Inside SXRD™ Technology

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Unleashing The Full Power of HD

High Definition programming is becoming mainstream:

• As of July 2005, the National Association of Broadcasters reports that over 1,500 television stations in the US are broadcasting HD. And a healthy proportion of the broadcast television schedule is now presented in HD, including dramas, sitcoms, sports, specials and late night talk shows.

• The National Cable & Telecommunications Association has announced that 92 million US households are passed by HD cable service, while the list of HD cable channels now includes Cinemax HD, Comcast SportsNet HDTV, Discovery HD Theater, ESPN HD, ESPN2 HD, FSN HD, HBO HD, HDNet, HDNet Movies, INHD, INHD2, MSG Networks in HD, NBA TV, NFL Network HD, Outdoor Channel 2 HD, Showtime HD, Spice HD, STARZ! HDTV, The Movie Channel HD, TNT in HD, Universal HD and YES-HD.

• The DISH Network and DIRECTV satellite services provide an impressive range of HD programming, including over 100 NFL games in HD on DIRECTV.

• Consumers can now shoot their own home videos on HDV 1080i High Definition camcorders, play back prerecorded HD movies on D-VHS tapes and even record TV shows on HD personal video recorders.

• In Japan, Blu-Ray™ Disc High Definition optical recorders have already reached the consumer market.

Despite all these programming riches, most video projectors that meet the Consumer Electronics Association's standard for "High Definition" actually cannot display every pixel of the majority of HD content, which is 1920 horizontal x 1080 vertical pixels. In these projectors, "down-conversion" or "down-scaling" circuits are required to reduce the resolution to fit on a panel that typically offers just 1280 x 720 pixels. This effectively discards pixels from the original 1920 x 1080 broadcast.

The Full Power of HD requires more. It requires a full 1920 x 1080 pixels, progressively scanned 60 times per second. In this way, all of the original pixels can be reproduced without any “downscaling.”

In addition to Sony's legacy of technical excellence in television, Sony is a global leader in High Definition broadcasting and digital cinematography equipment. And Sony Pictures Entertainment is a force in HD television program production and digital motion pictures. No wonder Sony engineers are so passionate about creating home televisions that do justice to HD source material. We know exactly how High Definition looks in the studio and we believe viewers deserve that same experience at home. The result of this commitment is Sony's SXRD™ (Silicon X-tal Reflective Display) panel.
From CRTs to microdisplays

Not long ago, the Cathode Ray Tube (CRT) was the dominant technology in video projection. Unfortunately, CRTs are responsible for supplying both brightness and resolution. Pushing CRT brightness often compromises resolution—and vice versa. Projection CRTs often operate at the outer edge of their performance envelope, requiring periodic alignment, adjustment and eventual replacement. For this reason, CRTs have almost completely disappeared in front projection and are losing share in rear projection. CRTs are giving way to fixed-pixel microdisplay panels that supply only the resolution—while an external projector lamp supplies the brightness.

In the United States, literally hundreds of fixed-pixel projector models are available from dozens of companies. But under the surface, almost every one of these projectors depends on one of just three types of microdisplay:

1. **H-LCD.** High Temperature Polysilicon Liquid Crystal Displays, a transmissive technology in which the light shines through the panel.

2. **DLP™ panels.** Digital Light Processing™ displays, a reflective technology that uses a micro-mirror array.

3. **LCoS.** Liquid Crystal on Silicon panels, a category of reflective panels that includes the Direct drive Image Light Amplifier (D-ILA) display.

The birth of the SXRD™ microdisplay

From the outset, Sony was determined to create something fundamentally better. The challenge was to build a device with the highest pixel density and smallest possible inter-pixel spacing, along with world-class contrast, color stability and picture clarity. The answer was an all-new approach to reflective liquid crystal technology: the SXRD panel.

*Photomicrograph of the SXRD panel silicon backplane in cross section.*
SXRD™ panel production

Unlike conventional LCoS panels, which are notoriously difficult to manufacture, the SXRD panel uses a production process that Sony has perfected in the company’s own, dedicated manufacturing facilities. This has enabled Sony to bring SXRD technology smoothly into full production, while taking full advantage of its many benefits.

Sony assembles the IMITO glass and silicon backplane prior to cutting the wafer into individual panels (singlation). In this way, Sony achieves three key advantages: a narrow cell gap, dust-free process and no LC gap spacers in the image area.

Sony produces the SXRD panel’s silicon backplane at our Kokubu Technology Center. The backplane uses a 0.35 micron process and an innovative drive circuit. The panels themselves are assembled at Sony's Kumamoto Technology Center. There, Sony affixes the Index Matching Indium-Tin-Oxide (IMITO) glass to the backplane before we cut the wafer into individual panels. This process minimizes the Liquid Crystal cell gap, minimizes dust and keeps LC gap spacers clear of the image area—all important considerations in picture quality.

The rapid evolution of SXRD technology

The very first product to incorporate SXRD technology was Sony's Qualia™ 004 custom installation front projector in early 2004. Critics were dazzled by its stable color, vivid contrast and full HD resolution: 1920 x 1080 pixels. Sony soon incorporated the same SXRD panel into the Qualia 006 home theater rear projection television.
Sony’s Qualia™ 004 custom installation projector was the first product to incorporate SXRD™ technology.

The Qualia 006 first brought SXRD technology into home theater rear projection television. (Shown with optional stand.)

A substantially larger panel became the key to Sony’s incredible "4K" professional projectors, the SRX-R110 and the SRX-R105. Designed for digital cinema, large
venues, command & control, museums and exhibits, these projectors offer a jaw-dropping 4096 x 2160 resolution.

The highly acclaimed SRX-R110 professional projector.

Now Sony debuts the company's third generation. At 0.61 inches diagonal, this is the world's smallest microdisplay panel with full 1920 x 1080 resolution. Thanks to this new device, Sony's KDS-R60XBR1 and KDS-R50XBR1 place SXRD™ technology within the reach of more consumers than ever before.

Sony's KDS-R60XBR1 home theater projection television brings SXRD technology within the reach of more consumers.
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Sony's third-generation SXRD™ panel is now the world's smallest microdisplay with full 1920 x 1080 native resolution

### HD resolution... and Beyond

We've seen that many products designated "High Definition" fall well short of the full resolution of 1080-line HD sources: 1920 pixels horizontal x 1080 pixels vertical. Right from the outset, Sony's very first SXRD products achieved this full HD resolution using a one-to-one relationship between the pixels on the microdisplay panel and the pixels on the screen.

![Sony Consumer SXRD Panels: Full HD Resolution](image)

Compared to many microdisplay panels that are designated "High Definition," Sony SXRD panels for consumer television have more than twice as many pixels.

Originally, DLP panels also offered a one-to-one relationship between the pixels on the panel and the pixels on the screen. But in a move oddly reminiscent of interlace scanning, recent DLP panels divide each display frame into two "subframes". A pivoting mirror outside the display panel called the "optical actuator" toggles the screen image back and forth. The system shows the pixels...
of the first subframe, then toggles to show the pixels of the second. This is a cost-reduction strategy because when the pixel count of the microdisplay is cut in half, the resulting chip is less expensive.

The DLP "optical actuator" system works to double the native resolution of the panel itself.

The optical actuator system also uses a different orientation for the microdisplay pixels. The first DLP panels used an "orthogonal" array of pixels, arranged in vertical columns and horizontal rows. The DLP panels used with optical actuators adopt a diamond or diagonal pixel array.

Unlike either 1280 x 720 panels or optical actuator approaches, SXRD™ panels achieve full 1920 x 1080 native resolution, which shows all the pixels, all the time. Sony can do what others can’t thanks in part to the extremely fine "pitch" of the SXRD pixels. In Sony’s latest SXRD panel, refinements to the panel drive circuit layout have enabled Sony to reduce the pixel pitch to just 7 micrometers. (For comparison, a human hair is roughly 70 micrometers thick!) This 7-micrometer pitch delivers 4.0 times the picture density of Sony’s own H-LCD panels. The fine pitch enables Sony to put 2,073,600 pixels (1920 x 1080) on an integrated circuit.
chip surface just 0.61 inches diagonal. So 1080-line HD sources appear in their full glory—never blurred, never "downsampled"—and pixel information is never discarded.

As the pixels become smaller, the "pixel density" becomes greater. Higher pixel density is the key to providing a television with full High Definition and three microdisplays at a price where others offer just one chip!

To achieve maximum resolution at minimum cost, microdisplay panel suppliers are pushing toward higher pixel density. Sony SXRD technology is in the lead. DLP "optical actuator" systems are shown at both the native panel pixel densities (lower diamond) and their approximate field sequential densities (arrow).
More than 8 megapixels on an inch and a half of silicon, this is the professional version of Sony's SXRD™ panel. (Sony's third generation 0.61” 1920 x 1080 SXRD panel is shown on the front cover.)

There's more. Sony designed SXRD technology from the outset to support multiple markets. So each SXRD silicon wafer can be easily sliced into large or small panels, in order to suit a variety of applications—from home theaters to the most demanding multiplex cinemas. In this way, Sony created a giant 1.55-inch diagonal SXRD panel for our professional "4K" projectors. It brings SXRD technology to the most stringent applications in entertainment and information display.

Sony Professional SXRD Panel: “4K” Resolution

4096 H x 2160 V
8,847,360 pixels

Sony Consumer SXRD Panels: Full HD Resolution

1920 H x 1080 V
2,073,600 pixels

Typical HD Projection

1280 H x 720 V
921,600 pixels

Standard Def

720 H x 480 V
345,600 pixels

SXRD technology is also scalable. The panels for our professional projectors achieve "4K" resolution—more than four times the pixels of full High Definition.
Stable, natural color

To hold down cost, many DLP projectors use a single microdisplay panel. In a throwback to the mechanical color television proposals of the 1950s, color is separated by a rotating color wheel that is timed to coincide with a subframe for each color segment on the wheel, such as Red, Green and Blue. DLP color wheels now use as many as eight segments. Regardless of the number of segments, the single-chip DLP system can only flash one color at a time. In fact, the colors remain completely separate until they are combined by the human visual system!

This single-chip system generates adequate color under static viewing conditions—a steady gaze at a motionless object. However, under certain high contrast conditions color breakup—rainbow flashes of the individual colors—can occur when looking away from the screen or even blinking. Combining the requirements of the color wheel with those of the optical actuator, each video picture could be represented by as many as sixteen subframes (the eight color segments times the two optical actuator positions).

In designing SXRD™ projection systems, Sony engineers wanted more. These Sony projectors use three SXRD panels, one each for Red, Green and Blue. In this way, SXRD projectors display all the colors, on all the pixels, all the time! There are no "subframes," and no rainbow artifacts, ever. Thanks to Sony’s three-panel design, you get stable, consistent color under all viewing conditions, in
addition to high optical efficiency. These benefits of three-panel architecture are so widely recognized that in high-end projectors, even DLP systems use three panels!

This conceptual view of the SXRD™ optical engine shows the filtered Red, Green and Blue light entering at left, the three SXRD panels and the combined light exiting the prism, at right.

Minimal screen-door effect

On all fixed-pixel panels, the pixels are separated by gaps that contain no picture information. To generate the effect of a seamless, continuous image, these gaps should be minimized. Unfortunately, High Temperature Polysilicon LCD panels, which the projector light shines through, require substantial gaps between pixels because the transistors must exist in the same plane as the pixel electrodes.

On the screen, large inter-pixel gaps can appear to have heavy black outlines. At close distances it can appear as if you are viewing the image through a screen door. You can always moderate this "screen door" effect by sitting further back from the television. But that tends to reduce the apparent resolution, defeating the whole reason people bring home High Definition in the first place!
Conceptual view of three projectors using the same screen size. Left: the screen door effect on a typical H-LCD panel. Center: the native DLP panel is much closer to a continuous image. Right: the SXRD panel is better still, thanks to its higher 1920 x 1080 native resolution.

While light *shines through* H-LCD panels, light *reflects from* the SXRD™ panel. All the transistors are hidden in the silicon backplane behind the reflective surface. This arrangement enabled Sony to design inter-pixel gaps just 1/10 the width found in H-LCD panels. While the distance from the center of one SXRD pixel to the center of the next is 7 micrometers, the inter-pixel gap is just 0.35 micrometers! According to Sony's review of currently available technology, this is *the world’s smallest inter-pixel spacing*. This tight spacing means that up to 92% of the SXRD panel surface is devoted to live image area. This is known as the fill factor of the panel.

*Photomicrograph of the SXRD panel surface, showing the fill factor of up to 92% and 0.35 micrometer inter-pixel gap.*

The design of the silicon backplane not only controls screen door effect, but also contributes to superb uniformity and low crosstalk, minimizing any noise in the image.
High speed

It is well known that CRTs exhibit very fast response to the dynamic changes in television pictures. So movement is rendered crisply and accurately. Unfortunately, Liquid Crystal Displays are typically not as fast. That's because the liquid crystals are viscous, with consistency more like honey than water. When the transistors command a pixel to change its state, the liquid crystal takes a few milliseconds to respond. In video, milliseconds are important. Typical 60 Hz interlaced material requires the projector to display a new scene every 16.7 milliseconds. Slow LCD response can blur fast motion, for example a race car zooming past a trackside camera.

Transmissive H-LCDs aren't the only panels that use a liquid crystal layer. So does the SXRD™ panel. But while light travels through the transmissive H-LCD liquid only once, light passes through the SXRD panel liquid twice, first coming in to strike the mirrored backplane and then reflecting out toward the screen undergoing a change in polarization depending on the applied voltage. Because the light passes through twice, the liquid crystal layer can be only half as thick.

![Conceptual drawing, not to scale, of Sony's 3rd-generation SXRD panel in cross section. Light from the projection lamp enters through the glass substrate at the top, passes through the 2-micrometer Liquid Crystal layer, reflects off the mirrored surface of the Silicon backplane, and passes out through the Liquid Crystal, toward the screen.](image)

Having an LC layer that's half as thick is a huge advantage because thinner layers mean fewer LC molecules to twist. And that means more power is available to twist each molecule, and thus a faster response time. In practice, response time varies as the square of the LC layer thickness. So reducing the panel thickness by 50% means the response time is cut by 75%!
A thinner Liquid Crystal layer (right) means fewer LC molecules to twist and more available power to twist each molecule. The result? Faster response.

At less than 2 micrometers, the SXRD™ panel's liquid crystal layer is not only thinner than that of transmissive H-LCD; it's also thinner than the typical LCoS device. So the picture remains crisp and clear, even during fast-action scenes such as those seen in sports like hockey, basketball and auto racing. The specified response is 2.5 milliseconds for the rise time (tr) and also 2.5 milliseconds for fall time (tf).

High contrast

Contrast, an essential requirement of any display system, is measured as the ratio between the brightest possible bright and the darkest possible black. Sony's SXRD panels achieve superb contrast ratio, thanks to three distinct innovations.

- **Vertically Aligned Nematic (VAN) liquid crystal.** Most H-LCD projectors use Twisted Nematic (TN) liquid crystal, which displays white when no voltage is applied. The SXRD panel uses VAN liquid crystal optimized for SXRD, which displays black when no voltage is applied.

- **Ultra-thin LC layer, less than 2 micrometers.** The contrast ratio is defined in part by the "dark level"—the blackest possible black that the panel can display. Lower dark levels are better. As with response time, the dark level varies as the square of the LC layer thickness. For this reason, Sony's ultra-thin LC layer—less than 2 micrometers—contributes directly to a higher contrast ratio.
• **Spacer-less design.** Many LCD panels require spacers in the image area to maintain a uniform cell gap. Unfortunately, these spacers interrupt the regularity of the nearby liquid crystal molecules, affecting contrast. The SXRD panel incorporates a spacer/sealer around the periphery of the live display area. As a result, the image area is entirely free from spacers, and maintains maximum contrast. This process also maintains highly precise cell gap uniformity.

Thanks to these features and additional refinements to the SXRD™ panel structure, the contrast ratio of Sony's third-generation SXRD panel alone, when measured with a conoscope, is 5000:1—a substantial improvement over H-LCD designs.

**Long life**

CRTs and Plasma displays have phosphors that can be subject to burn-in when an image stays on the screen too long. Fixed-pixel projector display panels are resistant to burn-in, offering far longer life. And the SXRD panel is particularly robust.

Two thin sheets of material hold the liquid crystal in alignment. Typically this material is organic polyimide film. This generally works well but has less than optimal operating life in the stressful, high-heat environment of a video projector. Sony's inorganic thin film alignment layer not only maintains vertical liquid crystal alignment but also exhibits exceptional thermal stability. This substantially extends the operating life of the SXRD panel.

In addition, H-LCD panels are squarely in the light transmission path, making them relatively difficult to cool. Because light reflects off the SXRD panels, their "dark" side is out of the light transmission path, allowing for much simpler and more effective cooling, prolonging the panel life further still.
A new benchmark

Hailed by critics, movie theater owners, demanding professionals and astute consumers, SXRD™ technology has helped establish Sony's latest video projectors as industry benchmarks. Sony is a leader in applications as varied as digital cinema, custom installation and home theater. SXRD panels are breaking new ground for the two most important parameters of picture quality: resolution and contrast ratio. The technology also achieves blistering response speed, long operating life and superb freedom from the screen door effect, while the three-panel design delivers exquisite, ultra-stable color. In this way, SXRD technology unleashes The Full Power of HD.