TV Application of New Type Display : Microdisplay

Chang-Wan Hong,
DTV group, Visual Display Division
Digital Media network, Samsung Electronics Co.

Introduction

It has been demanded Digital Displays such as video Image, graphics, and all kinds of display devices for communicating a number of information and data in rapidly changing communities. Display panels have been used in TV, computer, measurements system and control system in industry and science. Especially, display is used in the field of traffic systems, aerospace, military as well as in consumer electronics. In these days, 3D-display has been developed for communications with realism and vivid expressions. In the High information technology period, people want to have display with high resolution, large size, less weight and slim depth. Therefore, lots of new type display has been developed for satisfying those demand. One of the promising new types of display is flat panel display. Flat panel display has good advantages such as slim depth and less weight, so, it is expected FPD is core technology in the future multimedia period. There are couple of type in flat panel display, for example, TFT-LCD, PDP(plasma display panel), FED(Field emission display) and LED(lighting emission display). Another new types of display field are projection systems using microdisplay. Microdisplay projection TV has advantages than CRT projection TV, however, price is expensive than CRT projection TV. Right now, the market share of CRT projection TV is bigger than that of microdisplay projection, however, In the future, microdisplay projection market share should be increased. Here, I would like to examine trend of technology and market in microdisplay.

1. Aspect of Technology

MD(Microdisplay) is micro device which has millions pixel in around one inch panel.

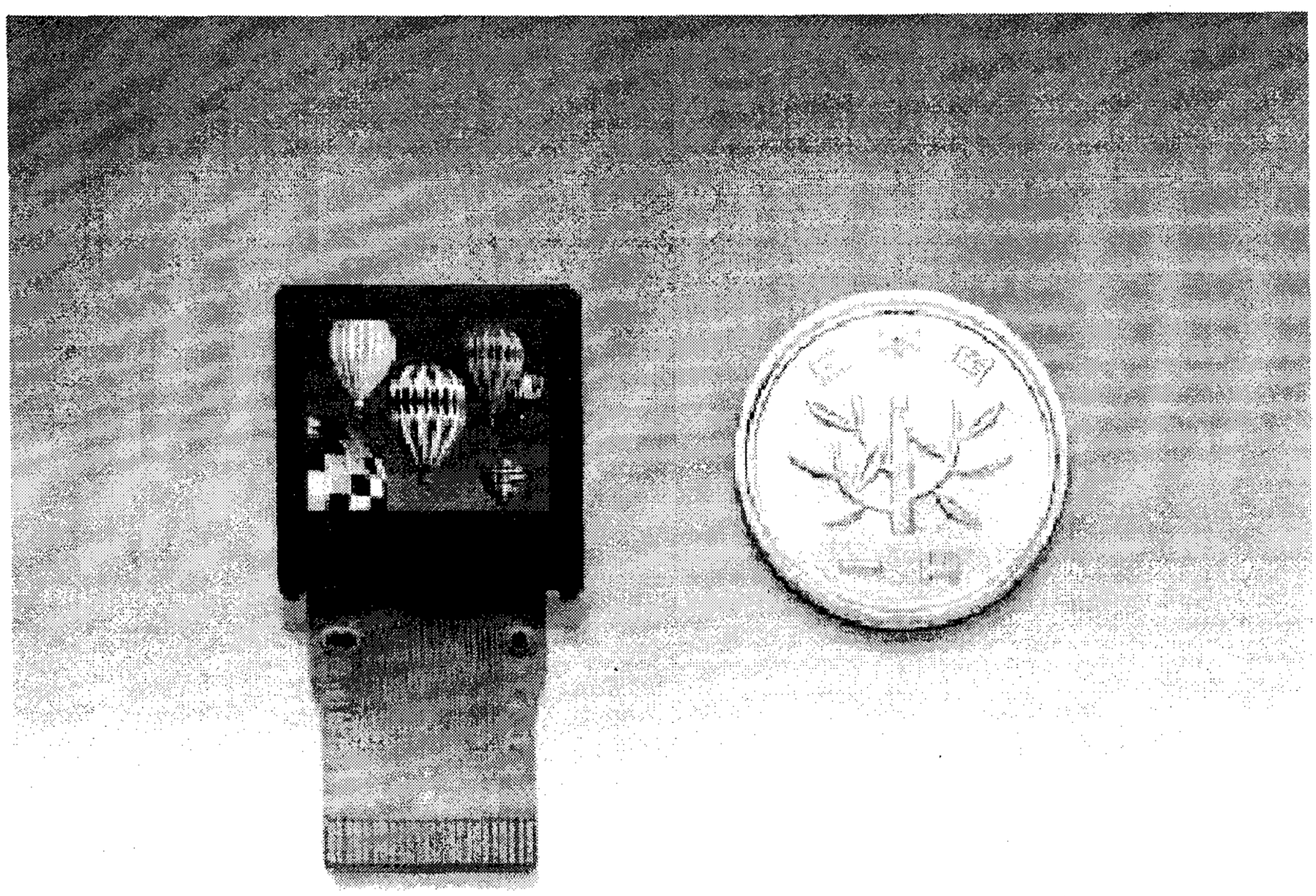
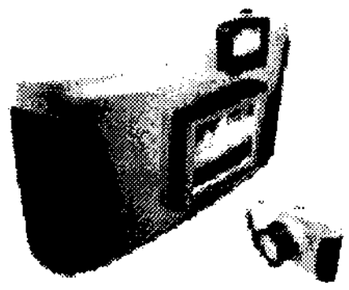


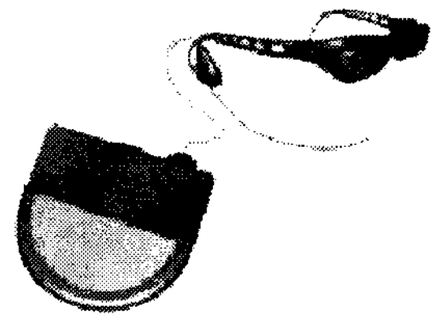
Figure 1. Example of Microdisplay : 0.55" LTPS(Low Temperature Poly Silicon) Panel

In General, MD is used in cell phone display and head set display, also, projection display with reflected or transmisive types. The example of near-to eye product using MD is view finder and kind of head sets and wearable display, for example, HMD(Head Mounted Display) and hand sets such as cell phone(Figure 2).

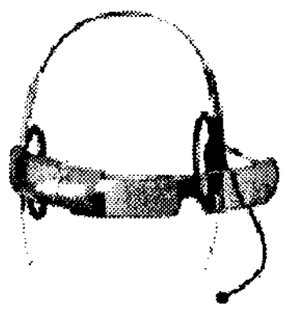


Viewfinders for digital camera and camcorders

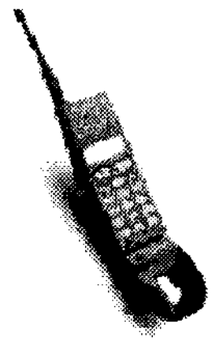
PDA/Internet Appliances



DVD Headsets



Headsets for Wearable and Notebook PCs



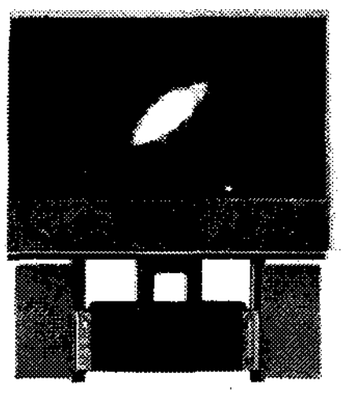
Advanced Cell Phones

Figure 2. Near-To-Eye Display Products using microdisplay

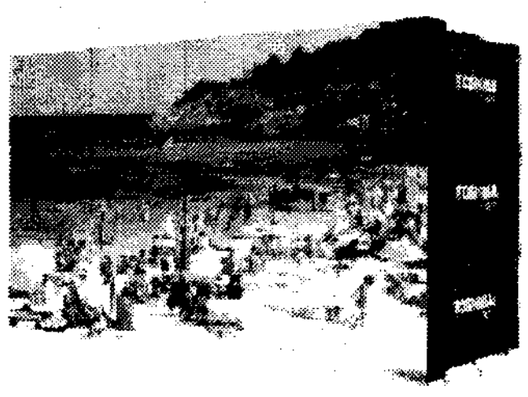
Another application of microdisplay is projector and projection system. As the performance of microdisplay has been improved, for example, high resolution, high contrast ratio, good uniformity, microdisplay is one of promising display for next generation TV and monitor over 40" size (Figure 3).

Electronic Picture Frame

Personal Projectors

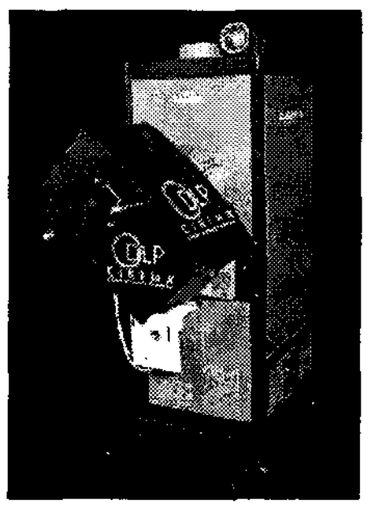


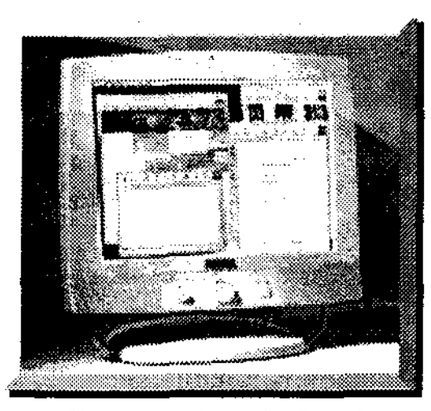
Rear-Projection HDTV



Video Walls

Digital Cinema





Rear-Projection Monitors

Figure 3. Projection Products using microdisplay

Microdisplay can be classified HTPS(High Temperature Poly-silicon), reflective LCOS(liquid Crystal On Silicon) and reflective MEMS(Micro Electro-Mechanical System) by projecting types. All of those have advantage and disadvantage in structure of optical engine and driving method of panel and image improving algorithm. Here, I would like to examine three types of microdisplay more details.

1.1 Transmisive type HTPS(High temperature Poly Silicon)

One of transmissive type in MD is HTPS(High Temperature Poly Silicon). HTPS is use in most projectors and projection systems. In HTPS, quarts substrate is used for circuit board instead of silicon wafer. The poly silicon layer is made from amorphous silicon layer which is made by CVD(chemical vapor deposition) on substrate and heat treatment in 800~1,000℃. Poly silicon has a good mobility than amorphous silicon, so, poly silicon layer has enough electrons for operating liquid crystal layer. And liquid crystal between transparent electrodes control transmitted light from back light for making image. Even transmisive HTPS has been developed for projection systems, it has limitation of structures for improving performance. One of the main problem is aperture ratio(percentage of light passing area). HTPS is consisted of two parts, on screen transistor and address line. And then, those part occupied part of space in display pixel. So, those part block light pass way, and decreased brightness. If pixel size is enough large, it doesn't matter, however, if pixel size is below 10㎛, brightness is abruptly decreased caused by aperture ratio. In order to make high-resolution panel with cheap price, panel size should be small size, and then, pixel size should be small as well. There are limitation for decreasing transistor size in pixel, so aperture ratio should be decreased. To solve that problem, micro lens array is applied to HTPS, as a results, brightness is increased even small aperture ratio, however, price is very expensive. One of best solution for making panel cheap price, LTPS(Low Temperature poly silicon) methods is applied to microdisplay. However, in case of LTPS, mobility is not good compare to HTPS.

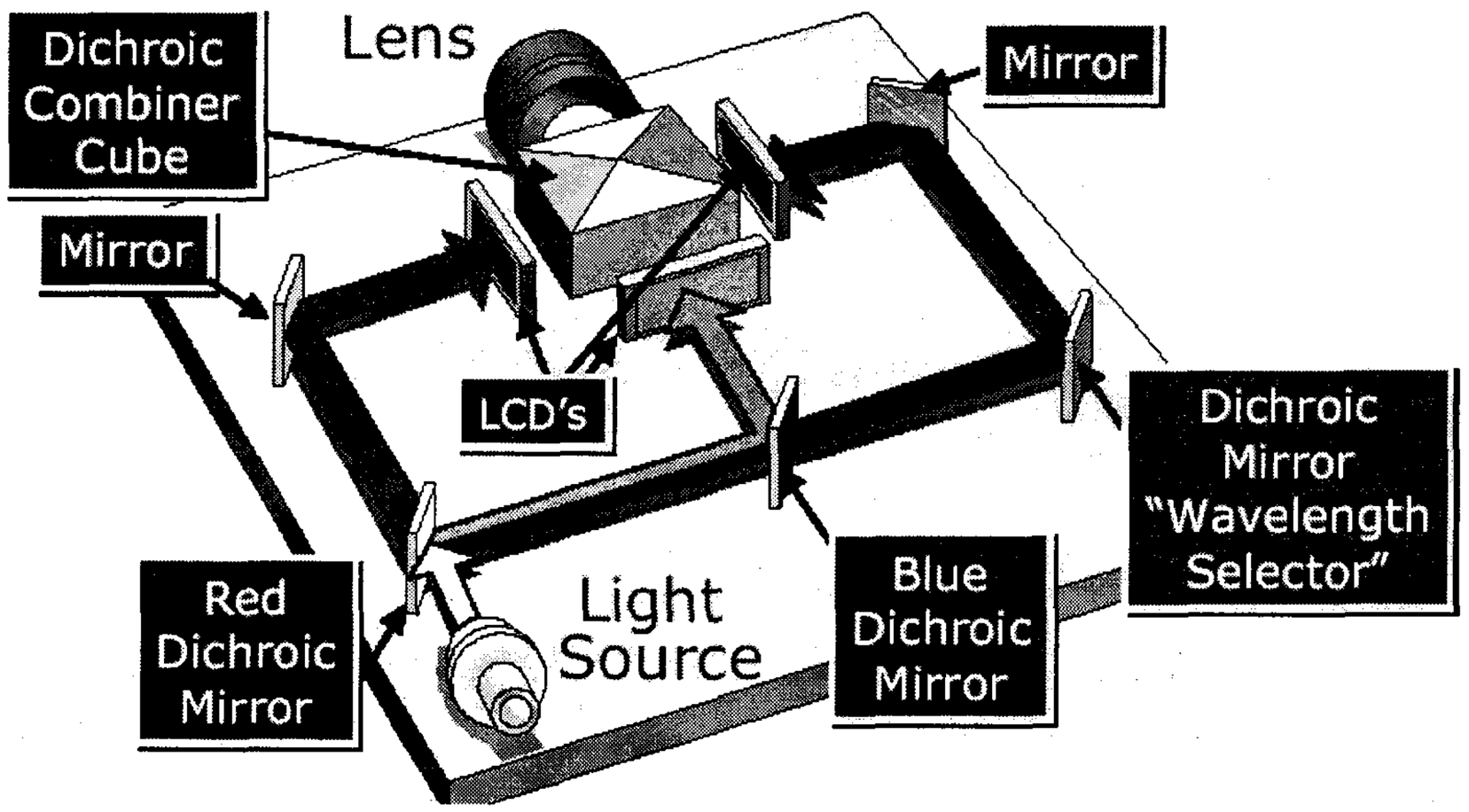


Figure 4. Structure of light engine in transmisive type HTPS(High Temperature Poly Silicon) Microdisplay Projection system.

Figure 4 shows typical color separation/recombination method in microdisplay projection system using tranmisive type HTPS. White Light from metal halide lamp is separated by dichroic filter to red, green and blue and transmitted light through HTPS is recombined by color prism. At the first time, HTPS has been developed for projection system first, so, HTPS has a good reliability for mass production. However, couple of problems in performance found out in HTPS, such as low aperture ration, separating pixel by masking and low resolution, It is believe that performance will be improved for full HDTV sooner or later.

1.2 Reflective type LCOS(Liquid Crystal On Silicon)

LCOS is one of semiconductor based technology using silicon wafer for operating liquid crystal on back plane. The structure of LCOS is consisted of back plane, liquid crystal on back plane and ITO glass on liquid crystal and glass substrate on it. Reflective LCOS has good mobility than HTPS because back plane is single crystal silicon and aperture ration is high because all electronics below reflective top electrode. Compare with DLP technology, When LCOS was developing at the first time, it is expected that LCOS has merit of low price and easy to make high resolution and high performance image is expected, however, so far, there are problems in low uniformity, low contrast ratio and

low product yield. Many company have been trying to improve performance and reliability and product yield. It is necessary to use polarized retardation filter in case that twisted nematic liquid crystal is used in LCOS display. Polarized retardation filter improved contrast ratio and make more clear color, however, polarized retardation filter has critical problem in heat deformation. Heat deformation of polarized retardation filter is one of problem should be solved in LCOS system.

There are two types of operation method in LCOS, one is digital, another one is analog method. The back plane of analog operating system has DRAM memory based circuit structure (Figure 5). In general, the DRAM structure is consisted of transistor and capacitor in each pixel. Capacitors make stabilize the system with keeping constant voltage between liquid crystal. Actually, DRAM structure is same structure of active matrix LCD and each pixel transistor is connected to row and column operator and address line. The back plane of analog operator controlled by voltage. If operating voltage is maximum or minimum, illuminated light will be reflected all or will not be reflected at all. Of course, half voltage reflected half of illuminated light. Applied operating voltage is depended on design of back plane, liquid crystal mode and cell gap. Sometimes operating voltage has up to 18V, and analog voltage has positive and negative DC components for protecting liquid crystal damage.

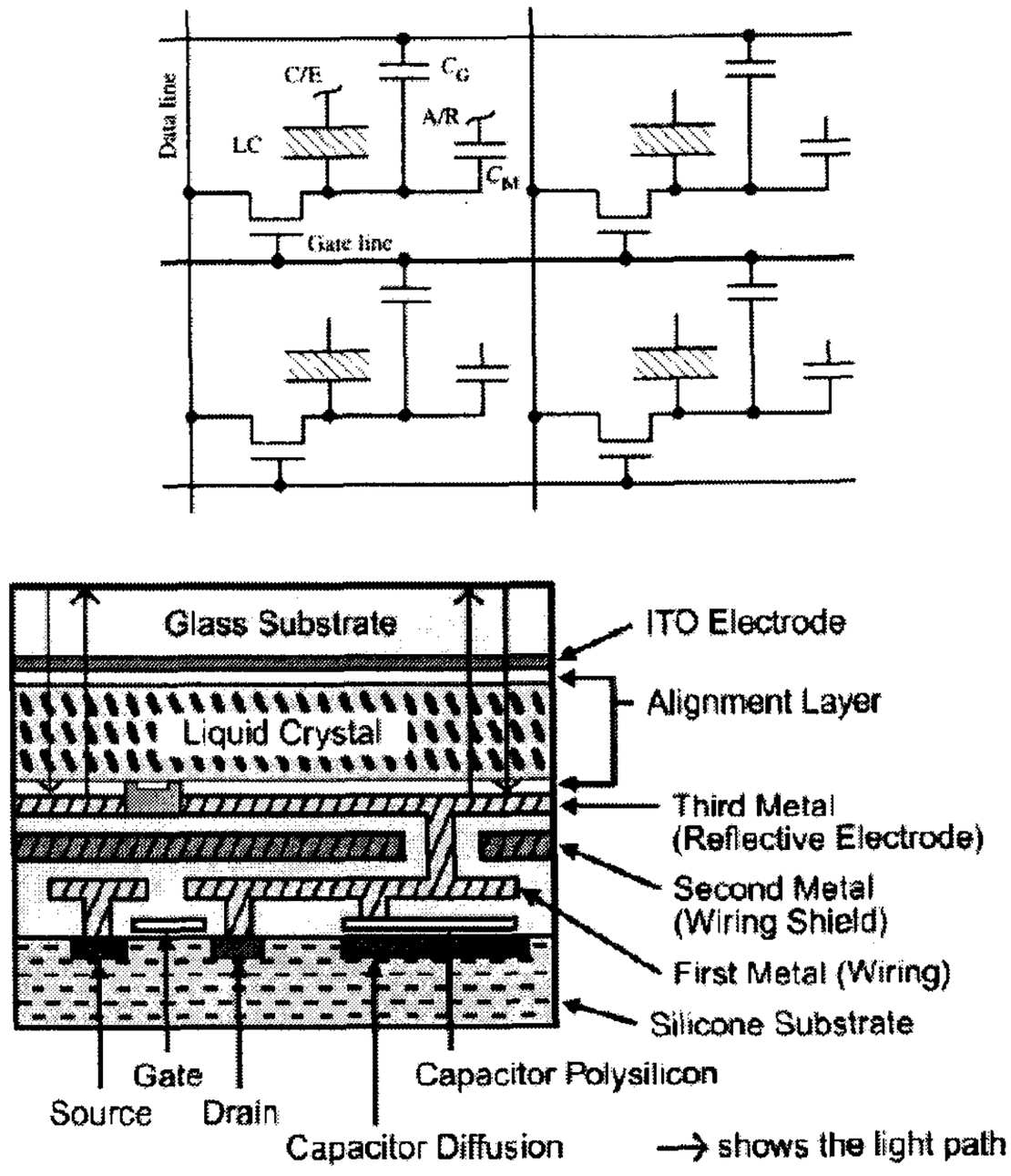


Figure 5. The schematic diagram of active matrix DRAM type Analog LCOS Back plane

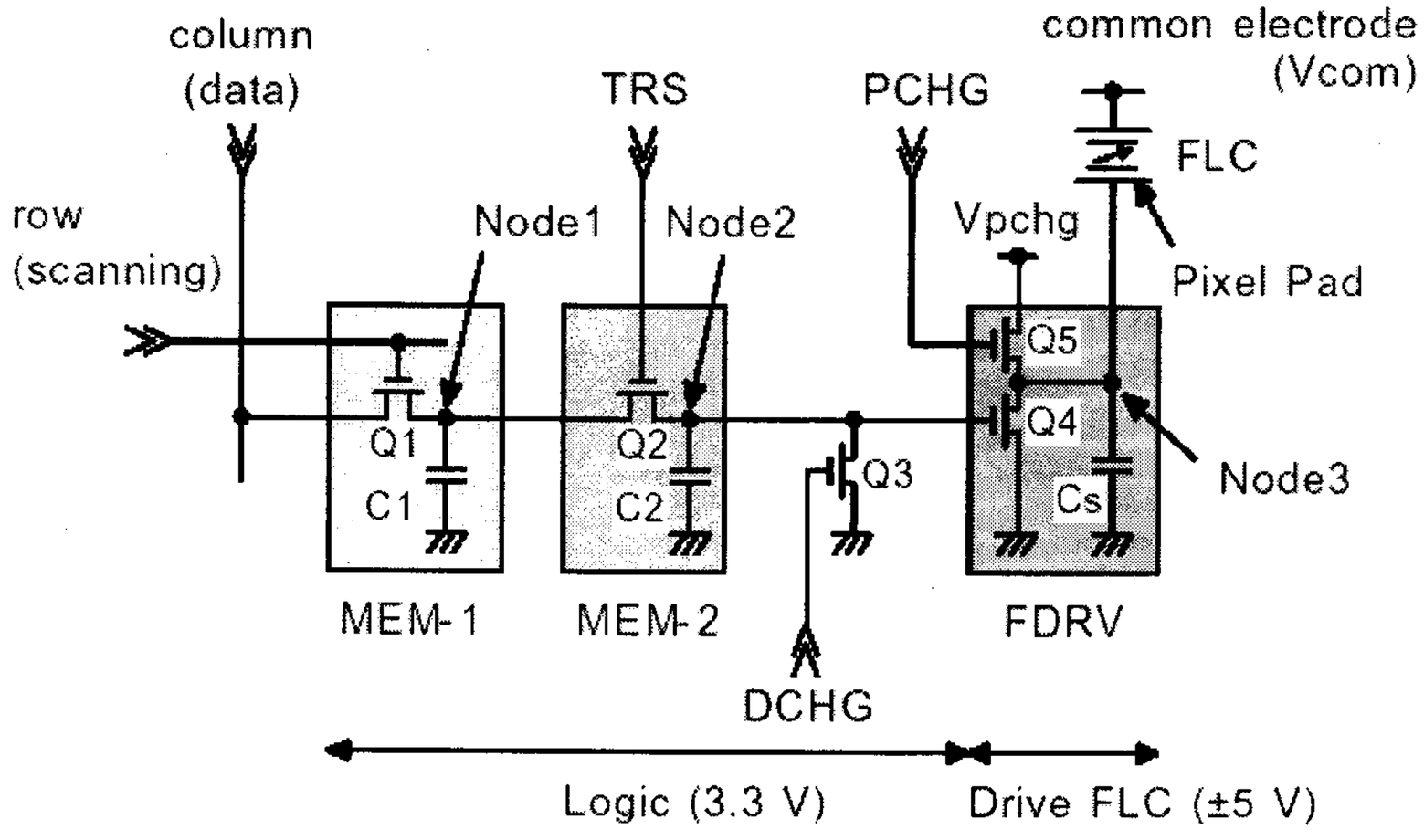


Figure 6. The schematic diagram of SRAM type Digital LCOS Back plane

Basically, back plane of digital operation uses four or six transistor in the below of each pixel and has SRAM memory structure (Figure 6). SRAM structure don't need capacitor and just on-off voltage values.

In gray scale, voltage is changed gradually in analog back plane structure, and pulse with modulation technology is used in digital back plane structure. For operating middle scale gray level, pixel is operated on and off rapidly in the given period. So, if pixel pulse is fast enough, brightness is increased. All kind of SRAM structure is digital operating system can be worked by signal processing method.

According to panel number, There are three types of light engine in LCOS systems, three panel, two panel, single panel systems. More details, three panel system can classified by four method, which is, three PBS system, Philips prism and color-quad(color-link) in on-axis system and off-axis system(Aurora). Also single type LCOS system has four method, color wheel, color switch(color-link), color scrolling(Philips) and color filter(JVC) method.

In general mechanism of color separation/recombination in three panel, white light from lamp is separated to red, green and blue, and then, separated color is reflected on each panel using PBS and recombined using color prism. The color filter method, one of single panel LCOS system is applied to TFT-LCD monitor and TV. Each pixel has sub G, G, B

color pixel, these sub pixels show one color pixel. Only one company (JVC) choose color filter method in single panel LCOS system. In this case, holographic color filter is applied to color filter method.

Another method for making color image is, FSC(Field-sequential color), which can be applied to all kinds of single panel system in projection. In general, the color wheel is used for color separation/recombination and color images are made from continuous coming R, G, B images (Figure 7). The operating speed for single panel should be fast from three time to six times than that of three panel systems in FSC operations, otherwise, color image is broken on screen. Light emitting diode is used in the near-to-eye system and metal halide lamp is used in projection system as a light sources. Color wheel made pulsed R, G, B light continuously. FSC technology made color image with keeping high resolution in single panel system, however, in low frequency color sequence, color break-up is shown. For solving color break-up problem, we need high frequency color sequence, however, operating in high frequency color sequence is difficult because operating method is so complicated in single panel system. Color break-up can be seen easy in large size screen than near-to-eye display because of flickering of eye and peripheral vision.

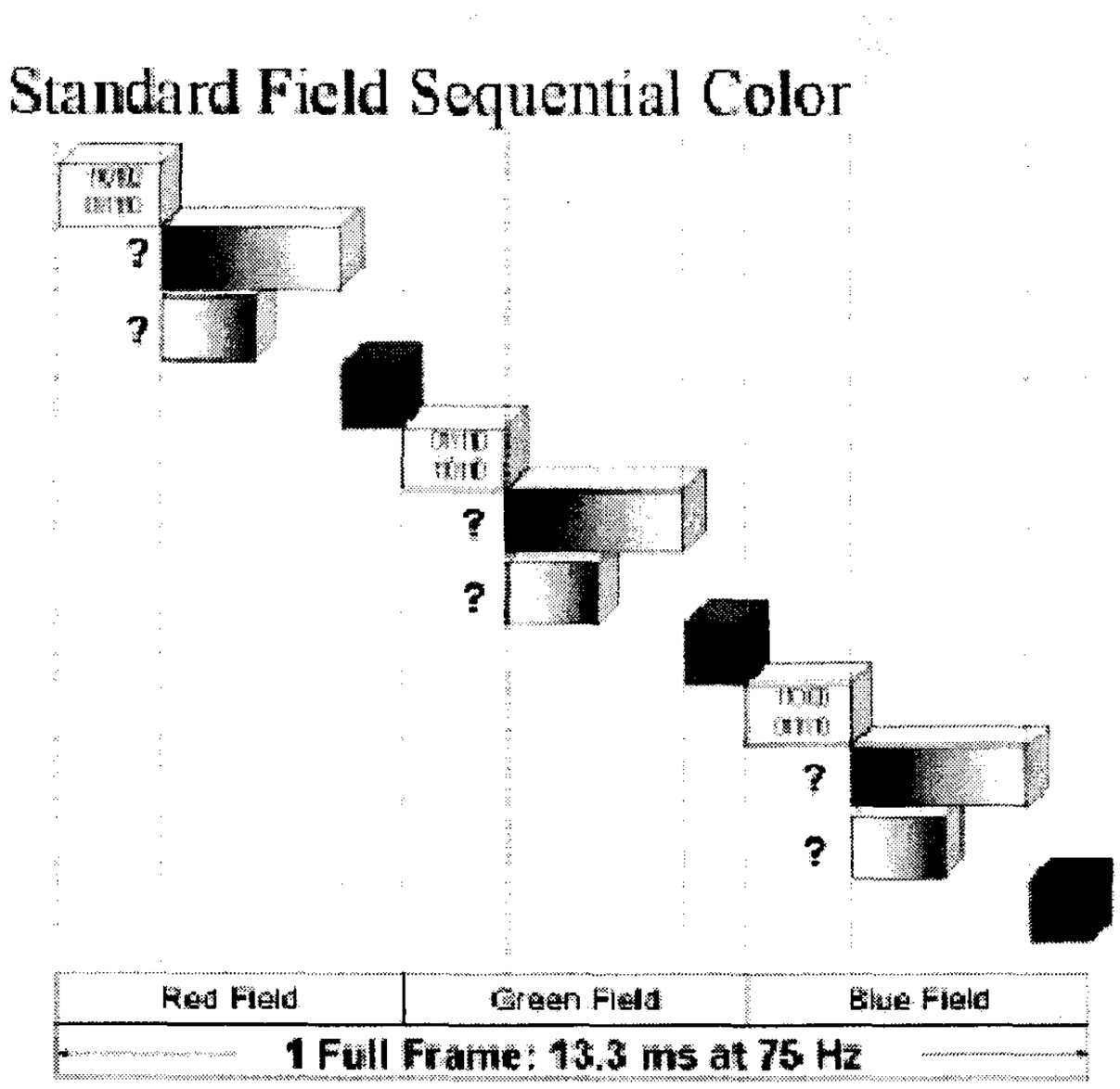


Figure 7. The principle of FSC(Field Sequential Color) Mechnism

Figure 8 shows typical three panel LCOS light engine for color separation and recombination. For separating red, green and blue, dichroic filter is used same as HTPS optical light engine. And separated R, G, B is reflected on panel using three PBS and reflected image on panel is recombined using color prism.

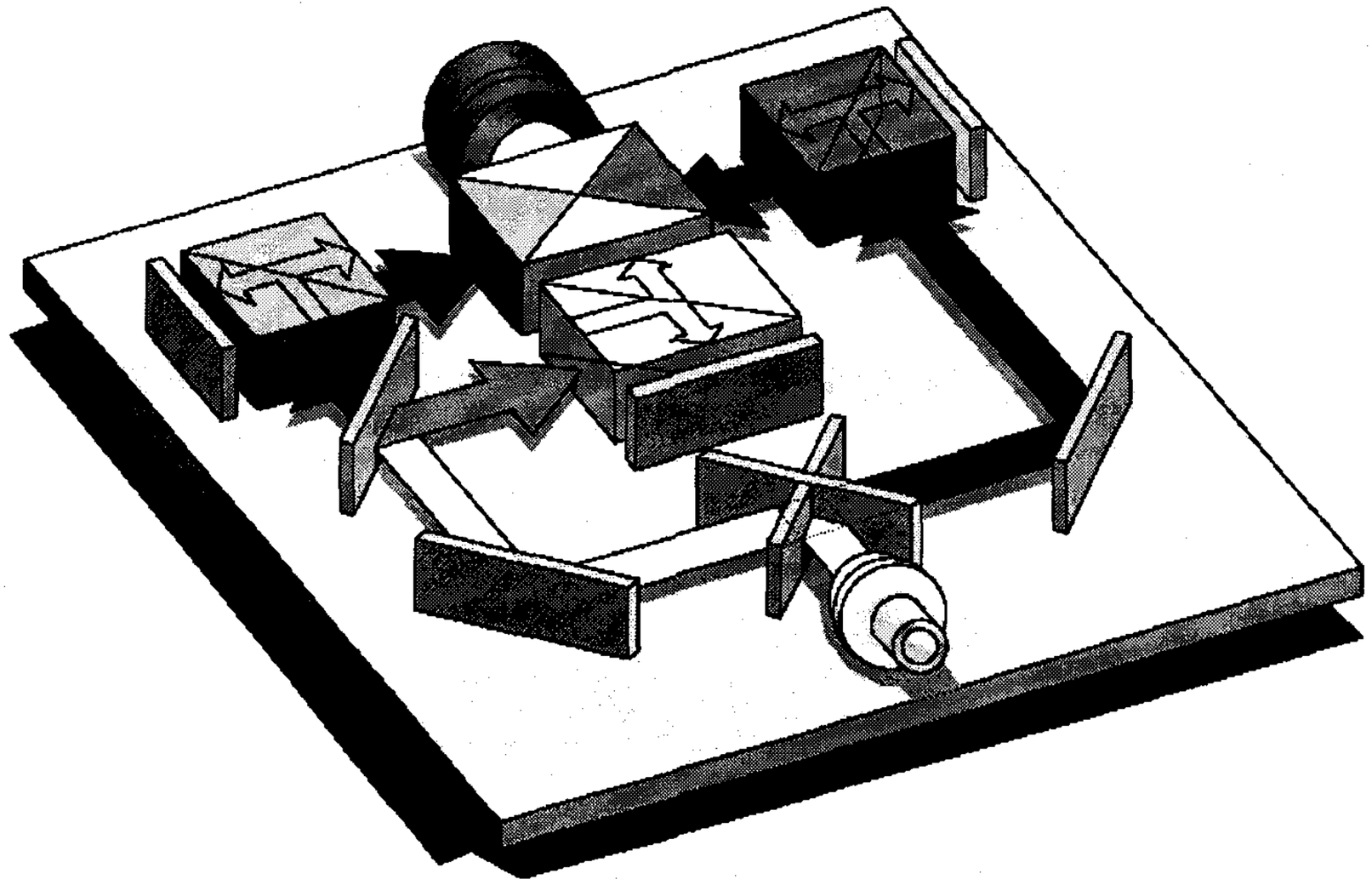


Figure 8. The schematic diagram of three PBS optical light engine using reflective LCOS(Liquid Crystal On Silicon) microdisplay.

1.3 Reflective MEMS(Micro ElectroMechnical System)

DMD(Digital Mirror Device) is one of reflective MEMS panel, and millions of aluminum mirror on DMD chip reflect light to projection lenses at on-states and reflect light to dummy stop at off-states as shown in figure 9. Electrostatic force interaction is worked between york and memory cell. Applied voltage is 5V and operating angle of mirror is ±12 degree In HD 2 chip. In DLP(Digital light Processing) optical engine, light incident with 20 degree and light reflected to projection lenses on states and pixel shows brightness spot in case of on-states and in case of off-states, light reflected with 40 degree to dummy stop and pixel show black spot.

Even DMD had high reflectivity, high contrast ratio and fast response time than HTPS and

LCOS, price is very expensive because lot of semiconducting process is working for making DMD chip. In general, DMD chip is used for single panel optical engine using color wheel, which is simple and cheap than three panel system, however, color break-up is shown in low frequency operation

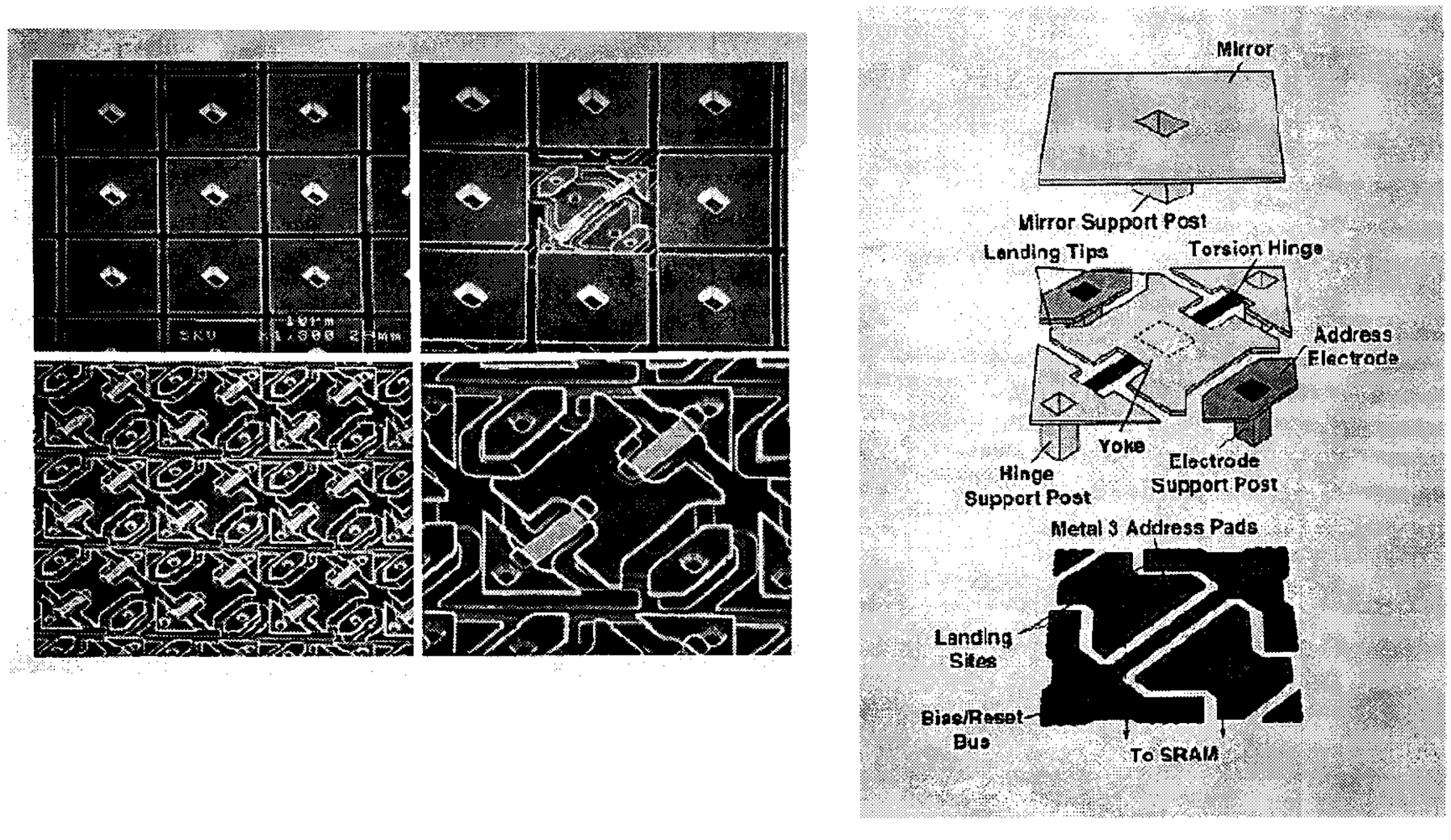


그림 9. The schematic diagram of DMD structure

For gray scale operation, PWM(Pulse Width Modulation) method is used in DLP systems. PWM method controlled on, off switching time width. PWM divide Video field time as bit time for express the gray scale(Figure 10). The gray scale resolution is 8 bit, 256gray/24 bit color at 60 Hz image frame in single or two chip DLP system, and 10 bit 1024 gray/30 bit color in three chip DLP system. And if TI's algorithm is applied to DLP, gray scale resolution in digital image is increased to effective 13 bit, 8,186 gray/39 bit color. The performance of (DLP Cinema™) projector developed at TI shows effective 42 bit color(14 bit, 16,384 gray) at 24 Hz image frame.

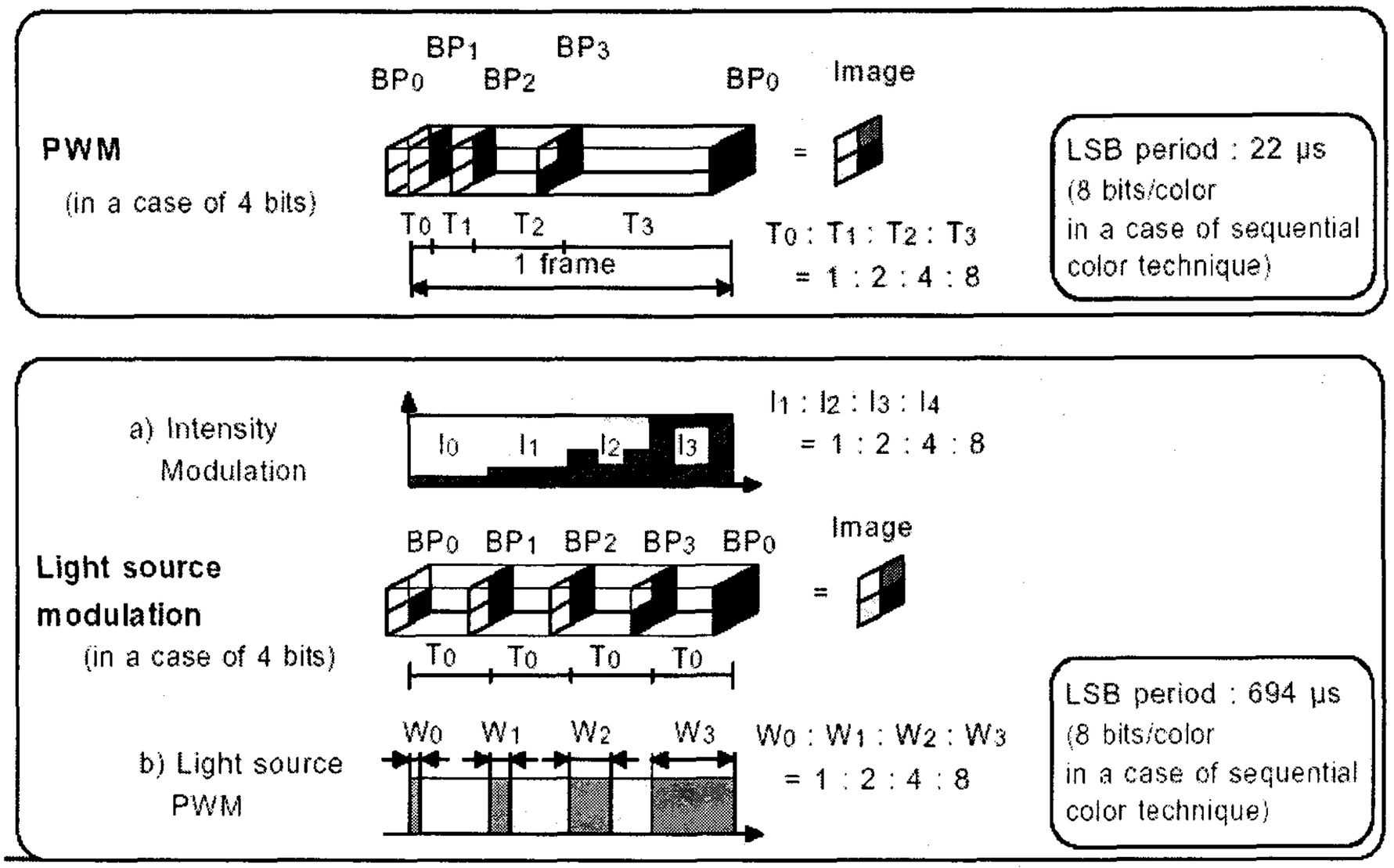


Figure 10. Basic principle of PWM(Pulse Width Modulation)and light Modulation method

Especially, Polarized light don't need in DLP optical engine because DMD is simple reflection type and response time of DMD is so fast that DLP optical engine can be designed as single/two panel system. In case of single panel DLP light engine, color wheel is used for color image and minimum specification for color operation is 24bit color and 300Hz color frequency. Usually, three panel DLP system is applied to cinema projector with high brightness and wide range of color coordination. Figure 11 shows structure of single panel DLP light engine using color wheel.

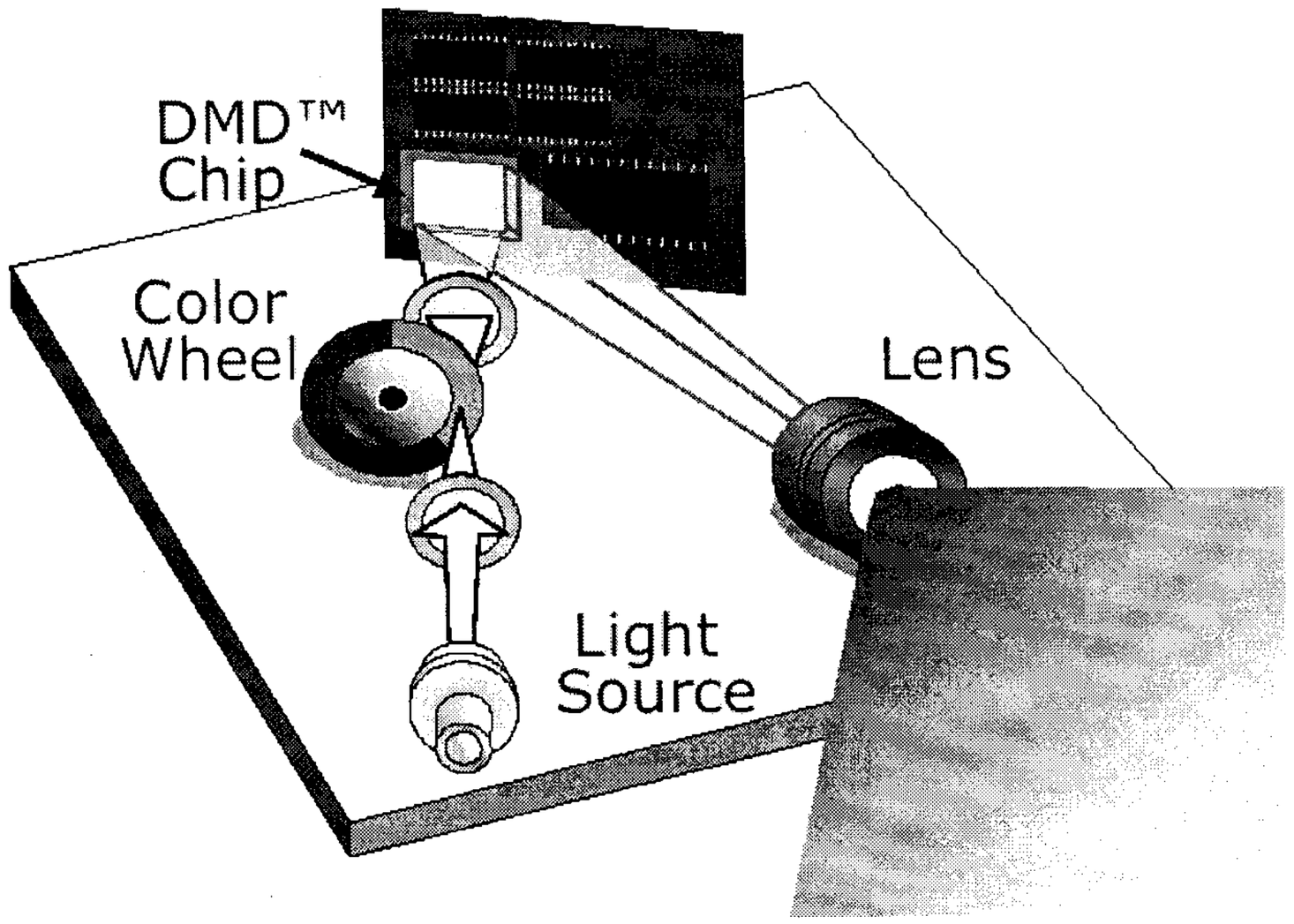


Figure 11. The schematic diagram of Single Panel DLP light engine using color wheel.

The specifications of each microdisplay device are shown in table 1. Comparing with devices itself, performance of DMD is better than others, however, optical engine has advantage and disadvantage in each other. In case of single panel DMD and LCOS system, even there is price advantage, there are couple of problem have to solve in technical aspect such as brightness, color break-up and so on.

Table 1. The specifications of Microdisplay Device

Item	DMD	HTPS (Epson)	LCOS(JVC)
Resolution	1280x720	1280x720	1400x1050 (1920x1080)
C/R	1500:1	400:1	1000:1
Response Time	□□□□sec	15 msec	16 msec
Panel Size (inch)	0.8	0.9	0.72(active, 0.6")
Pixel Pitch	13.68□m	15□m	10.4□m
Operating Panel #	Single	Three	Three
Color management	Color Wheel	X-Cube	Three PBS system

1.4 Market Trend and Expectations

MD projection market is gradually increased because performance is better than before and has been improving day by day and set price is decreasing continuously. I can't say which microdisplay device has better performance than others. I just can say there are advantage and disadvantage according to MD device. According to research of Techno Systems Research Co. in Japan, the market share of HTPS in MD projection is large than that of DLP and LCOS and market share of DLP is increased gradually, and LCOS needs more development for reliability and increase the product yield.

Remarkably, market share of home theater projector is rapidly increased than business projector. That means home theater projector market share is enlarged in the future and main MD device is HTPS. So far, the market share of CRT is large in RPTV market, and it's trend that DLP and LCOS is more favorable than HTPS in RPTV market. This result might be caused from price decrease in microdisplay systems.

Table 2. Expectation of Market Share according to Microdisplay Device (K Units)

Market	Device	2001	2002	2003	2004	2005
Front Home	HTPS	25	170	335	1,805	4,705
	DMD	3	10	100	400	1,200
	LCOS				22	80
	Total	28	180	435	2,205	5,905
Front Business	HTPS	1,066	1,095	1,190	1,552	1,730
	DMD	280	400	650	600	600
	LCOS	4	5	30	38	60
	Total	1,350	1,500	1,870	2,190	2,390
Rear Business	HTPS	25	23	22	22	22
	DMD	12	23	28	30	33
	CRT	2				
	Total	40	46	50	52	55
PDP Business		208	286	430	575	650
RPTV	HTPS	50	60	120	150	170
	LTPS	10	10	40	60	70
	DMD	1	20	90	200	500
	LCOS	1	5	20	90	360
	CRT	2,238	2,405	2,330	2,200	1,700
	Total	2,300	2,500	2,600	2,700	2,800
PDP Home		142	320	760	1,520	2,130
종합	HTPS	1,166	1,348	1,667	3,529	6,627
	LTPS	10	10	40	60	70
	DMD	297	453	868	1,230	2,333
	LCOS	5	10	50	150	500
	CRT	2,240	2,405	2,330	2,200	1,700
	TOTAL	3,718	4,226	4,955	7,169	11,230

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