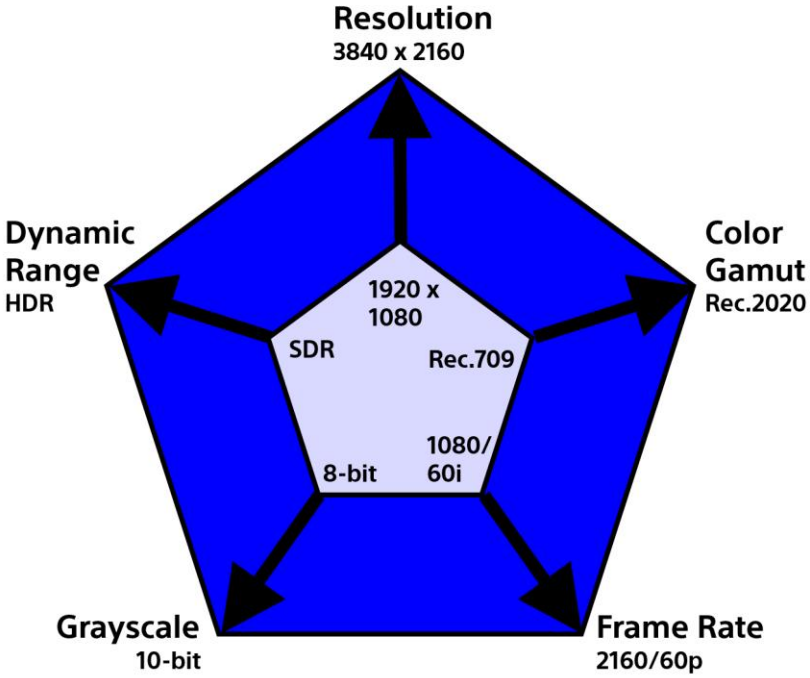
expression in the very brightest areas of the picture, those approaching 1,000 nits of brightness. These are typically small areas of the screen depicting such objects as fireworks, car headlights at night or sunlight reflecting off glass and metal. Sony's HDR Reference Mode optimizes brightness at these levels, with satisfying colour saturation. HDR Reference Mode is included on the VPL-VW870ES, VW760ES, VW570ES and VW270ES and is expected to be added to the VPL-VW5000ES via future firmware update.



HDR Reference Mode optimizes colour expression in the very brightest areas of HDR10 scenes.

Picture quality enhancements associated with HDR

Accompanying HDR is a substantial portfolio of image enhancements. In addition to 4K Ultra HD resolution, options available to cinema and television producers include Wide Colour Gamut, improved grayscale rendition and High Frame Rate.



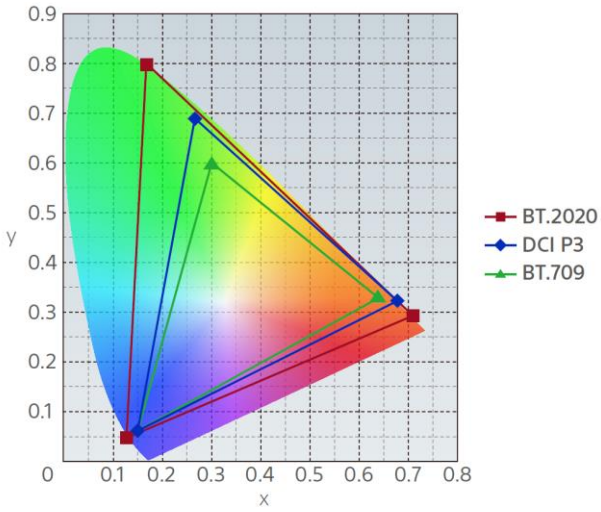
HDR is not about any single specification. It marks a simultaneous improvement in five key aspects of picture quality.

These quality improvements work in concert, particularly 4K Ultra HD resolution and HDR. So you're not just getting more colour gradations, you're also getting more pixels on which to apply them. HDR and 4K work synergistically to deliver more organic images – a picture more like life itself.

Wide Colour Gamut with BT.2020 emulation

Constrained by CRT television phosphors and tube-equipped television cameras, SDTV had a limited range or "gamut" of possible colours. This means that subjects with the deepest, most saturated green, yellow, orange, red and violet appear muted or muddied. This can degrade the reproduction of both natural colours (flowers) and artificial colours (neon lights) as well as other emissive sources (volcanoes, sunsets). The CIE chromaticity chart is a two dimensional plot that shows every visible hue. In RGB reproduction systems, the gamut forms a triangle defined by the Red, Green and Blue primaries at each corner. Surprisingly, the digital SDTV colour system occupied a CIE chromaticity triangle that covers only about 36% of visible hues. The International Telecommunication Union standardized this colour space as ITU-R BT.601 (called BT.601 or Rec. 601 for short).

Because CRTs were still the dominant display technology during the development of HDTV, the HD colour range was no larger. The HD colour gamut defined by ITU-R BT.709 (Rec. 709) was no more extensive than the SDTV gamut.

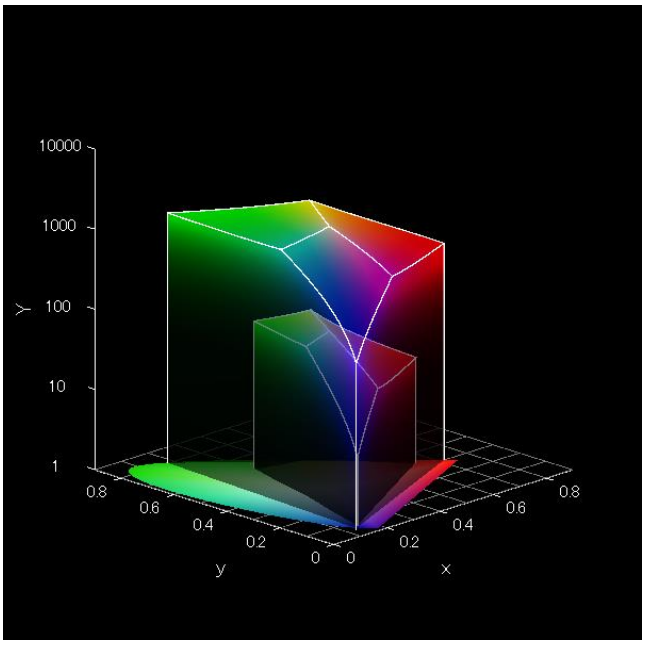


The HDTV colour gamut, ITU-R BT.709 (inner triangle) covers only about 36% of visible colours. The Digital Cinema Initiatives P3 gamut (middle triangle) is larger. Ultra HD ITU-R BT.2020 colour dwarfs them both, covering about 76% of visible colours.

The development of plasma and OLED flat panel displays plus the availability of LCD displays with a range of backlight technologies have opened up a new world of colour reproduction. On the digital projection side, new light sources and filters have also enabled superior colour. It was to overcome previous limitations and to anticipate future improvements in display technology that the ITU specified a far greater range of colour for 4K Ultra HD. The Rec. 2020 standard more than doubles the range of reproducible colours. Compared to SDTV (Rec. 601) and HDTV (Rec. 709), both of which deliver 36% of visible colours, the Rec. 2020 gamut covers 76% of visible colours.

Connect a compatible source and you'll see flowers, foliage and other natural colours with newfound realism. You'll notice the difference in the most saturated greens, yellows, oranges and reds. Emissive light sources – particularly fire, lava and neon lights – display with unprecedented realism.

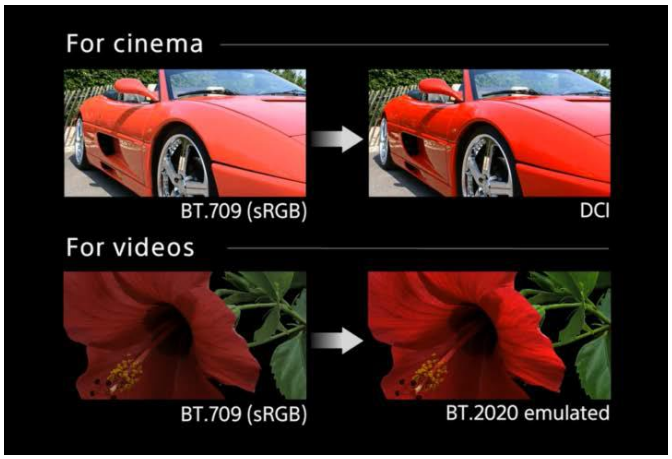
And the CIE chromaticity chart only tells part of the story. It says nothing about reproducing colours across the range from dark to light. To do that, we need to add another dimension, going from colour "area" to colour "volume." In terms of colour volume, the difference between HDTV and 4K Ultra HD is staggering.



Because HDR combines wider colour gamut with higher peak brightness, you not only get a wider colour area. You also get greater colour volume with the vertical axis representing peak brightness in nits (cd/m^2). This chart compares 100 nit Rec. 709 and 1,000 nit Rec. 2020 direct view displays, but the concept also applies to Sony's 4K projectors.

TRILUMINOS DISPLAY

Thanks to Sony's TRILUMINOS® Display colour system, Sony's colour gamut extends beyond BT.709. For example, the VPL-VZ1000ES achieve 125% of the BT.709 colour gamut. The VPL-VW870ES, VW760ES, VW570ES and VW270ES go slightly further, to 127%. The VPL-VW5000ES does more. An Auto Colour filter engages to increase the projected gamut to 137% of BT.709. In this way, the projector covers full extent – 100% – of the Digital Cinema Initiatives P3 colour gamut and the majority of the BT.2020 colour gamut.



Sony's 4K projectors optimize colour with BT.2020 Emulation while the VPL-VW5000ES adds native DCI P3 presentation. (Images simulated.)

To take full advantage, the projectors include BT.2020 Emulation for 4K UHD, delivering deeper, more saturated colour optimized for whatever you're watching. In addition, the VPL-VW5000ES offers native reproduction of the Digital Cinema P3 colour space.

Improved grayscale rendition

In theory, we could imagine an HDR video system with one-bit encoding. A digital 1 could represent white, while a digital 0 could represent black. In practice, we need our video pictures to represent grayscale values between peak white and black. And that requires more bits. Conventional HD recording systems, HDTV broadcasting and conventional Blu-ray Disc all represent images with 8-bit digital samples.

While careful observers will sometimes see issues, under most circumstances these 8-bit samples are sufficient to represent SDR images. But when you try to squeeze HDR images into an 8-bit pipeline and then stretch HDR back out on the screen, problems tend to appear. Tonal gradations that should appear smooth and continuous become visibly stair-stepped. The problem, called "banding" or "posterization," is bad enough on still images. On moving pictures, it can be extremely distracting. So along with High Dynamic Range, 4K Ultra HD can also deliver higher bit depth, such as 12-bit image capture and distribution. Because major HDR distribution channels are opting for 10-bit, our discussion will focus on that.

In these simulated images, insufficient grayscale rendition (left) causes horizontal banding in the sky. This artifact is absent in the image on the right.

In digital pulse code modulation, each additional bit of accuracy doubles the number of available quantization levels or "codelevels" available in the three channels: black-and-white luminance (Y), blue colour difference (C_b) and red colour difference (C_r). While 8-bit video has about 250 codelevels per channel, 10-bit video increases that to about 1000 codelevels.

HDR not only increases the number of codelevels, but can also improve their efficiency. SDR video is tied to gamma encoding, a system created to compensate for the characteristics of 1950s era cathode ray tube televisions. HDR can replace gamma with approaches better matched to the needs of the human visual system. These include Perceptual Quantization (PQ) and Hybrid Log-Gamma (HLG).

The combination of HDR, wide colour gamut and 10-bit quantization enables far more accurate rendition of grayscale. If you're not a professional photographer, it may be hard to appreciate how important this is. When photographers and cinematographers light a scene, they're looking for much more than adequate exposure; they're "painting with light." Cinematographers use lighting to show the viewer where to look in the frame. Lighting also helps convey emotion, defining moments of terror, intimacy, conflict and peace.

SDR tends to oversimplify these subtle gradations, flattening faces and muting the intended emotional impact. For cinematographers, HDR provides a vastly expanded canvas on which to tell stories. For audiences, HDR provides a more immediate, more immersive, more emotionally compelling entertainment experience.

The combination of 10-bit grayscale and 4K Ultra HD resolution results in powerful synergies. Expanded grayscale offers a wider range of brightness levels while 4K provides more pixels across which to paint those levels.

Based on a section of the sky from the image on the previous page, this simulation shows how 4K resolution and HDR go hand-in-hand to create a more organic picture. HDR alone does nothing to improve resolution. 4K alone does nothing to alleviate "banding." 4K HDR clearly delivers the smoothest, most natural rendition.

Sony's 4K projectors are primed to take advantage of HDR content distribution. The HDMI 2.0 inputs accommodate a maximum data rate of 18 Gigabits per second. In HDR mode, the projector accepts signals of 3840x2160 resolution and 10-bit or 12-bit quantization at frame rates of 24p, 25p, 30p, 50p and 60p.

High Frame Rates (HFR)

For an additional measure of you-are-there realism, High Frame Rates can make a big difference. Almost all movies are shot at the relatively low rate of 24 frames per second (fps). Conventional HDTV offers a choice: maximum resolution or maximum frame rate. For maximum resolution, most US television broadcasting takes place at 1080/60i. This means you get 60 half-frames (fields) per second, but only 30 complete frames per second. While 1080/60i renders motionless backgrounds in great detail, the frame rate can add blur to moving parts of the image.

Other US broadcasters have opted for maximum frame rate, in order to render motion as smoothly as possible. By broadcasting at 720/60p, they deliver 60 complete frames per second, which can be a benefit for TV sports.

Introduced in 2015, Sony's Emmy® Award winning HDC-4300 became an instant hit with sports broadcasters by combining HFR and 4K Ultra HD together with the ability to accept standard broadcast lenses.

With 4K HFR, there's no reason to choose. Sony's 4K projectors can deliver high resolution and high frame rates at the same time, up to a maximum of 2160/60p. That's *eight times* the information of either 1080/60i or 720/60p. This is incredible resolution on both still and moving parts of the image.

This football simulates motion blur. Higher frame rates render motion with more intermediate steps. Although shutter speed is a creative choice, higher frame rates are also associated with the faster shutter speeds that minimize motion blur.

Some Hollywood directors are eager to adopt High Frame Rates in the movie theater while others remain cool to the prospect. Opinions differ at the movies, but there are other entertainment platforms where High Frame Rates are gratefully accepted: videogames and televised sports.

- **HFR videogames** represent a major leap forward in immersion and pulse-pounding excitement. Scenes are rendered with heightened detail. And even the most frenetic action appears smooth and sharp.
- **4K/60p sports** are breathtaking. You can survey the entire football field, sideline to sideline and read all the players' names. When athletes spring into action, they remain free from motion blur.

The primacy of creative intent

An engineer might imagine that the purpose of home entertainment is to recreate the original scene as accurately as possible. To this way of thinking, High Dynamic Range, better grayscale rendition, higher frame rates and wider colour gamut are all indisputable advantages, slated for use on every occasion. However, content creators don't think like engineers – and they don't all think alike. Sports producers, original content producers for over-the-top streaming companies, videogame producers and moviemakers can approach picture quality with very different priorities. As just one example, we've seen that the high frame rates that may be irresistible for TV sports are less attractive for movies, where most cinematographers continue to choose 24 fps, a standard that dates to the 1920s.

You can think of HDR, 10-bit grayscale, wide colour gamut and HFR as new tools in the creative toolkit, new keys on the piano keyboard or even new colours in the artist's palette. While some producers will leap at the opportunity to use these new tools for all they're worth, others may use just one or two. It all depends on creative intent.

The consumer entertainment ecosystem

Until recently, the entire infrastructure of motion imaging – both for the cinema and the home – had been built on the basis of Standard Dynamic Range. This means Digital Cinema, HDTV broadcasting, DVD and conventional Blu-ray Disc were all designed around SDR.

To get the best out of HDR, you need content that was captured in HDR, colour graded in HDR, distributed in HDR and displayed in HDR. The entertainment industry is moving rapidly to make the complete HDR production and distribution chain a reality. Sony 4K projectors can deliver the full benefits of HDR both in the movie theater and in the home.

- **Digital cinema.** In the movie theater, the Digital Cinema Package (DCP) that studios send into the theater can accommodate HDR. And theaters are installing Sony's HDR capable SRX-R815P 4K SXRD projectors.

- **Over-the-top streaming.** Sensing an opportunity to stake a claim on the frontiers of picture quality, streaming services have been eager to exploit the potential of HDR. Popular services including Amazon Prime, Netflix and BBC iPlayer are already producing and distributing highly promoted original series and live content in HDR.

- **Packaged media: Ultra HD Blu-ray.** Standardized in May 2015, Ultra HD Blu-ray embraces 4K resolution (3840 x 2160), the BT.2020 colour gamut, High Frame Rates and HDR with 10-bit grayscale encoding. Sony's UBP-X1000ES, X800 and X700 Ultra HD Blu-ray players bring this performance home.

- **Videogame consoles.** Both Sony's PLAYSTATION® 4 Pro and the Microsoft® Xbox® One S consoles support 4K HDR gaming. Every aspect of HDR can benefit game play. Improved sharpness, frame rates, contrast and colour gamut all add excitement to white-knuckle experiences.

Sony's PLAYSTATION 4 Pro and the Microsoft Xbox One S entertainment consoles support 4K and HDR.

- **Satellite and cable television.** BT, Sky and Virgin have all started HDR transmissions on selected content, especially sports including live golf, hockey and football.

- **Over-the-air broadcasting.** The Federal government does not require broadcasters to adopt either 4K Ultra HDTV or HDR. However, the government does permit next-generation ATSC 3.0 transmission, which can support both 4K Ultra HDTV and HDR.

Key technology #5:
Z-Phosphor laser light source (VPL-VW5000ES, VW870ES, VW760ES, VZ1000ES)

The world of video projection changed decisively at InfoComm 2013. That's when Sony introduced the world's first 3LCD laser projector, the VPL-FHZ55 industrial model. Here was a combination of brightness, resolution, convenience and virtually no maintenance that the world had never seen before. The projector won accolades from independent reviewers, glowing endorsements from delighted owners and several of the industry's top awards.

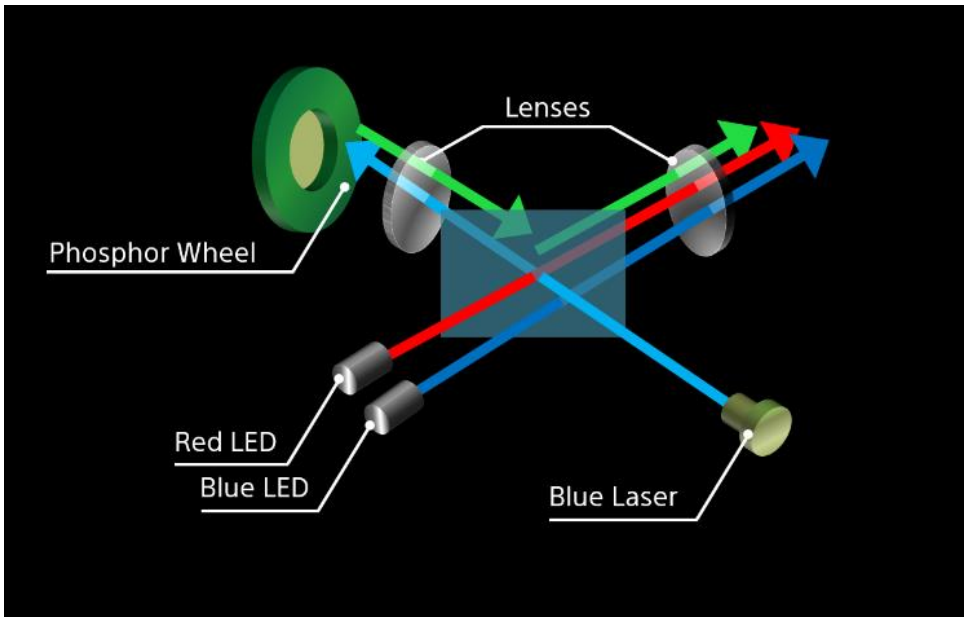
Types of lamp-free projection

Sony's Z-Phosphor™ laser light source is a breakthrough among lamp-free projection systems. In order to appreciate Sony's design in context, it helps to recognize the different classes of lamp-free projectors:

- **LED.** Generally, this is the most affordable, lowest-output type.
- **LED/laser hybrid.** A step up in performance and price, these use LEDs for some colours of light and a laser phosphor arrangement for others. As we will see, LEDs continue to impose performance limitations.
- **Laser phosphor.** A major step up, these projectors use laser light to excite a phosphor, which provides 100% of the illumination for the screen. Sony's VPL-FHZ55 Z-Phosphor projector was an early member of this group. But even compared to other laser phosphor models, Sony Z-Phosphor projectors stand apart for combining high resolution, high brightness and high colour brightness.
- **Direct laser/phosphor hybrid.** The VPL-VW5000ES projector uses a combination of direct laser light in addition to light from a phosphor excited by laser. This approach also forms the foundation of two Z-Phosphor industrial projectors: Sony's VPL-GTZ280 and GTZ270.
- **Direct laser.** For the largest venues, some projectors have begun to use a direct laser system: Red, Green and Blue lasers that illuminate the screen without intermediary phosphors. In 2005, Sony created a 60,000-lumen RGB direct laser projection system, which we exhibited at the Aichi World Exposition.

The limitations of LEDs

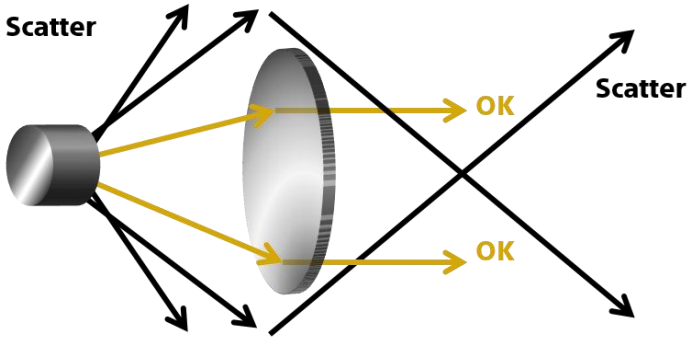
The advantages of Sony's Z-Phosphor design become clearer when we take a quick look at LED/laser hybrid technology. While individual models vary, one representative LED/laser hybrid design uses three light sources. A blue laser excites a rotating phosphor wheel to provide only the Green light. Red and Blue are provided via LEDs. While this arrangement does incorporate a laser and does eliminate the projection lamp, reliance on LEDs becomes a major limitation.



While LED/laser hybrid systems vary, this example is representative. Here the laser is responsible only for Green illumination. Red and Blue are handled by LEDs.

Compared to laser illumination, LEDs just aren't as bright. You might think it a simple matter to increase the brightness by increasing the LED driving power. However, this incurs reliability issues that may someday be resolved by further research and development. Until then, drive power remains limited.

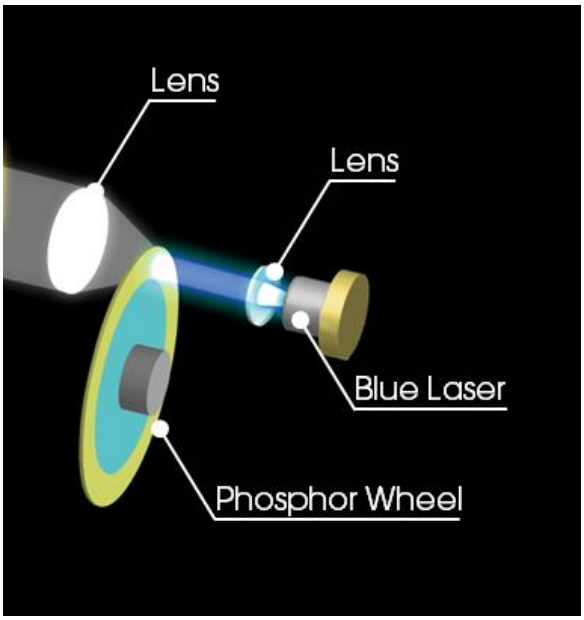
Alternately, you might try increasing brightness by using bigger LEDs or even multiple LEDs. Unfortunately, projection LEDs are already 1,000 times larger than projection lasers of equivalent brightness. The larger the light source, the more diffuse and difficult it is to channel toward the screen. Light tends to be wasted through scatter.



Sony's Z-Phosphor laser light source

Where LED/laser hybrid systems typically provide two out of three colours from LEDs, Sony's Z-Phosphor design starts with 100% laser light. And while other projectors can also make this claim, Sony stands alone, delivering a combination of end-user benefits that is unmatched.

The majority of our Z-Phosphor™ projectors start with a miniature blue laser. An aspheric lens concentrates the blue laser light and directs it toward a rotating phosphor wheel. As the phosphor glows bright white, its light is concentrated by a second lens and directed towards the SXRD® microdisplays.



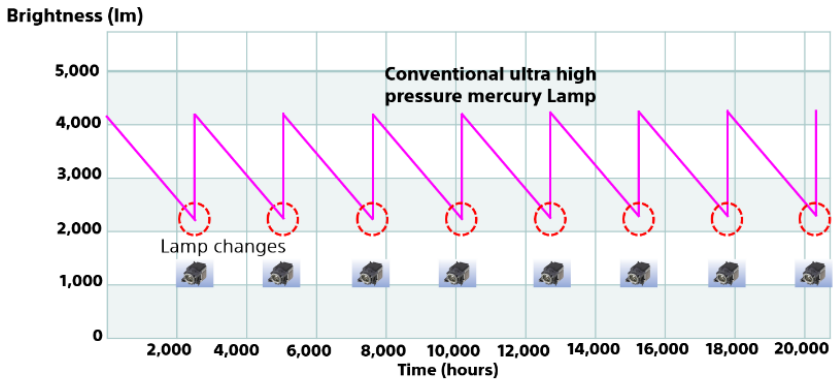
Sony's Z-Phosphor laser light source operates entirely without LEDs. Most Z-Phosphor models use a laser and phosphor wheel to generate the full spectrum of white light.

Both the laser and the phosphor embody Sony's deep understanding of these technologies. For example, Sony Semiconductor began manufacturing lasers in 1986, becoming a leading supplier for the CD, DVD and game console markets. By 2010, we had shipped over 3 billion lasers. Our mastery of blue lasers extends to Blu-ray Disc™ players, PLAYSTATION® consoles and XDCAM® professional optical disc camcorders. We drew on this experience to build multiple blue lasers into an array roughly 1/1000 the size of an LED of equivalent brightness. Our laser array is highly redundant. So the failure of any single laser has negligible effect on output brightness. Because laser light is coherent, light scattering and waste are less significant. And the miniature size of the laser array reduces light scatter further still.

The phosphor is another unique formulation, based on decades of Sony experience with phosphor coatings in television and projection CRTs. The result is a complete projection system that can simultaneously achieve superb resolution and high brightness.

Up to 20,000 hours with virtually no maintenance

The ultra-high-pressure (UHP) mercury lamp inside conventional projectors is essentially a high-tech light bulb. And like more familiar light bulbs, it burns out, typically needing replacement every 1,500 to 3,000 hours. (Some of the latest lamps need replacement every 6,000 hours.) In dramatic contrast, Sony's Z-Phosphor™ laser light source is rated at 20,000 hours of life. That's equal to 10 hours a day, 5 days a week, 50 weeks a year for *eight years*. Projection with virtually no maintenance is a major advance for simplicity, convenience and peace of mind.



Conventional projectors incur the performance degradation of fluctuating light levels and variations in lamp colour, not to mention the headache and cost of periodic lamp replacement.

Beyond maintenance headaches, conventional UHP mercury lamps yield inconsistent performance. As a UHP lamp ages, light levels tend to decline and colour balance tends to shift. Sony's Z-Phosphor laser light source is far more consistent. The colourimetry of the laser system remains stable, while brightness will decrease somewhat over the years.

Worry free

Conventional projector lamps can fail, putting your entire home cinema out of action. Sony's Z-Phosphor™ system drastically minimizes downtime. The blue laser light source is actually an array of multiple redundant lasers. This means that the failure of any individual laser is not a show-stopper.

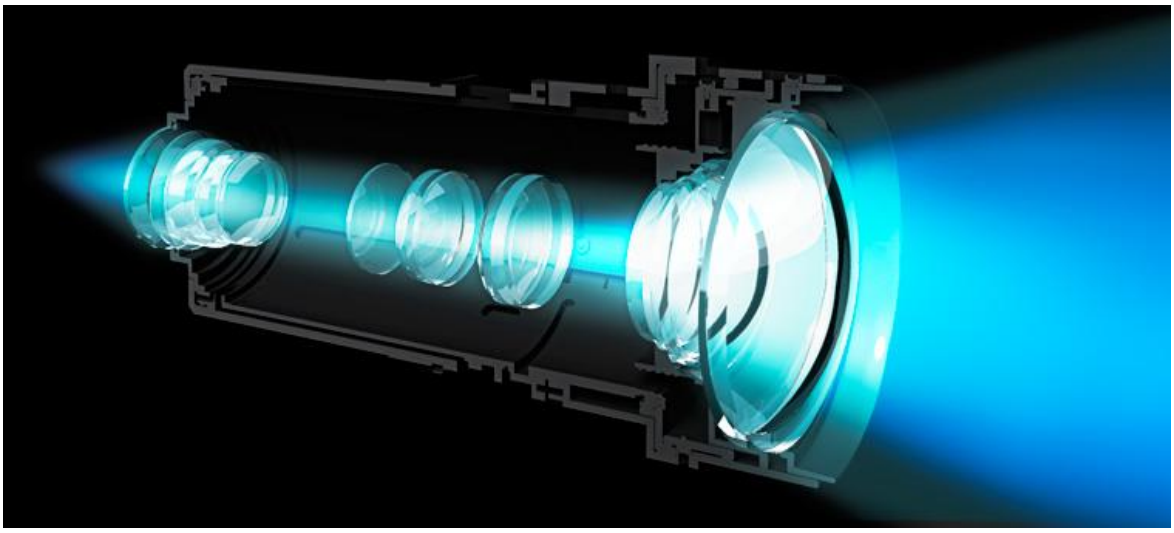
Mercury free

The projector even has better chemistry. As the name implies, the ultra-high-pressure mercury lamp contains mercury, a poison. The Sony laser system is mercury free, a better choice for the environment.

Key technology #6:
ARC-F lens (VPL-VW5000ES and VW870ES only)

As projector resolution increases, the demands on projection lenses also increase. The lens must not only resolve more pixels, but also maintain high contrast and preserve focus from corner to corner. Each one of these requirements is a challenge.

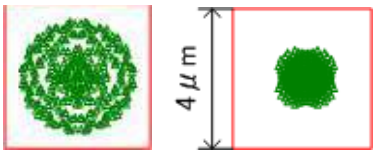
- **Resolution.** The lens must project individual pixels from the SXRD chip, pixels that measure just 4 µm. This is almost unimaginably small. As we've said, over 100,000 of these pixels could fit on the letter "E" in the word LIBERTY on a U.S. quarter dollar.
- **Contrast.** Resolution and contrast go hand in hand in creating the human perception of picture sharpness. Maintaining contrast means achieving what lens designers call high Modulation Transfer Function.
- **Focus.** In projection, the distance from the lens to the screen corner can be substantially longer than the distance from lens to screen center. Maintaining focus across the full screen surface is no easy task.



Sony's ARC-F lens is engineered for meticulous 4K image projection.

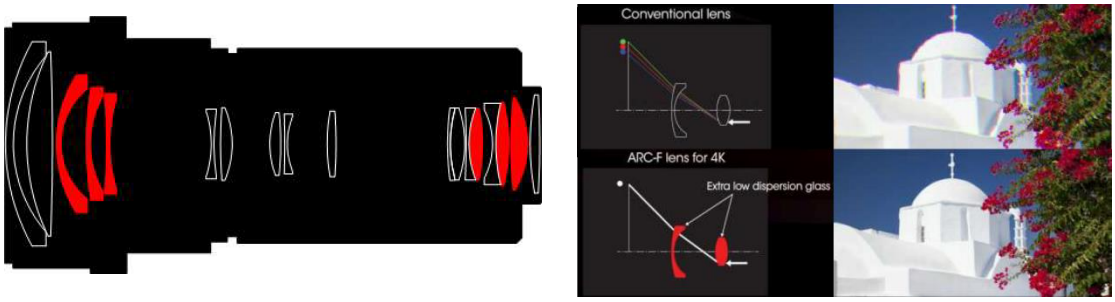
Sony's goals for the VPL-VW5000ES and VW870ES required a projection lens far above the ordinary. We drew on our experience designing large-barrel lenses and coatings for our own Digital Cinema projectors. The result is the 4K version of our All Range Crisp Focus (ARC-F) lens. It's distinguished by several powerful features:

- **Glass instead of plastic.** Not only are all the lens elements glass, but Sony's sophisticated design also specifies 18 glass elements in 15 groups. This is a large-barrel lens, with an aperture that varies by zoom setting from f/2.9 to 3.9.
- **High resolving power.** True to its mission, the ARC-F lens is fully capable of resolving the SXRD microdisplay's 4 µm pixels and conveying full resolution to the screen.



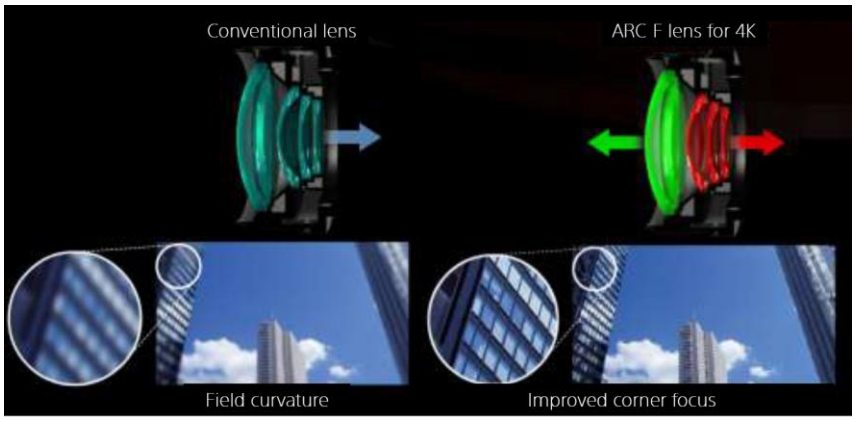
This spot diagram analysis of a Full HD lens (left) and the 4K ARC-F lens (right) demonstrates the vast improvement. The ARC-F lens conveys the full benefit of 4K to the screen.

- **Extra-low Dispersion (ED) glass.** Lens elements are prone to dispersion, a phenomenon where the different wavelengths of light (red, green and blue) project in slightly different directions. This can lead to telltale “colour fringing” on high contrast transitions in the projected picture. The ARC-F lens uses six ED elements – three positive and three negative – to control dispersion for consistent focus across the colour spectrum.



The ARC-F lens includes three positive and three negative Extra Low Dispersion (ED) glass elements. They minimize colour fringing on high-contrast scene transitions. (Simulated images.)

- **Consistent center-to-corner focus.** Conventional projection lenses focus by moving the group closest to the screen. However, this arrangement does not maintain the most consistent focus across the screen face. That’s why the ARC-F lens moves two groups simultaneously. A “floating” group at the front of the lens makes adjustments while a second group achieves focus. The arrangement is more expensive, but it makes for a far more consistent picture.



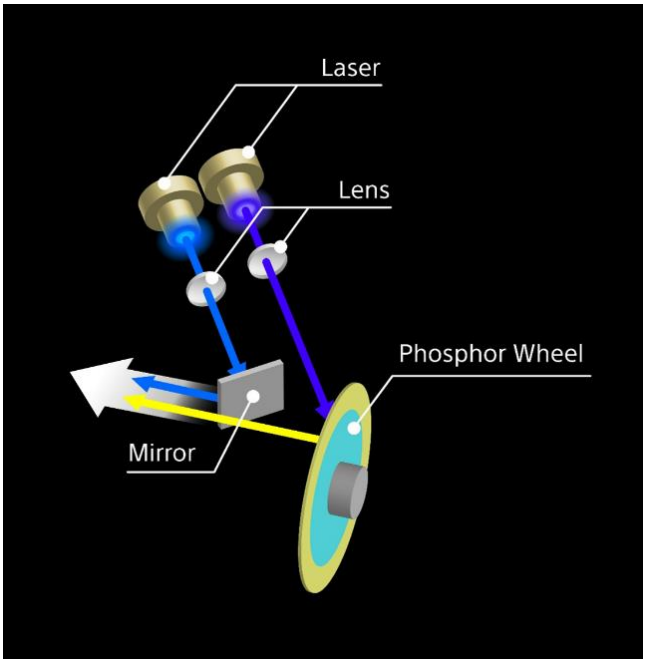
The ARC-F lens moves two element groups instead of one. The result is consistent focus from the center of the screen all the way to the corners. (Simulated images.)

Picture quality features

5,000 lumens brightness (VPL-VW5000ES only)

The ultimate presentation of HDR calls for high peak brightness levels, particularly for small areas of the screen that may show car headlights at night or sunlight reflecting off windows. (Brightness for full screen white is typically much lower.) To deliver the full benefit of HDR, Sony designed the top-of-the-line VPL-VW5000ES to combine superlative picture quality with high brightness: 5,000 lumens white light output and 5,000 lumens colour light output. The brightest of Sony's home cinema projectors, the VW5000ES elevates the presentation of HDR.

To achieve 5,000 lumens of output, the projector uses an advanced version of the Z-Phosphor™ system. Here, two lasers provide separate paths for Blue and Yellow light. The system creates Blue by reflecting blue laser light toward the screen. The system creates Yellow by reflecting light from a separate blue laser array off a phosphor wheel that glows Yellow. A dichroic mirror then divides Yellow into Red and Green.



To achieve higher output, Sony's VPL-VW5000ES and the industrial VPL-GTZ280 and GTZ270 projectors provide separate paths for Blue and Yellow light. This system projects Blue reflected from one laser, while it creates Yellow by shining a second blue laser onto the phosphor wheel.

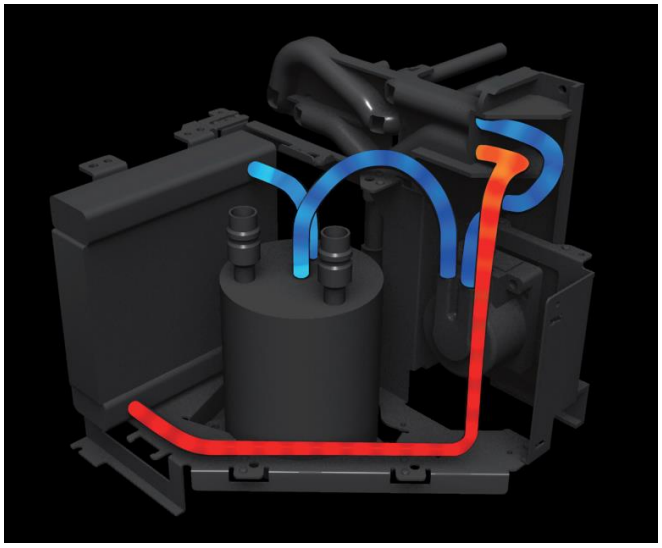
As a result, the VW5000ES far exceeds SDR-based brightness guidelines. In movie theaters, according to the Society of Motion Picture and Television Engineers SMPTE 196M standard, screen brightness should be 16 foot-Lamberts, which equals 55 cd/m^2 also called 55 "nits." In home cinemas, the rule-of-thumb for screen brightness in a darkened room has been in the same range: 12 to 22 foot-Lamberts (41 to 75 nits). With the VW5000ES, actual brightness will depend on operating conditions, screen size, screen gain and several other factors. The following chart shows gross brightness for screens of gain 1.0.

Screen Gain	Screen Width	Peak Brightness	SDR rule of thumb
1.0	10.0 feet	325 nits	41 to 75 nits
1.0	12.5 feet	208 nits	
1.0	15.0 feet	144 nits	
1.0	17.5 feet	106 nits	
1.0	20.0 feet	81 nits	

How you use this superior performance is up to you. While many owners will use the high brightness of the VW5000ES in the service of HDR, others may choose to go for larger screens or clear viewing even in ambient light.

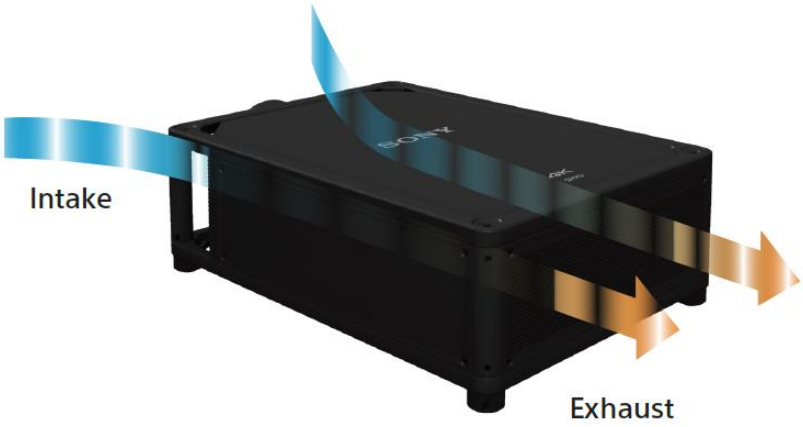
While 5,000 lumens represents high-flying performance, the design is well grounded in practicality. It's a projector you can live with.

- **Stable.** The optical system is designed to deliver thousands of hours of operating life with almost zero maintenance, thanks to Sony's Z-Phosphor™ laser light source, sealed optics and a meticulously designed chassis.
- **Cool.** Liquid cooling, high-capacity fans and one-way airflow keep the projector operating in the thermal comfort zone. And there's no need for special ductwork to handle the exhaust.



Sony's liquid cooling system is extremely efficient at conducting heat away from the optical block.

- **Quiet.** You won't need to build a special enclosure or projection room to shield your audience from fan noise. Under normal operating conditions, acoustic noise is 30 to 35 dB. (Fan noise will vary depending on the environment and other operating conditions.)



Ample ventilation cools the projector effectively – and quietly.

“Reality Creation” 4K upscaling with X1 video processor (all models)

Sony understands that most of the content you’ll be watching will still originate in High Definition – and will have been subjected to video compression. That’s why we took special care in the noise reduction and HD-to-4K upscaling processes. Simple upscalers interpolate the new pixels by taking the average of the two adjacent pixels. Upscalers that are more sophisticated look at vertical, diagonal and horizontal neighboring pixels, plus the corresponding pixel on previous and following frames. As performed by Sony’s exclusive X1 video processor, “Reality Creation” 4K upscaling does all of that, and more.

- **Content-aware noise reduction.** The system starts by cleaning up the incoming signal with intelligent, content-aware noise reduction.
- **Pattern analysis.** Three-dimensional analysis recognizes patterns in the image.
- **“Reality Creation” database matching.** The system compares actual picture patterns to a large internal database of images.
- **Minimizing compression artifacts.** Noise reduction, pattern analysis and database matching do more than simply upscale HD to 4K. They also minimize “mosquito noise” and other compression artifacts. These most often occur in web-based or over-the-top streaming services, but they can also happen in cable and satellite services. Even broadcast and packaged media are not immune. Sony understands compression in production, broadcast and consumer media authoring environments. So we know how to identify compression artifacts and how to remedy them.

The “Reality Creation” database is a vast portfolio of professionally shot images we’ve collected across more than a decade. They represent a range of subjects including people, landscapes, sea, sky, trees, clouds, flowers, sports and household objects.

Every pixel is matched with the most appropriate patterns in Sony’s vast database.

“Reality Creation” 4K upscaling compares patterns in the original image with patterns in the database, matches them up and actually replaces original HD patterns with optimized 4K patterns. With this process, which goes far beyond interpolation, the projectors can upscale HD to uniquely compelling 4K.

Digital Focus Optimizer (VPL-VW870ES only)

Even the best lenses incur some blur as you move away from the image center and as you vary the zoom setting. That’s why Sony compiled a database of optical variations specific to the ARC-F lens on the VW870ES. Our engineers sampled 25 screen regions at lens positions across the zoom range. The Digital Focus Optimizer takes note of the lens shift and zoom settings, applies electronic pre-compensation for optical variations, then outputs the optimum, corrected images. Working in concert with Sony’s ARC-F lens, the result is even higher image sharpness and improved corner-to-corner consistency.

Dynamic Laser Control (VPL-VW5000ES, VW870ES, VW760ES, VZ1000ES)

To maximize “sequential” or scene-to-scene contrast, selected models have Dynamic Laser Control. As the name implies, this varies laser light level according to the needs of each scene. So daytime scenes have appropriate impact while night scenes have deep, rich shadows.

Advanced Iris (VPL-VW870ES, VW570ES)

Another technology that improves sequential contrast is Advanced Iris. This uses a motor-activated iris in the light path to control overall light according to the needs of each scene. Sony’s sophisticated mechanism enables the iris to operate with split-second accuracy.

Dual Dynamic Contrast (VPL-VW870ES)

For the ultimate degree of sequential contrast, the VPL-VW870ES incorporates both Dynamic Laser Control (to vary the light source) and Advanced Iris (to vary the lens throughput). The result is even more vivid rendition of dark and bright scenes.

“Mastered in 4K” mode (all models)

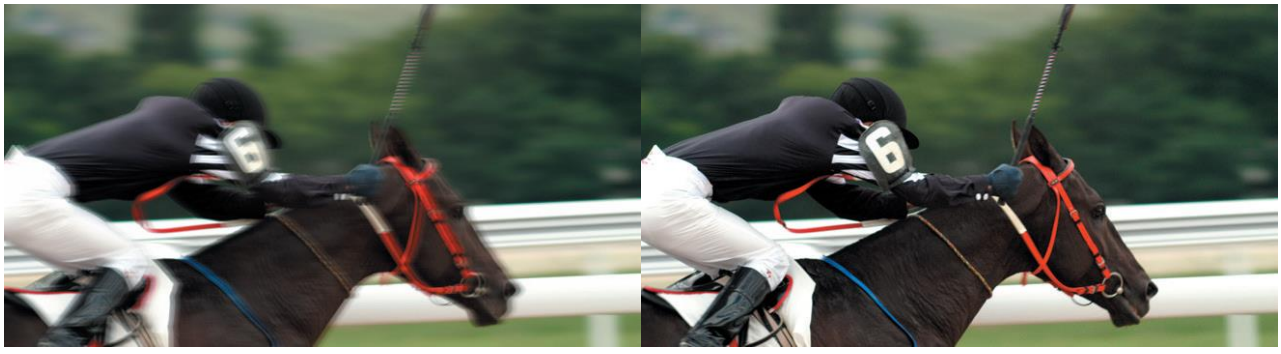
Since 2013, Sony Pictures Home Entertainment has offered a series of Blu-ray Disc™ titles with the designation “Mastered in 4K.” This mastering process preserves maximum resolution in the downconversion to HD. The discs themselves encode 24p movies with an enhanced bitrate and support the improved reproduction of the x.v.Colour™ system. There’s one additional benefit. Sony knows the precise filter used to downconvert to HD in the mastering stage. So we can apply the same filter in reverse to upconvert to 4K in the projector. The resulting image is as close as you can get to native 4K when starting from an HD source.

18 Gbps HDMI input with 4K/60p capability (all models)

The projectors accommodate a phenomenal range of input sources, input resolutions and input frame rates through HDMI 2.0b inputs. The inputs accept a maximum data rate of 18 Gigabits per second. The inputs also support HDCP 2.2 content protection. Maximum input resolution is 4096 x 2160 at frame rates of up to 60p with 4:4:4 colour sampling at up to 8 bits or 4:2:2 colour sampling up to 12 bits.

4K Motionflow® processing (all models)

These projectors incorporate a comprehensive solution to the issue of motion blur. A range of user settings gives discriminating viewers the ability to vanquish motion blur while respecting the artistic intent of movie and television directors and cinematographers.

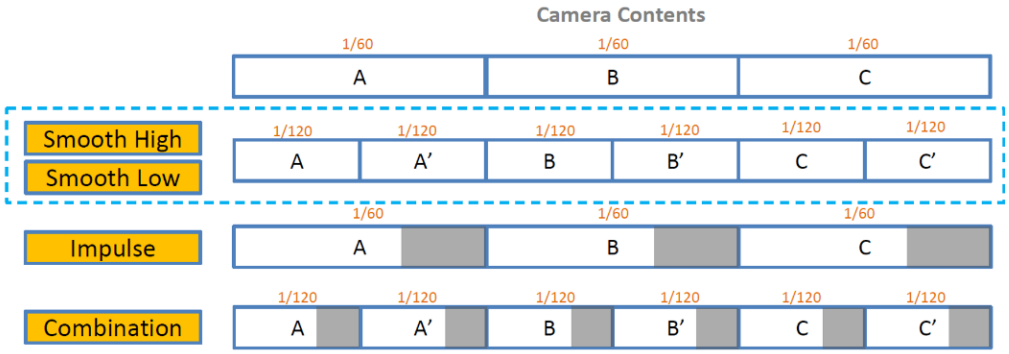


These simulated images suggest the effect of Motionflow processing, which yields substantially sharper rendition of moving subjects, ideal for TV sports.

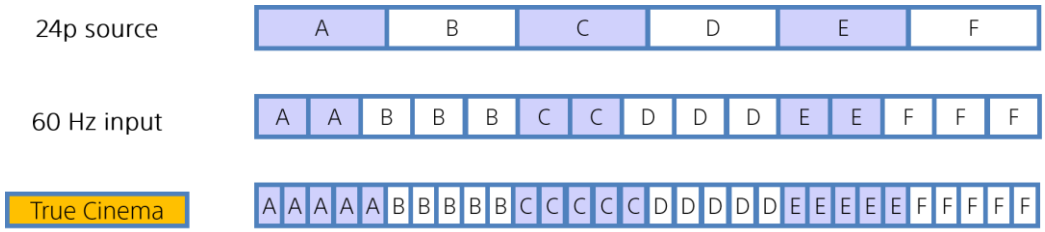
The system provides up to five settings, each optimized for a specific range of content.

- **Smooth High.** Provides smoother motion, especially effective for film-based content. Converts 60 fps images into 120 fps, inserting new frames based on mathematical interpolation.
- **Smooth Low.** Provides smoother motion for standard use. Converts 60 fps images into 120 fps, inserting new frames based on mathematical interpolation.

- **Impulse.** Reproduces original picture quality. Provides cinema-like picture, which may flicker. Inserts a black interval between frames. (Not available on the VPL-VW270ES.)
- **Combination.** Reduces motion blur while maintaining brightness for high-speed content. Converts 60 fps images into 120 fps, inserting new frames based on mathematical interpolation. Inserts a black interval between frames. (Not available on the VPL-VW270ES.)
- **True Cinema.** Reverses the 3:2 pull-down process used to put 24p content into 60 Hz distribution channels. Restores correct 24p playback.
- **Off.** Displays content at original frame rates.



Smooth High and Smooth Low modes insert new, mathematically interpolated frames (A', B', C'). The Impulse mode inserts black intervals. The Combination mode does both. (Impulse and Combination modes not available on the VPL-VW270ES.)



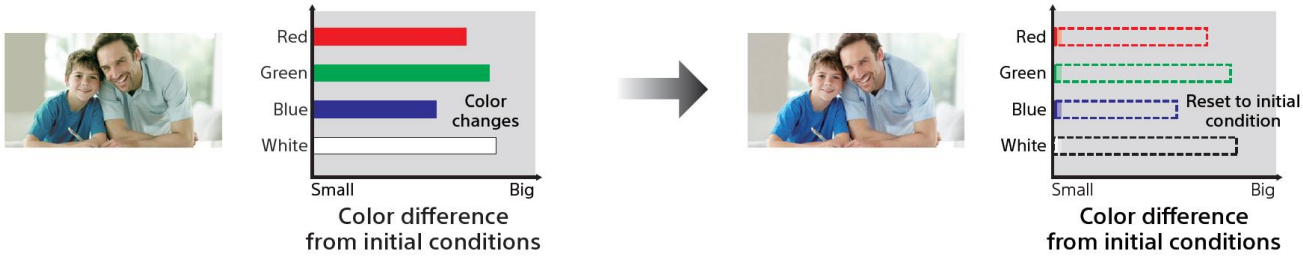
True Cinema mode reverses the 3:2 pull-down process required to convert 24p movies into 60 Hz video. So each movie frame appears for 1/24 second, as intended.

4K Low latency mode (all models)

The projectors incorporate sophisticated digital picture processing. Some of these processes take several microseconds, a delay that engineers call "latency." That's hardly an issue when you're watching movies and TV shows. But latency can be a real issue in gaming, where microseconds can make a difference. To support a first-rate gaming experience, Sony has implemented a special 4K Low Latency mode. You get our fastest ever response time between your controller and the screen, for the ultimate gaming action.

Built-in Auto Calibration (VPL-VW5000ES, VW870ES, VW760ES, VW570ES, VZ1000ES)

These projectors achieve exceptional colour stability. To compensate for even slight drift in colour reproduction over time, Sony provides Auto Calibration. This system uses a colour sensor built into the projector to automatically reset the colour to initial factory conditions. And this powerful correction does not affect the careful manual adjustments your installer makes when matching the projector to the characteristics of your screen and your room. You can activate Auto Calibration in the Advanced Picture menu.



Auto Calibration corrects for colour drift as the projector ages.

Panel alignment (all models)

The projectors include a Panel Alignment function for pinpoint spatial placement of the three colours – Red, Green and Blue. Panel Shift Alignment adjusts the whole picture across a ±3 pixel range in 0.1 pixel steps. To accommodate variations within the picture, Panel Zone Alignment adjusts any of 153 individual cross points over a ±3 pixel range, in 0.1 pixel steps.

3-year limited warranty (all models)

Rest assured that Sony has you covered. All of Sony's Elevated Standard (ES) projectors enjoy three-year limited warranties, including a special PrimeSupport hotline in case you encounter any issues.

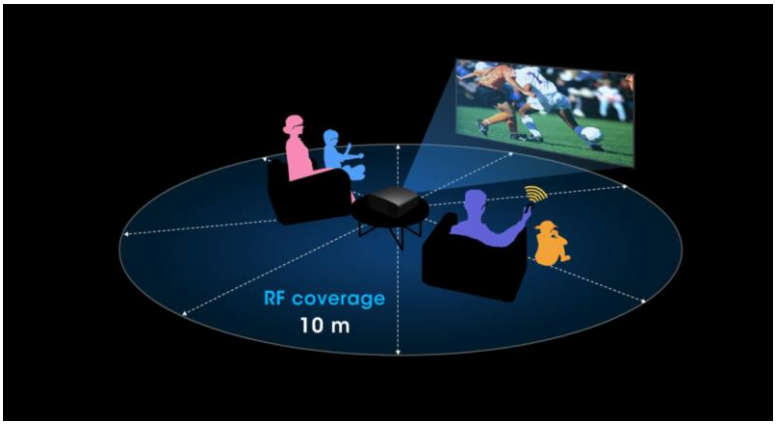
User features

Wireless remote control (all models)

The projectors include a slim, straightforward remote control with back-illuminated keys for easy operation in a darkened room.

Built-in RF 3D transmitter (all models)

The projectors support 3D projection with a built-in radio frequency (RF) transmitter for active 3D glasses. The transmitter works with glasses up to 10 meters (33 feet) in any direction. Because there's no infrared receiving eye on the glasses, there's no need to maintain line-of-sight between transmitter and glasses. And RF transmission won't get tripped up by infrared remote controls.



The system conforms to the Full HD 3D Initiatives standard for active glasses and is compatible with most glasses that conform to that specification, including Sony's TDG-BT500A glasses, sold separately.

Picture position memory (VPL-VW5000ES, VW870ES, VW760ES, VW570ES)

As aspect ratios change, these projectors can maximize the size of images on your screen via picture position memory. This memorizes the position of lens focus, zoom and shift for each aspect ratio, including 1.78:1 and 2.35:1. So you can store these settings in the projector for easy recall.

USB firmware updates (all models)

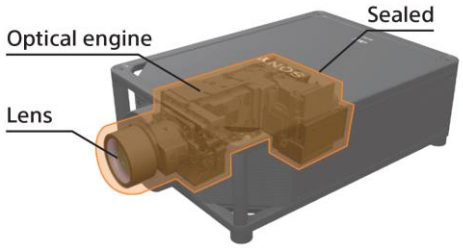
The capabilities aren't locked in when the projector ships from the factory. Firmware updates enable potential future improvements. Installers can download the updates from Sony's e-Support site, load them onto a USB memory drive and plug the drive into the projector to perform an update.

Low-noise operation (all models)

Even the brightest of these projectors, the VPL-VW5000ES runs so quietly, there's no need for special enclosures or separate projection rooms. As long as you maintain the specified clearances, you won't need special ductwork to vent the heated exhaust air away from the projector.

Dust resistant sealed optics (VPL-VW5000ES only)

In the top-of-the-line VPL-VW5000ES, all optical components from lens to light source are sealed, avoiding dust accumulation.



Installation features

Colour correction/colour space adjustment (all models)

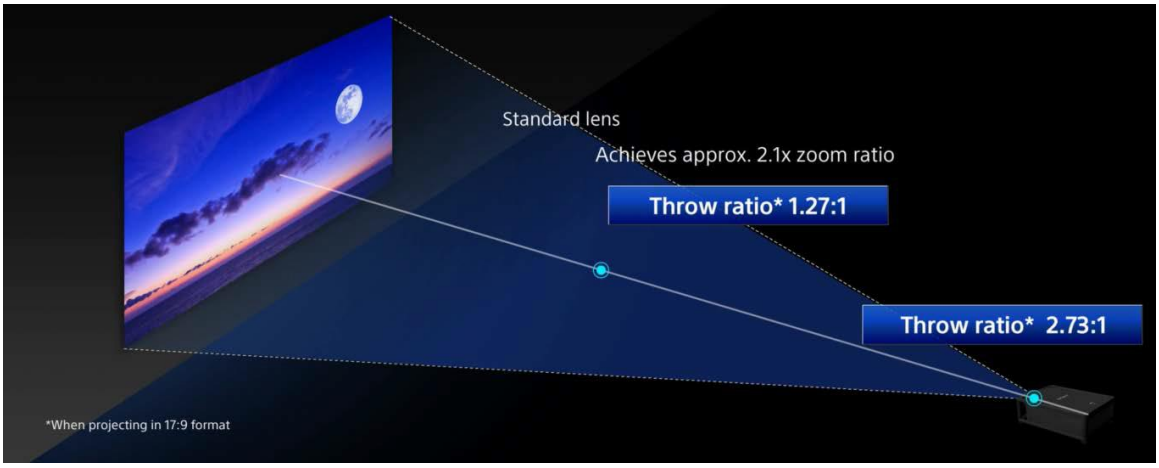
The on-screen display gives installers rapid access to colour calibration. Installers can select colour space (BT.709, BT.2020, DCI, Adobe RGB, Colour Space 1, Colour Space 2, Colour Space 3 and Custom) and then adjust HSV (Hue, Saturation, Value/Brightness) for each colour space.

Control panel convenience light (VPL-VW5000ES only)

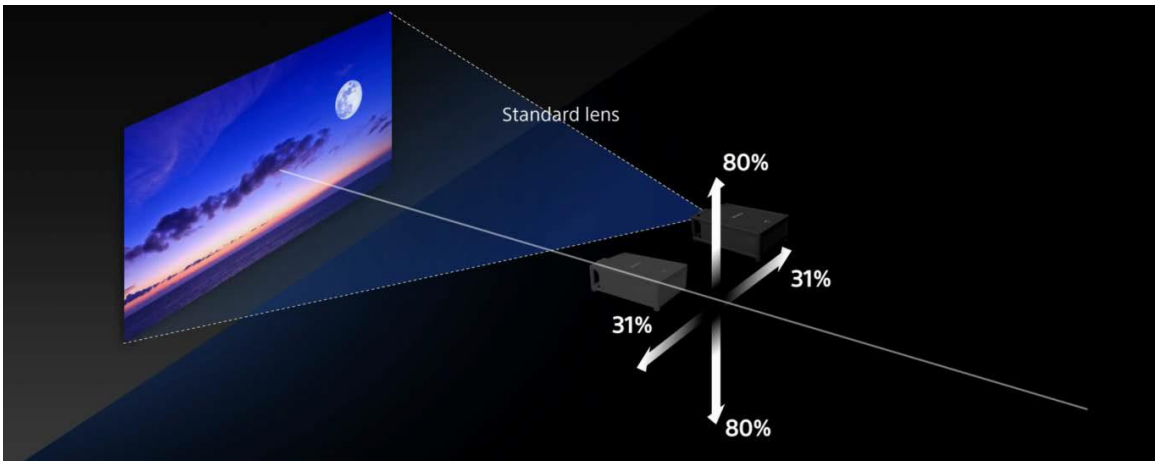
For the flagship VPL-VW5000ES, installers don't need to carry a flashlight up the ladder during installation. A built-in convenience light illuminates the control panel and inputs. When installation is done, a readily accessible switch turns the light off.

Wide throw ratio and lens shift (VPL-VW5000ES, VW870ES, VW760ES, VW570ES, VW270ES)

Sony designed the VPL-VZ1000ES as an ultra-short-throw projector for placement against or near the wall. Sony designed the other projectors to accommodate a wide range of home cinema installations. That means flexibility in screen size, flexibility in lens zoom (throw ratio) and flexibility in off-axis placement.



The supplied lenses accommodate a wide range of screen sizes and throw ratios. Shown here: the VPL-VW5000ES.



Sony also delivers a wide range of vertical and horizontal shift. Shown here: the VPL-VW5000ES.

High altitude mode (all models)

A special high altitude mode ensures proper cooling operation at elevations from 1,500 to 3,000 meters. There are very few European cities that come close to 1,500m altitude, the one and only with more than 10,000 inhabitants being Davos, in Switzerland at 1,560m above sea level.

Multi-projector stack design (VPL-VW5000ES only)

For redundant operation or passive glasses 3D, you can stack a pair of VPL-VW5000ES projectors, one on top of another. The feet of the top projector fit neatly into recesses in the bottom projector. You can also position two projectors side-by-side, flipping the second projector over on its back. To accommodate this configuration, you can remove and relocate the feet from the second projector.

Robust interfaces (all models)

Sony's projectors include a complete set of inputs and control interfaces.

- HDMI 2.0b inputs with 4K/60p (18 Gbps) capability
- RS-232C jack for remote control via home automation systems
- RJ-45 Ethernet port for remote control by home automation systems
- Sync In and Sync Out jacks for stacked projectors (VPL-VW5000ES only)
- Two Trigger interfaces for home automation control of curtains, room lighting, screens, masking and more (VPL-VW5000ES, VW870ES, VW760ES and VW570ES)
- One Trigger interface (VPL-VW270ES and VZ1000ES)
- IR in jack for connection to an external infrared remote control eye
- IR out jack for connection to an external infrared remote control repeater (VPL-VW5000ES)
- USB port for firmware updates

Powerful home automation (all models)

Sony understands that the projector is just one component in your home cinema. That's why we built the projectors to integrate well with leading third-party systems for home automation.

- **Crestron Connected inside.** The projectors offer embedded Crestron® control intelligence. When connected via Ethernet, the projectors operate as part of the native Crestron network. Using Crestron Fusion RV™ software, the projectors can be seamlessly monitored, managed and controlled from any web-enabled laptop computer or mobile device.
- **Control4 SDDP (Simple Device Discovery Protocol).** The projectors conform to Control4's original protocol to enable simple device pairing to a Control4® automation system. Features include automatic device discovery, device identification with a unique identifier (not an IP address), automatic driver installation and the ability of devices to use DHCP IP addressing and still be uniquely identified.
- **URC.** Universal Remote Control. Total Control integrates with the Sony home cinema projector lineup and UBP-X1000ES for robust, premium home automation and control.
- **AMX Device Discovery**
- **Savant Partner in Excellence**
- **RTI**

Sony’s 4K lineup

	VPL-VW5000ES	VPL-VW870ES	VPL-VW760ES
Native Resolution	4096 x 2160	4096 x 2160	4096 x 2160
Microdisplays	3 SXRD® chips	3 SXRD chips	3 SXRD chips
Light Engine	Z-Phosphor™ system	Z-Phosphor system	Z-Phosphor system
Brightness	5,000 lm	2,200 lm	2,000 lm
Colour Brightness	5,000 lm	2,200 lm	2,000 lm
Dynamic Contrast	∞ : 1	∞ : 1	∞ : 1
4K Reality Creation	Yes	Yes	Yes
4K All Range Crisp Focus Lens	Yes	Yes	-
Interchangeable Lenses	Yes	Yes	-
Mastered in 4K mode	Yes	Yes	Yes
High Dynamic Range	HDR10 + HLG	HDR10 + HLG	HDR10 + HLG
HDR Reference Mode	Expected future upgrade	Yes	Yes
Recommended lamp cycle	20,000 hrs.	20,000 hrs.	20,000 hrs.
Inputs	HDMI x2	HDMI x2	HDMI x2
Control interfaces	IR In/Out, Trigger x2, LAN, USB, 3D Sync, RS-232C	IR In, Trigger x2, LAN, USB, RS-232C	IR In, Trigger x2, LAN, USB, RS-232C
Limited Warranty	Three Years	Three Years	Three Years

	VPL-VZ1000ES	VPL-VW570ES	VPL-VW270ES
Native Resolution	4096 x 2160	4096 x 2160	4096 x 2160
Microdisplays	3 SXRD chips	3 SXRD chips	3 SXRD chips
Light Engine	Z-Phosphor system	UHP Lamp	UHP Lamp
Brightness	2,500 lm	1,800 lm	1,600 lm
Colour Brightness	2,500 lm	1,800 lm	1,600 lm
Dynamic Contrast	∞ : 1	350,000:1	n/s
4K Reality Creation	Yes	Yes	Yes
4K All Range Crisp Focus Lens	-	-	-
Interchangeable Lenses	-	-	-
Mastered in 4K mode	Yes	Yes	Yes
High Dynamic Range	HDR10 + HLG	HDR10 + HLG	HDR10 + HLG
HDR Reference Mode	-	Yes	Yes
Recommended lamp cycle	20,000 hrs.	6,000 hrs.	6,000 hrs.
Inputs	HDMI x4	HDMI x2	HDMI x2
Control interfaces	IR In, Trigger, LAN, USB, RS-232C	IR In, Trigger x2, LAN, USB, RS-232C	IR In, Trigger, LAN, USB, RS-232C
Limited Warranty	Three Years	Three Years	Three Years

A final word

Alone among projector manufacturers, Sony applies Total System Technology – embracing proprietary advances in digital processing, light engines, microdisplays, optical blocks and lenses – along with expertise across the content ecosystem from movie and television production to the cinema auditorium and home cinema.

In this document, you'll find these points supported by a wealth of charts, diagrams and technical explanations. But you won't find the true benefit of Sony's 4K projectors. You can only experience the difference sitting comfortably in a suitably darkened room with a well-chosen HDR 4K source and one of our projectors in action. Only then can you appreciate the full significance of Sony's achievement.

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