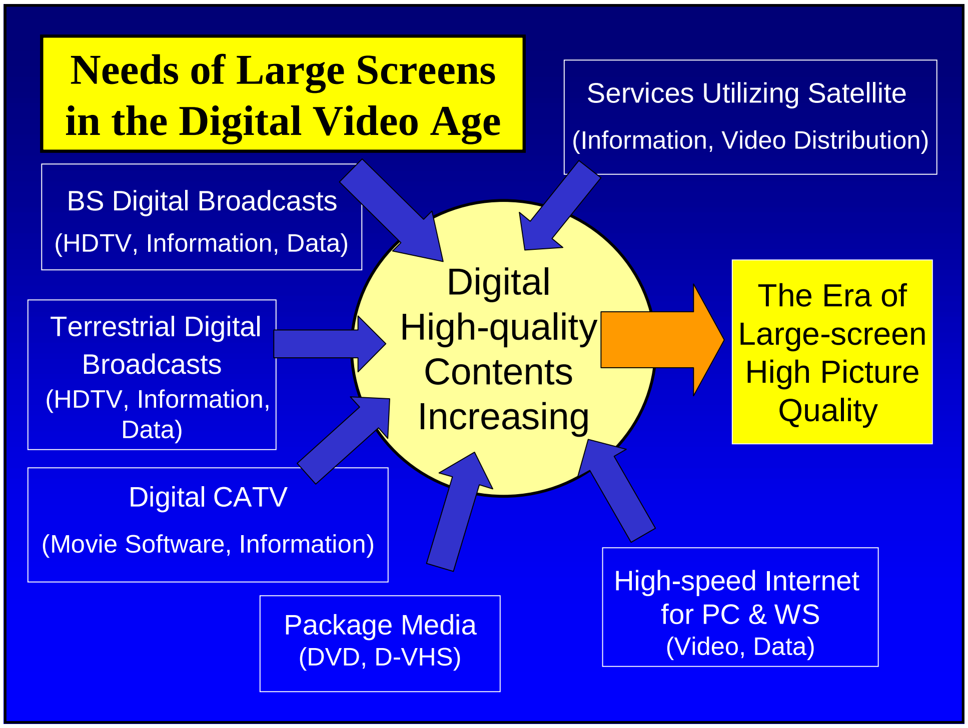
The Digital Video Age

Directions In Projection Technology in the 21st Century

-- The World of QXGA --

Today I'd like to introduce JVC's D-ILA high quality picture technology that has realized the world's first QXGA projector.



2) Needs of Large Screens in the Digital Video Age

In the 21st century, rapid development of digital video is expected. Digital satellite broadcasts have already started, and terrestrial digital broadcasting is now in development, with full-scale broadcasting scheduled to start in 2003. CATV digital broadcasting will also be starting soon. The goal of these new broadcast media is total popularization of digital HDTV. Packaged media are also moving in this direction, with HDTV versions of the D-VHS format as well as of DVD now in development. At the same time, advances in high-speed, broadband Internet capacity will enable HDTV broadcasts and ultra high-definition video from a high-performance personal computer or workstation to be delivered via the Internet. Live coverage and movie distribution using satellite systems will become more prevalent and digital movie theaters will become commonplace. Clearly, we are in an age where all media are rapidly digitizing and an incredible amount of high-quality digital content will be available. To meet the demands of this age, JVC has developed a projector with QXGA capability.

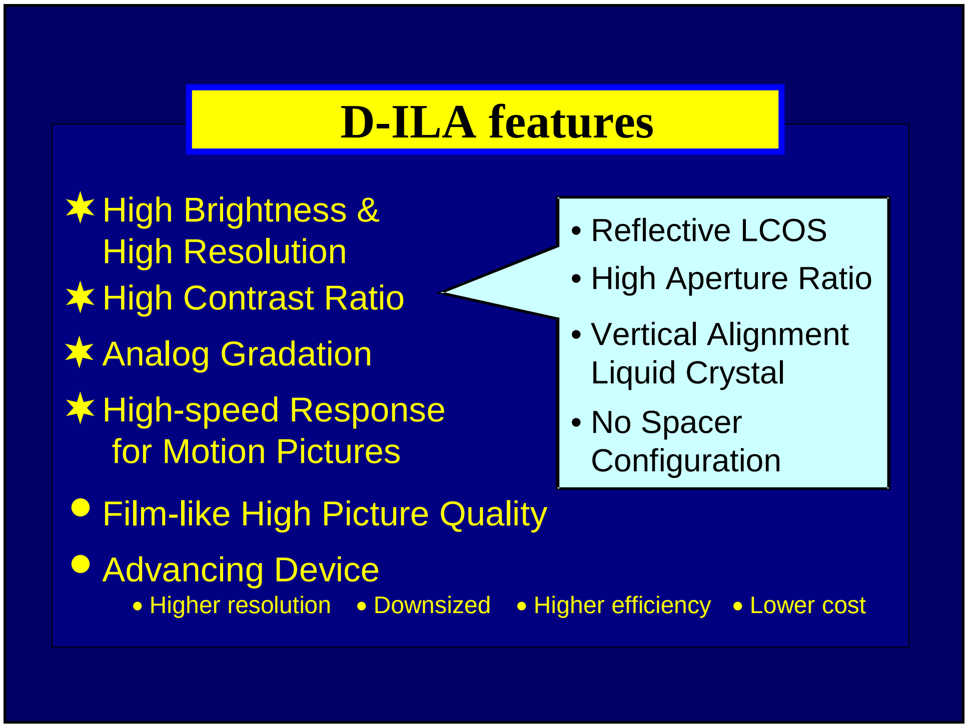
QXGA Device

- 2048 x 1536 pixels
- 1.3" diagonal (4:3)
- Contrast ratio > 1000: 1

3) QXGA device

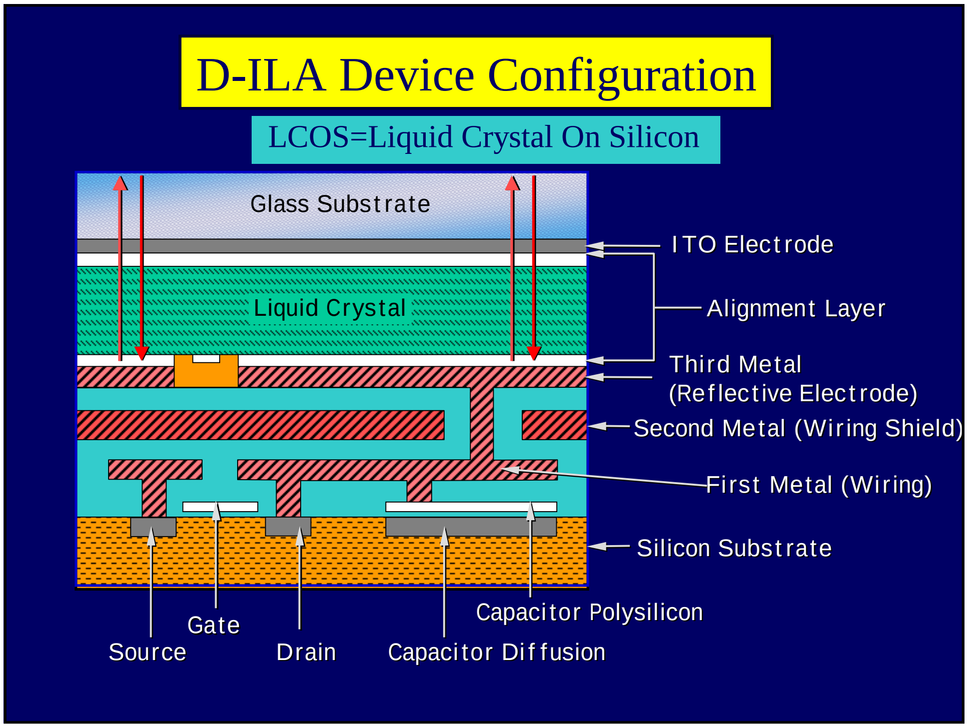
We announced this device at INFOCOMM2000, last June.

It features 2048 x 1536 pixels, a total of 3,200,000 pixels — more than twice the 1,400,000 pixels of the current SXGA device and the highest ever achieved in a projection device. This superior resolution makes it possible to display HD images as their full specifications of 1920 x 1080. The device size is 1.3 inches diagonal and higher brightness is under consideration. The contrast ratio is over 1000:1 with the device in itself and 1000:1 is planned for projectors.



4) D-ILA features

The major features of D-ILA include both high brightness and high resolution with no conflict between the two, high contrast ratio, analog gradation and high-speed response. As a result, film-like high picture quality is achieved. These features are made possible by the high aperture ratio of reflective LCOS, the use of vertical alignment liquid crystals, and the fact that D-ILA's structure has no spacer construction. These are explained in detail next.



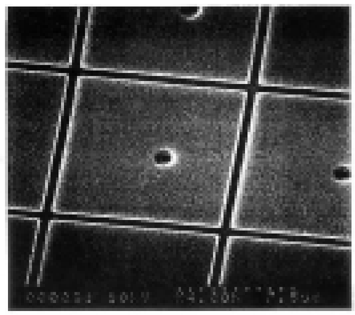
5) D-ILA Device Configuration as cross-section view

The high resolution of QXGA is achieved with our leading-edge LCOS (Liquid Crystal on Silicon) technology for the first time. As shown in the cross-section view of the LCOS, the addressing transistors and charge-hold capacitors are structured on the silicon substrate utilizing ordinary CMOS process. On the light blocking layer over this, the pixel electrode is located and connected to the capacitor. In the space between the glass substrate with transparent electrodes and this pixel electrode, liquid crystal is encapsulated and activated with the voltage applied to the pixel electrodes and transparent electrodes.

As this configuration is such a simple three-dimensional construction, pixels can be made very small. This maintains a high aperture ratio and makes it easy to achieve high density of pixels, resulting in the high resolution achieved for QXGA.

D-ILA **Closeup Photo. of Pixel Electrode** JVC

Pixel electrode



6) Close-up Photo. of Pixel Electrode

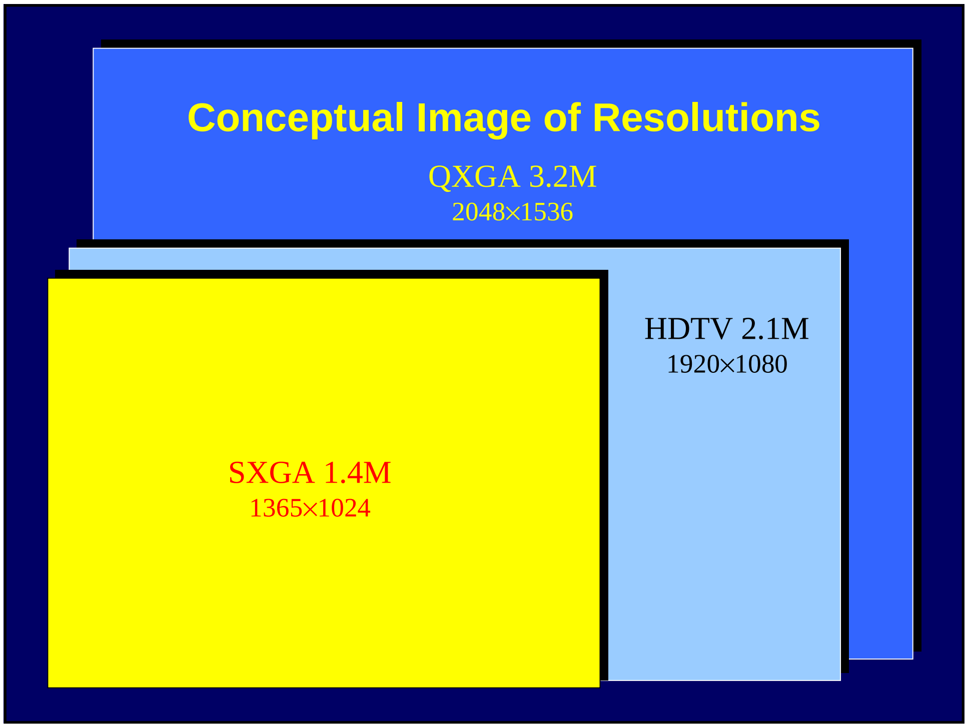
As shown in the photo, pixel pitch flexibility is so high that the pixels can be made very small, enabling high resolution to be easily achieved.

Device comparison

		a-ILA	D-ILA	Newly-developed		DMD
Number of pixels	H	1,600-equivalent	1,365	1,400	2,048	1,280
	V	1,200-equivalent	1,024	1,050	1,536	1,024
Pixel pitch (μm)	H / V	No pixels	13.5	10.4	12.9	17→14
Device size		1.7 to 2.5 inches (4:3)	0.91 inch (4:3)	0.71 inch (4:3)	1.3 inch (4:3)	1.1 inch (5:4)
			SXGA	SXGA+	QXGA	SXGA

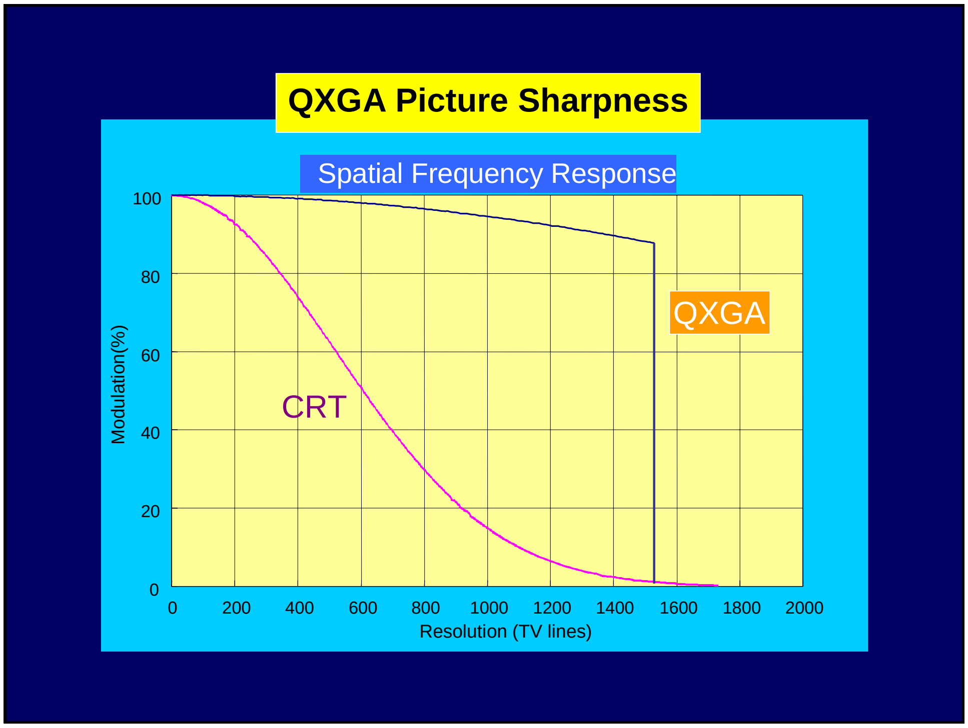
7) Device comparison

QXGA device is made reducing the pixel pitch from 13.5 microns of the current SXGA to 12.9 microns. For new SXGA+ device, which was announced at the same time, the pixel pitch is more reduced to 10.4 microns and the number of pixels is increased, achieving a 0.7-inch device. Further, it has been confirmed that decreasing pixels to 7 microns is possible with the current process. Consequently, higher resolution can be easily achieved with the LCOS technology used by the D-ILA device. With the DMD device, on the other hand, a 14-micron pitch has been achieved recently, but, as it has a mechanical construction, it cannot match the flexibility of D-ILA with LCOS construction.



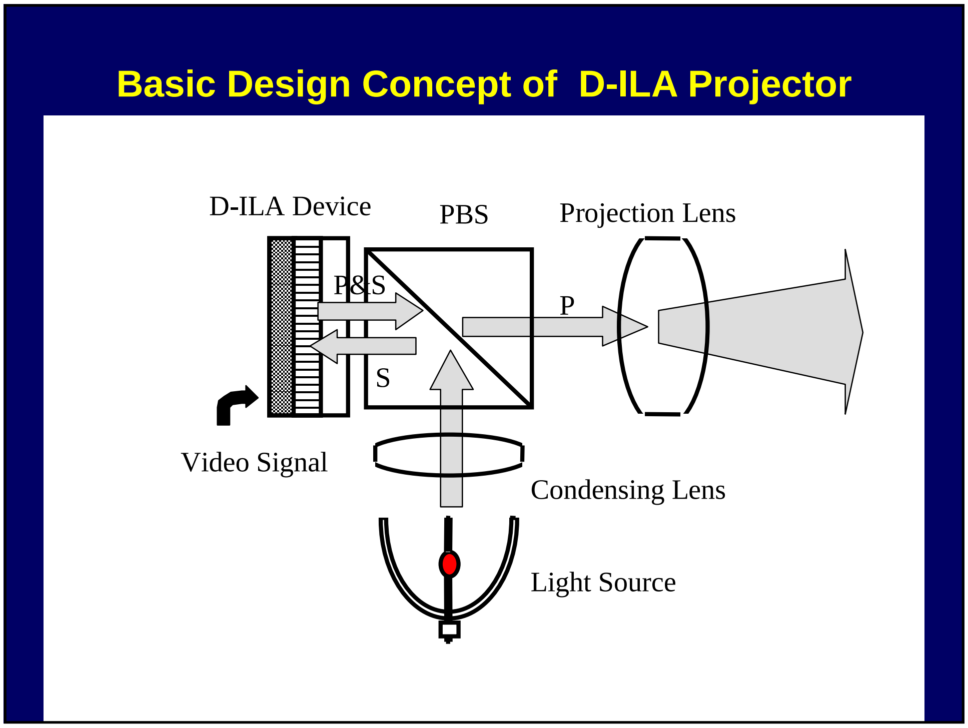
8) Conceptual image of the panel resolution

It is easy to compare the panel resolutions when they are shown as proportional areas. QXGA has 3,200,000 pixels against current SXGA of 1,400,000 pixels and has more than twice the resolution of SXGA. With QXGA, full HD specifications of 1920 x 1080 are completely contained. It goes without saying that this means that the real HD resolution can be obtained without resizing.



9) QXGA picture sharpness

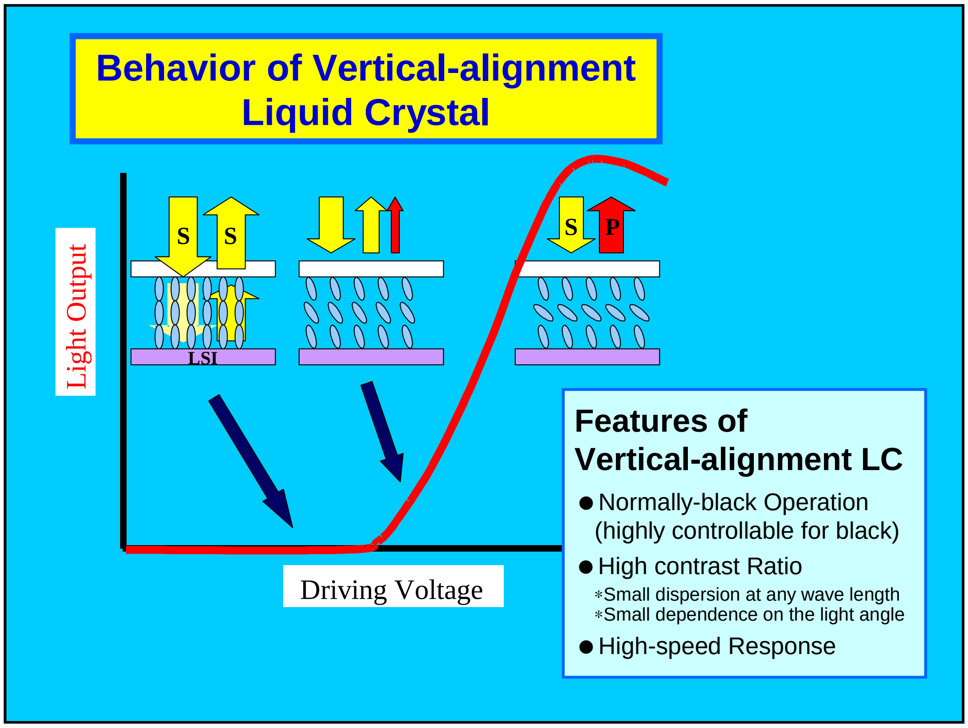
With the QXGA panel, extremely sharp pictures can be achieved. The spatial frequency characteristics (MTF) for CRT and QXGA are shown for comparison. For CRT, the response is attenuated in high frequencies due to the beam spot shape with Gaussian characteristics. In general, MTF5% is said to be the limit resolution of the CRT. Therefore, even with a master monitor, MTF is greatly lowered in resolution of 1000 TV lines. On the other hand, with the QXGA panel, attenuation of only about 10% occurs due to projection lens. So, 1536 TV lines of the number of vertical pixels can be obtained. The difference in area for the MTF characteristics clearly shows the difference in sharpness. Therefore, with QXGA panel, sharper and higher-resolution pictures than ever can be seen. On the down side, artifacts in sources will also show up clearly.



10) Basic Design Concept of D-ILA Projector

The high contrast of D-ILA comes from the operation principle as shown here.

The PBS located in front of the panel reflects the polarized P wave. The PBS allows the polarized P wave to pass through and serves to separate projection light from incident light. The S wave incident light passing through the PBS is phase-modulated in the liquid crystal layer of the panel. Then, only the P wave components of reflected light transmit and are projected. S wave components, on the other hand, are returned to the light source.

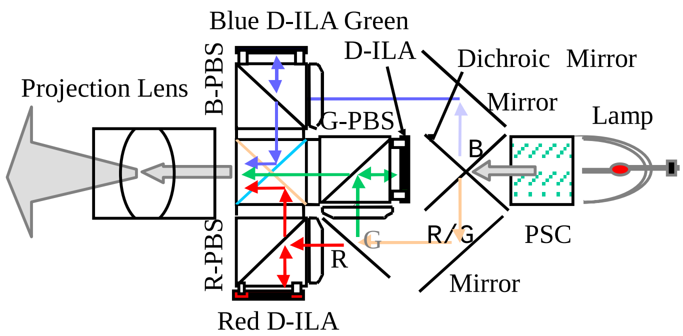


11) Behavior of Vertical-alignment Liquid Crystal

The operation of the vertical-alignment liquid crystal is shown here.

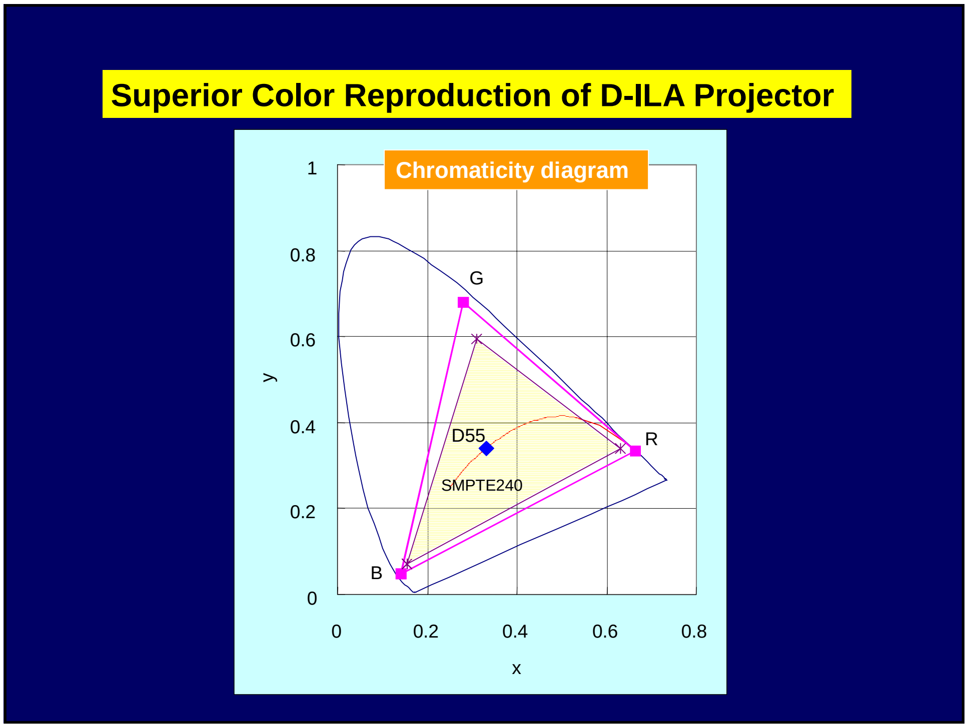
When the driving voltage is lower than the threshold, liquid crystal molecules are oriented vertically. The incident light S wave is not modulated. Instead, it is reflected to return to the light source, then shows as black. As the voltage is raised, the liquid crystal molecules are inclined and the reflected light is phase-modulated (with phase rotation), resulting in an increase in light output. When it turns to 90 degree, the brightness is maximal. Thus, for the vertical-alignment liquid crystal, black is normal and the operation so called as normally black mode is performed. This means that the stability of black reproduction is excellent. Also, because wavelength dispersion and light angle dependence of the vertical-alignment liquid crystal are small, they are not easily affected by differences in color and angle, making high contrast possible.

Optical System of D-ILA Projector



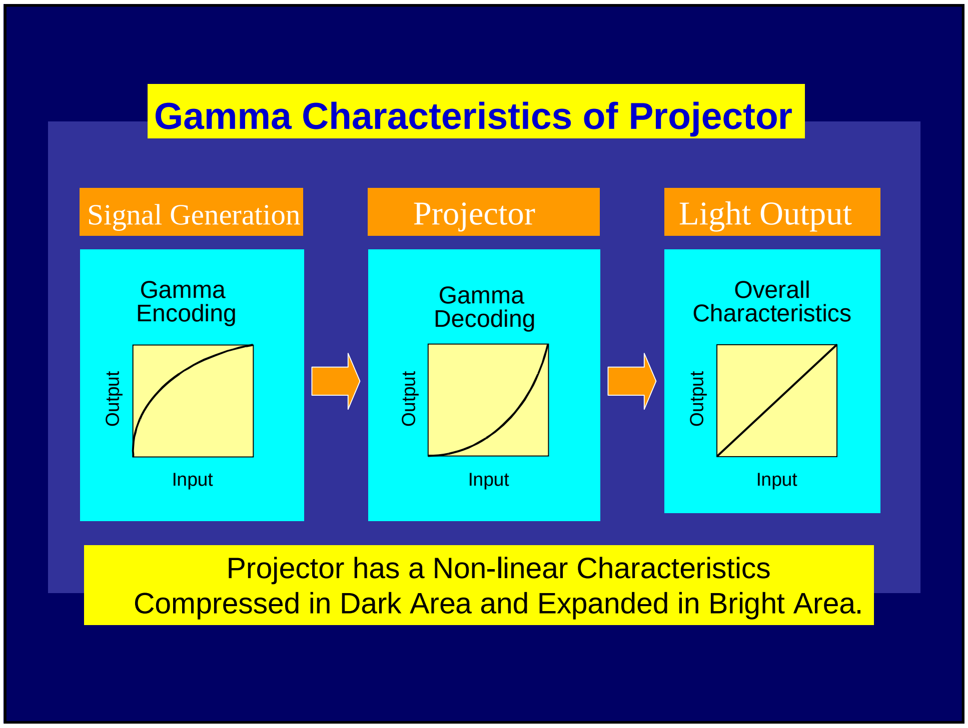
12) Optical system of the D-ILA projector

To make the most of the contrast characteristics of the device, the actual projector uses a separate high-precision optical system and PS Combiner (PSC) so that the characteristics of the color separation and color combining can be optimized. The PSC improves the brightness uniformity on the screen and contributes to contrast enhancement by increased degree of polarization. In combination, the vertical-alignment liquid crystal used for the device and the high-precision optical system are able to achieve a high contrast ratio of 1000:1.



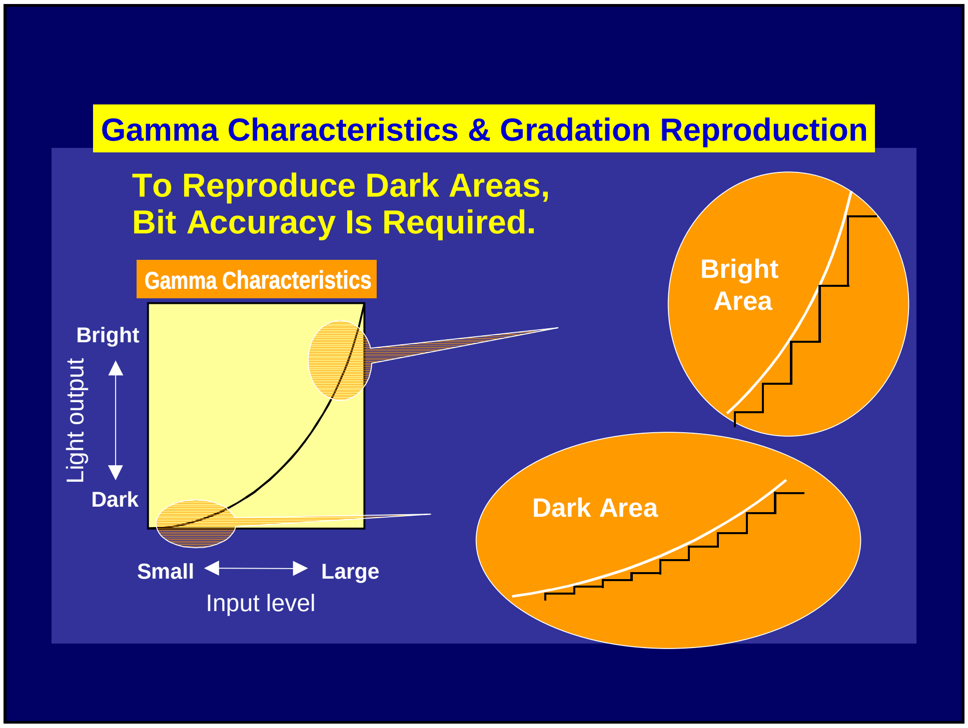
13) Superior color reproduction of the D-ILA projector

With the high-precision optical system that the color separation and the color combining are isolated, high-purity RGB primary colors as shown in the chromaticity diagram can be obtained. The color space is larger by 40% or more — surpassing the SMPTE240 standard. As the reference white point is set to D55, the most faithful color reproduction is possible for movie materials.



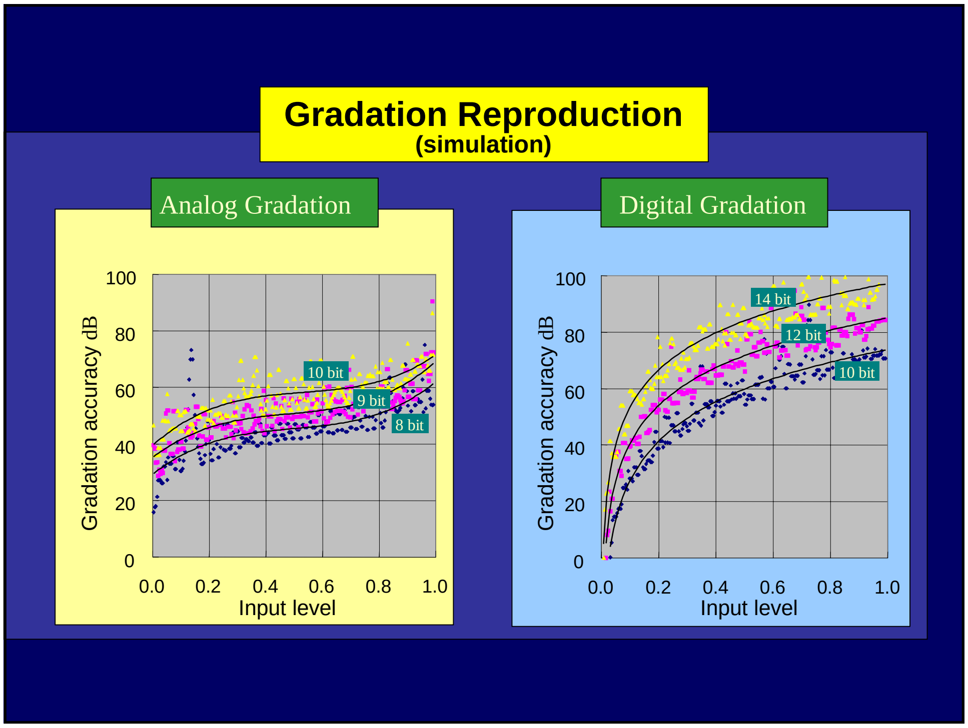
14) Gamma characteristics of the projector

There is a fundamental difference between the analog gradation used in D-ILA and the digital gradation used by other systems. To understand this difference, it is necessary to remind that the non-linear characteristics known as gamma characteristics are exactly necessary for any projectors. In video signals, the bright area is compressed with gamma compensation (gamma encode). Thus, the projector requires gamma characteristics to expand the bright areas and compress the dark areas (gamma decode). With this, the correct gradation can be reproduced for light output.



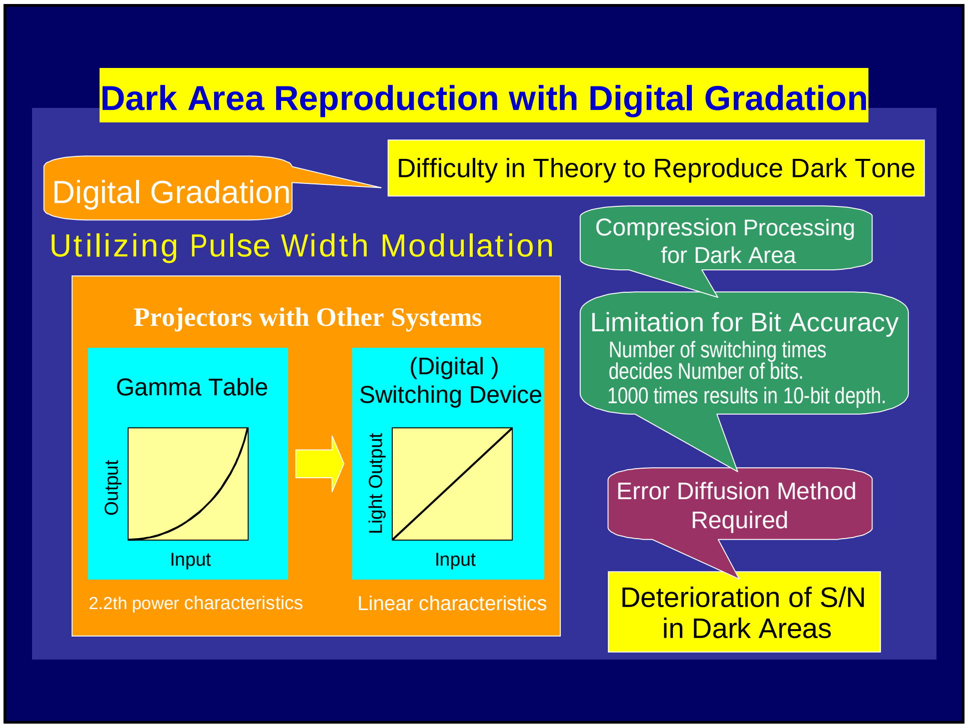
15) Gamma characteristics and gradation reproduction

The critical point here relates to where gamma characteristics are processed. When gamma characteristics (standard 2.2-power characteristics) are processed digitally, quantization steps have to be small and high bit depth is required to faithfully reproduce the gradation for the compressed dark areas.



16) Gradation reproduction

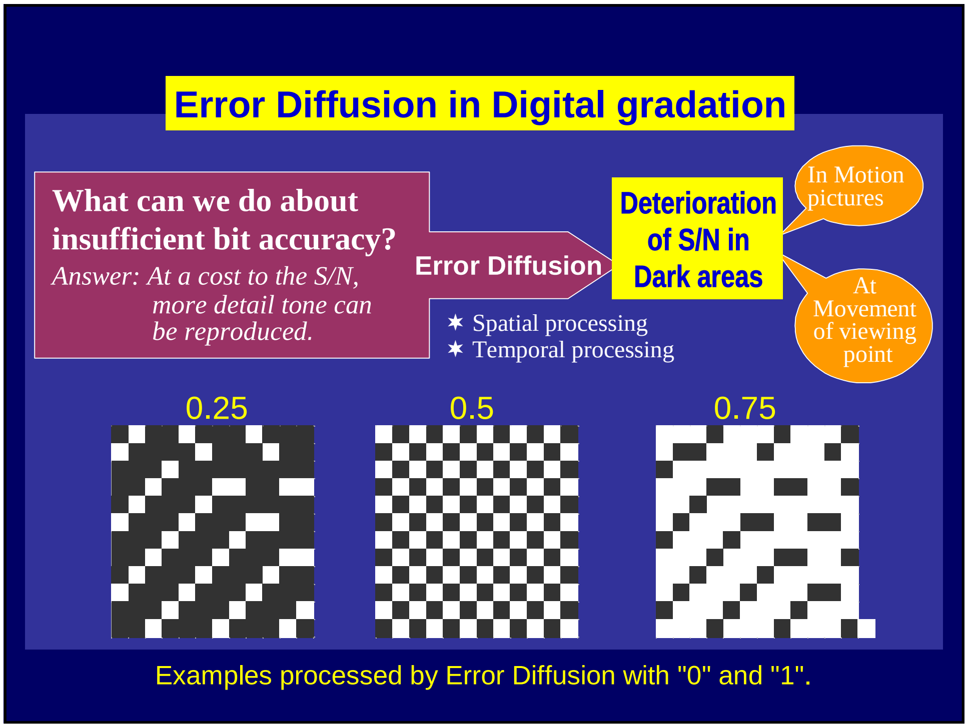
From the illustrated simulation, it is obvious that gradation reproduction is very different between the digital gradation and the analog gradation. The digital gradation has no problems in bright area; however, it tends to suddenly deteriorate in dark areas. Therefore, with digital gradation, it is necessary to increase the bit depth for gradation reproduction in dark areas. It is generally said that 14 bits are at least necessary. On the other hand, because the D-ILA's analog gradation has nearly flat characteristics, 10 bits are enough to reproduce gradation even in dark areas.



17) Dark area reproduction with digital gradation

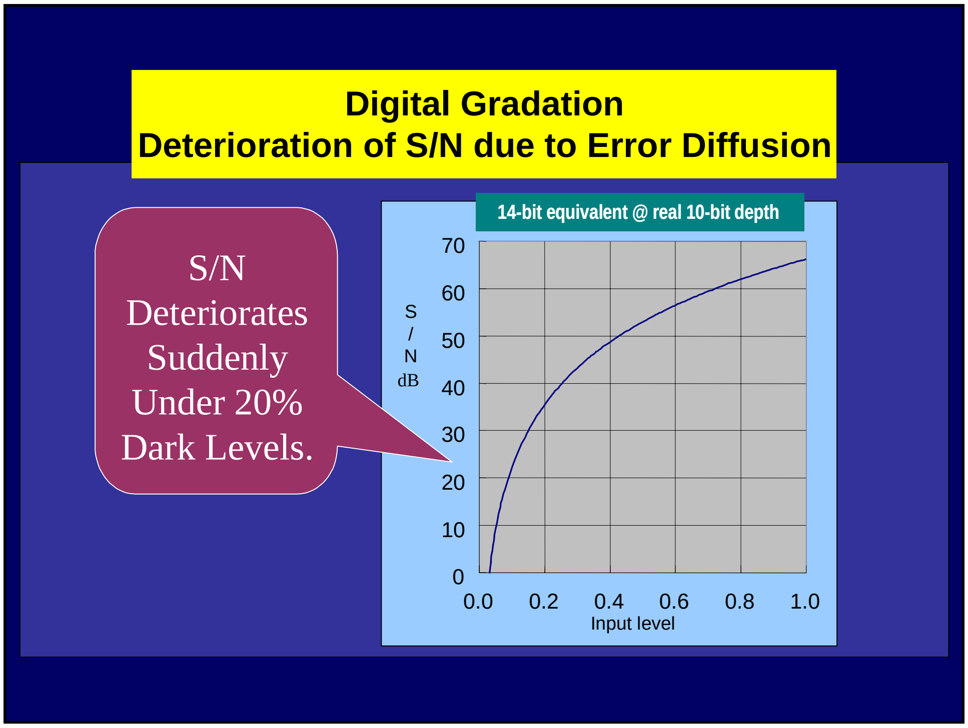
With digital gradation, there is a problem in principle that leads to the deterioration of S/N in dark areas.

With other systems with switching devices, which operate with two values (ON/OFF), the gradation characteristics are digital gradation utilizing pulse width modulation. Then the input/output characteristics of the device are linear. Therefore, the gamma characteristics required for the projector have to depend on only the gamma table (circuit). In this case, as explained before, at least 14 bits or more are necessary for gradation reproduction. Within 1-frame period (1/60 sec.), switching is required 16,384 times and the response time should be 1 µs. However, with the other system devices, the response time is said to be 15 µs. and 10 bits are the limit of the operation. Therefore, “Error Diffusion Method” is necessary and introduces deterioration of S/N in dark areas as a result as explained later. This is typical of digital gradation and is the same for PDP as well.



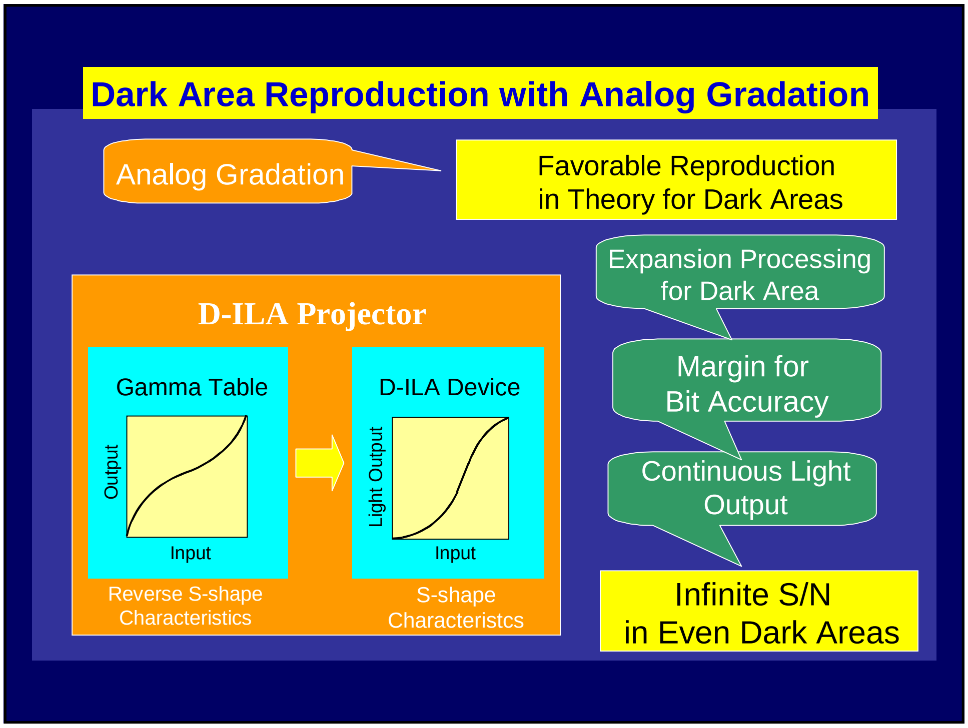
18) Error in digital gradation

"Error diffusion" is a technique to pseudo-reproduce mid-tones. This is done at a cost to the S/N so that insufficient bit depth is complemented. This technique uses the integrating effect in the sense of sight as similar as the dot method and dither method for printing. By diffusing errors from the fixed gradation spatially or temporally, the mid tone is expressed as an average. To help understanding, the mid tones expressed by two values are shown in the diagram as an example. Actually, it is processed so that these patterns are shown at random temporally and spatially. However, this processing causes noise on the screen and extreme deterioration of the S/N, especially in dark areas. Noise in these dark areas is not noticeable in static picture. However, with blinking and movement of visual point caused by eyeball motion, it can be detected. It is especially easy to notice in motion pictures, resulting in eyestrain.



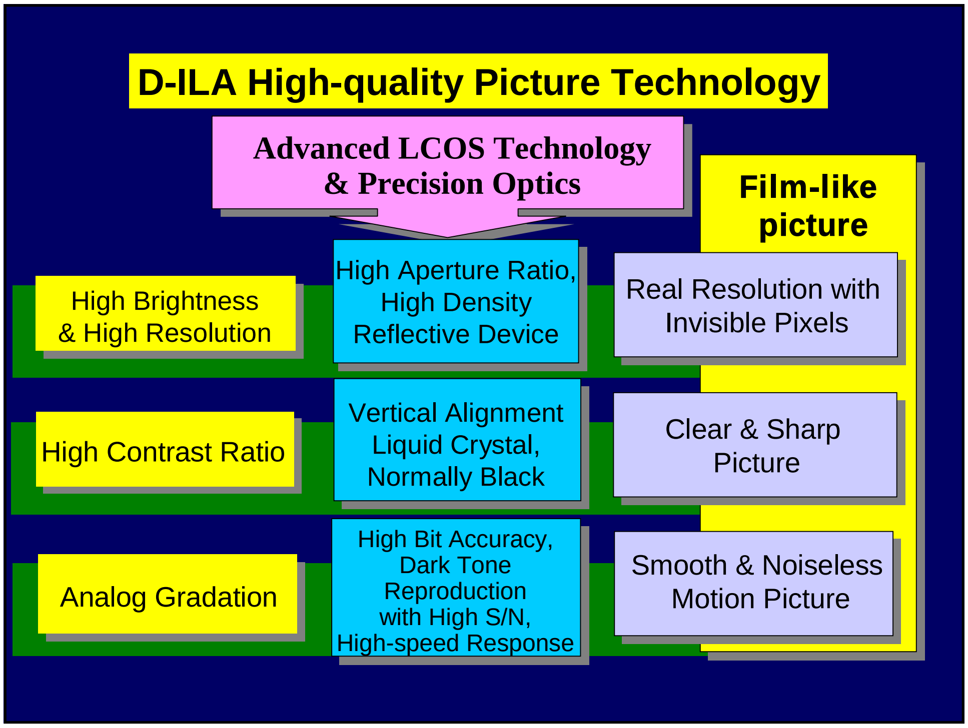
19) Digital Gradation: Deterioration of S/N due to Error Diffusion

The theoretical value of the S/N characteristics due to “Error Diffusion” can be calculated easily because noise amplitude is determined by the minimum quantization step. The figure shows the S/N characteristics when the error diffusion is applied to real 10-bit digital gradation for 14-bit equivalent. No problem is found in bright areas. However, S/N below 20 % dark level suddenly deteriorates to less than 40 dB. For movies where dark area expression is important, this phenomenon cannot be ignored. However, for animation and CG, there may be cases where this problem can be avoided if the deterioration of S/N is taken into consideration during production.



20) Dark area reproduction with analog gradation

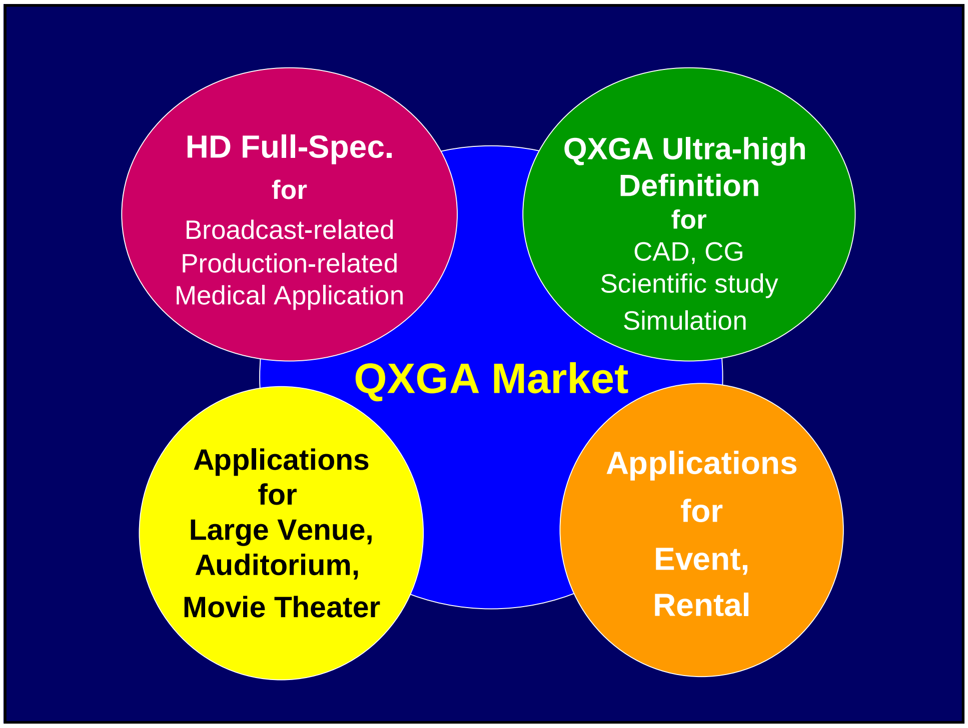
In theory, D-ILA analog gradation, on the other hand, accurately reproduces dark areas. Because, as the D-ILA device has an S-shape response in which dark areas are compressed, the gamma processing has a reverse S-shape response. As a result, the dark area is expanded in processing. So, the bit accuracy has more margins and gradation accuracy is good. As the output light is continuous light without switching, S/N is infinitely high for any gradation without deceiving the eyes. Thus, in principle, unlike digital gradation, D-ILA's analog gradation enables high-quality dark area reproduction.



21) D-ILA high-quality picture technology

The D-ILA high-quality picture technology for QXGA is summarized here.

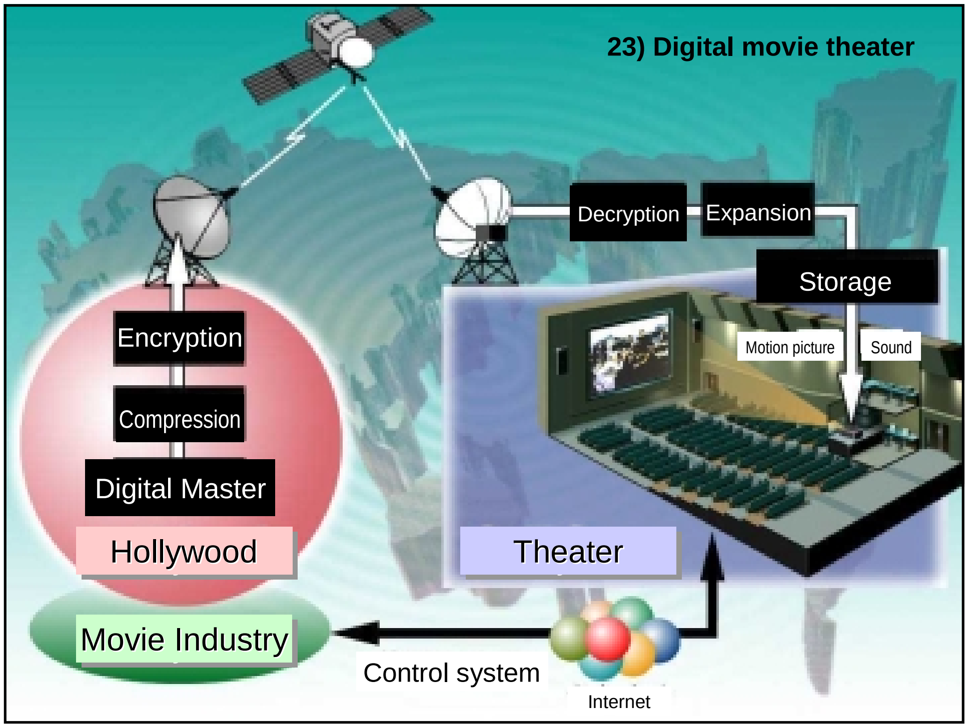
The high picture quality of D-ILA is derived from advanced LCOS technology and a high-precision optical system. What supports this high picture quality is high brightness, high resolution, high contrast and analog gradation. High brightness and high resolution are achieved using a reflective device with a high aperture ratio and high-density pixels, providing real resolution with invisible pixels. High contrast is achieved using vertical alignment liquid crystal of normally black operation and a high-precision optical system, providing clear and sharp pictures. Analog gradation makes it possible to reproduce dark areas with high S/N by using the high-bit accuracy. In combination with the high-speed response of the vertical alignment liquid crystal, this D-ILA makes it possible to reproduce smooth, noiseless motion pictures with high-definition and film-like picture quality.

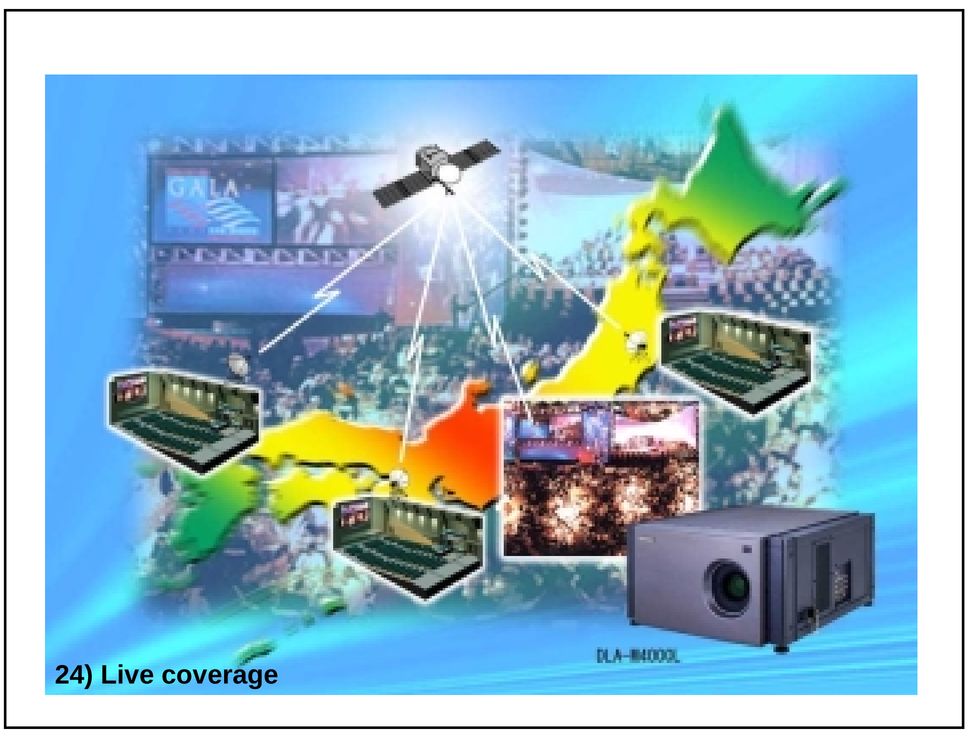


22) QXGA market

The QXGA market includes various fields where full HD specifications are required — including broadcast-related, production-related and medical fields. Also there are sectors in the CAD/CG field, scientific research and simulation markets, which require the previously unavailable ultra-high definition of QXGA.

Applications include digital movie theaters, large venues, auditoriums, sporting and other events such as the World Cup, and rentals. Here are some examples of various applications.


23) Digital movie theater
Encryption
Compression
Digital Master
Hollywood
Movie Industry
Decryption
Expansion
Storage
Motion picture
Sound
Theater
Control system
Internet


24) Live coverage


25) Championship game