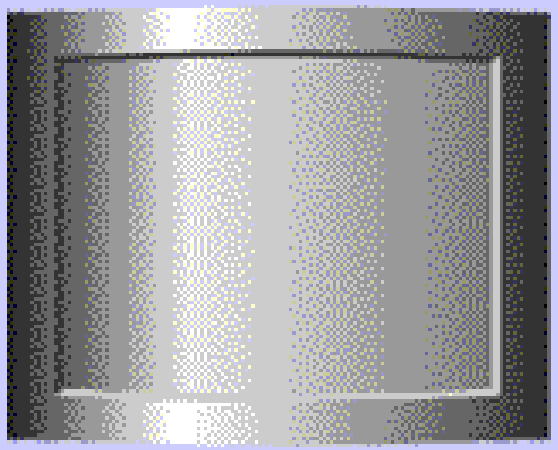
Display Technologies:

- **CRT and Flat-Panel Display**
  - Cathode Ray Tube (CRT) is the display technology of today
  - Flat-Panel Display is the technology of tomorrow
- **Flat-Panel Display Technologies**
  - There are many kinds of flat-panel display technologies
  - *Liquid crystal display* (LCD) and *plasma display* are the super stars
- **LCD is the Display of Many Choices**
  - The evolution of LCD
  - The wide LCD applications
  - The principles of LCD technologies
  - The future LCD applications
- **Plasma Display for Wall-Mounted Display**
  - The home theatre
- **Other Dark Horses**
  - *Silicon microdisplay*, *digital light processing, organic LED, ...*

Cathode Ray Tube (CRT):

- **CRT Þ 106 years old**
  - **The first CRT was built in 1896. But until very recently, most AV and data communication devices still used CRT monitors as their main display devices**
  - **It sold more than 100 million units in 2001**
  - **It has conventional 4:3 ratio and 16:9 HDTV ratio**
  - **However, CRT is bulky, requires high voltage for the emission of electron beams, and it is difficult to slim-down the size**
  - **Typical size is from 14” to 34” in diagonal**



Sony 34” Direct-View CRT:

- Display area 34”
- Aspect ratio 4:3
- Resolution HDTV
- Contrast 200:1
- Colors 16.7 million

- *Luminance 200 cd /m2*
- *Power 180 W*
- *Weight 83kg*
- View angle 160 degrees
- Cost ~US$1,000

Flat-Panel Display Technologies:

- **CRT and Flat-Panel Displays**
  - CRT is very “cost-effective” for 15” to 30” display size
    - » ~US$40 for 20” CRT (or US$2 per inch)
  - Flat panel display technology provides more diversity and can compete CRT in small and large display size.
- **Characteristics of flat panel displays**
  - thin and flat (1”)
  - low voltage operation and low power consumption (mostly)
  - high resolution and/or large size
- **Types of flat panel displays**
  - LCD (liquid crystal display) for small display size
  - PDP (plasma display) for large display size
  - LED (light emitting diode) (OLED)
  - EL (electro-luminescent display)
  - VFD (vacuum fluorescent display)
  - DMD (digital micro-mirror device) for projection
  - FED (field emission display)

Liquid Crystal Display (LCD):

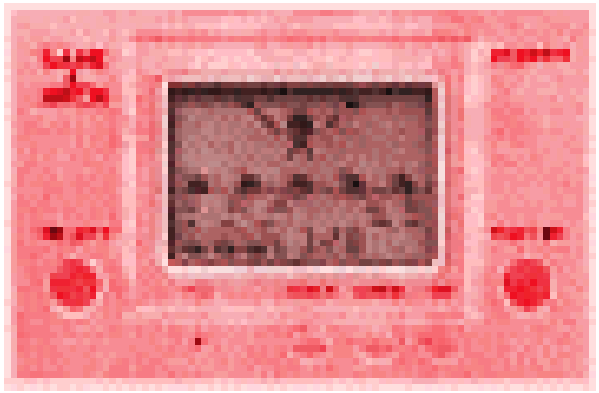
- **LCD Þ 31 years old**
  - **The first LCD was built in 1971.**
    - » **Initially for the number and character displays**
    - » ***Twisted nematic (TN) LCD***
  - **In the 1980's, LCD started to emerge as a small-size TV**
    - » **LCD is used for graphics and video display**
    - » ***Super twisted nematic (STN) LCD***
  - **In the early 1990's, LCD started to challenge the CRT**
    - » **LCD is used in notebook computers**
    - » ***Thin-film-Transistor (TFT) LCD***
  - **In the late 1990's, when will the LCD replace the CRT?**
    - » **28" direct-view LCD monitors (*a-Si TFT technology*)**
    - » **300" projection LCD monitors (*poly-Si TFT technology*)**
    - » **0.5" wearable LCD monitors (*silicon microdisplay*)**
  - **There are new competitors**
    - » **50" direct-view plasma display**
    - » **300" projection electro-mechanical display (DMD)**

The evolution of Sharp LCD:

1973
first calculator with an LCD for the *numerical* display

1975
Mass production of LCD clocks for the *numerical* display

1979
Japanese/English translator with dot-matrix LCD for the *alphanumerical* display



1980
Nintendo's Game Watch for the *character* display, sold 10M units

The evolution of Sharp LCD (since 1980):

1982
A word processor with an LCD for the *Kanji character* display

1987
A electronic organizer with an LCD for the *Kanji character* display

1987
3” color TFT LCD *TV*

1989
LCD *video* projector for up to 100”

The evolution of Sharp LCD (to 1996):

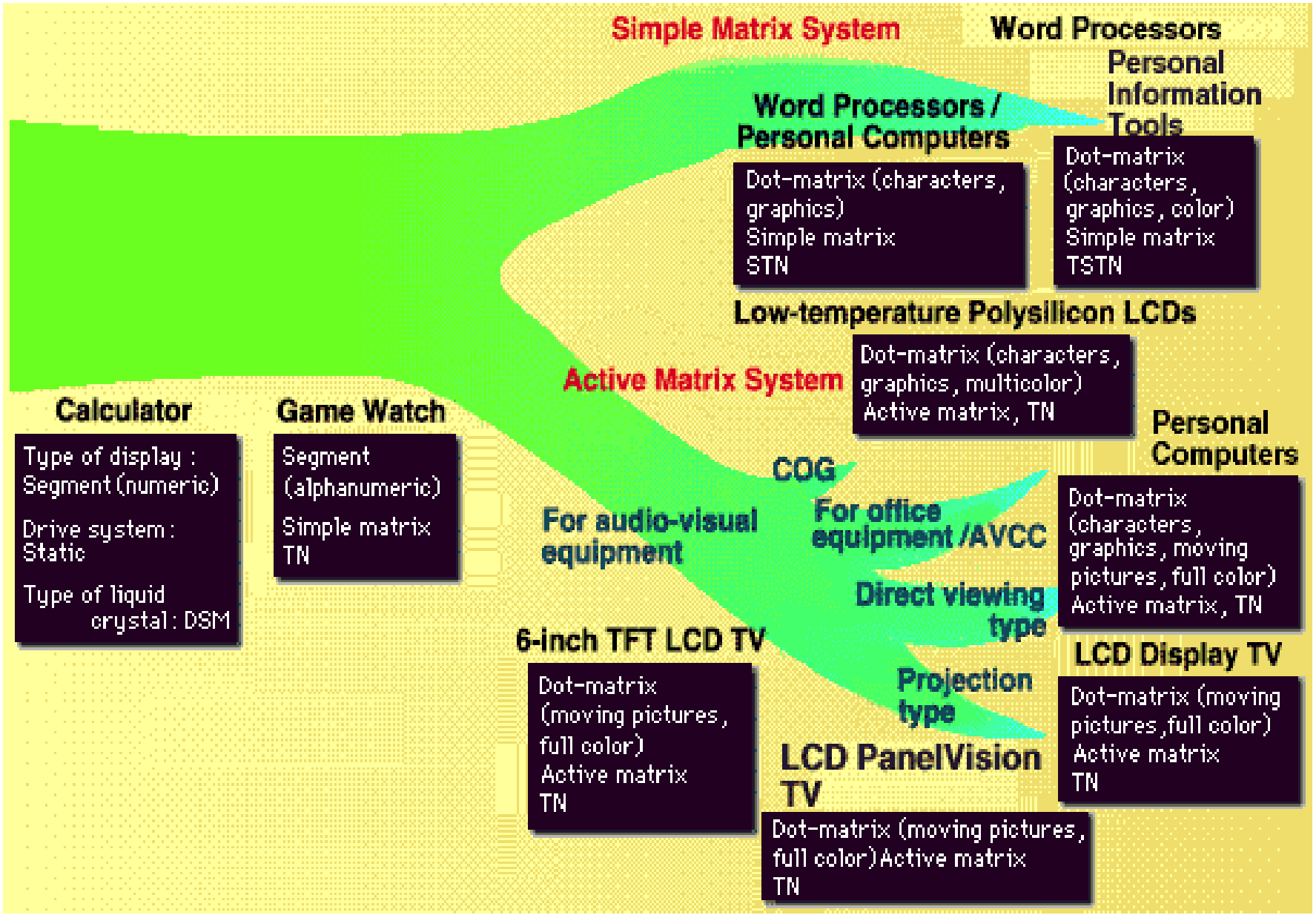
1990
Laptop computer with 10” STN color LCD

1992
A 4” LCD Camcorder, ViewCam.

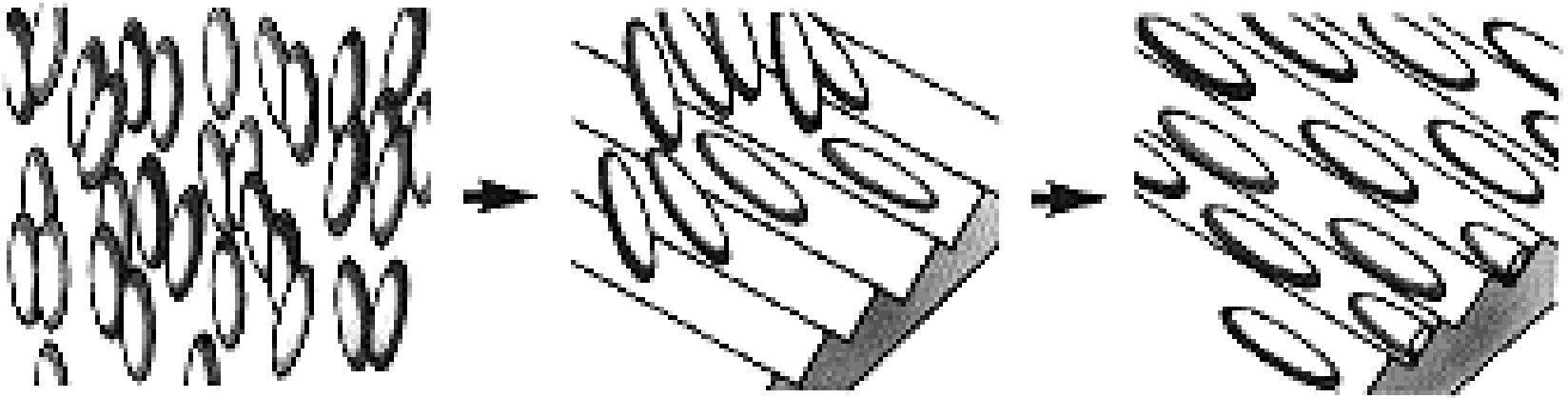
1995
8.4” and 10.4” color TFT LCD TV

1996
Personal data assistant with color LCD and digital camera.

LCD Evolutions:



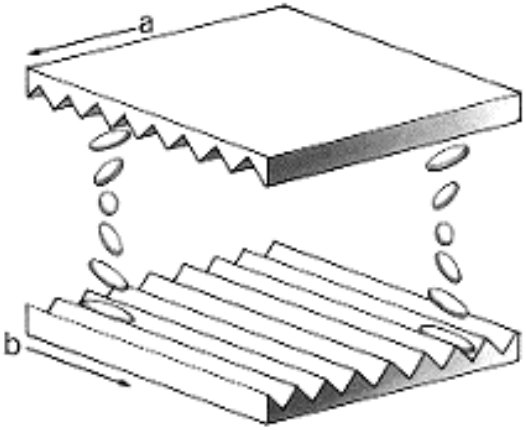
The parallel arrangement of liquid crystal molecules:



Molecules are arranged in a loosely ordered fashion with their long axes in parallel.

When coming into contact with a finely grooved surface (alignment layer).

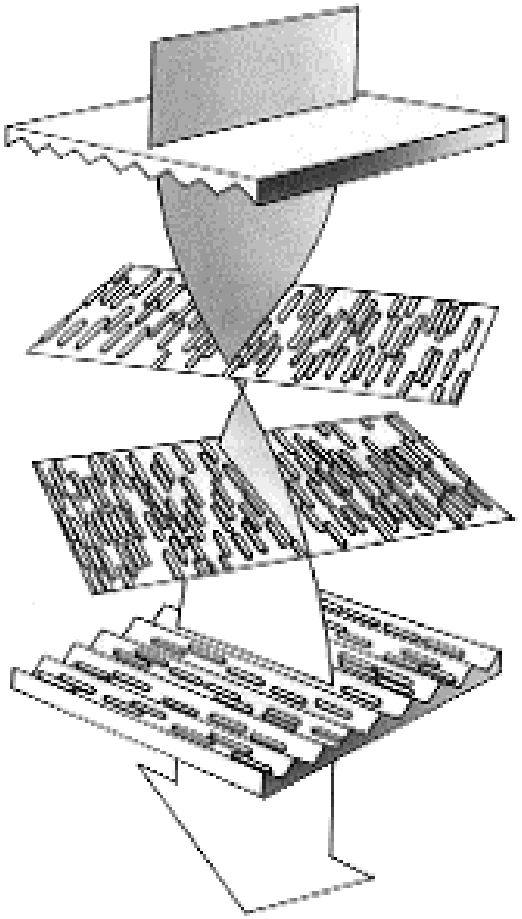
Molecules line up in parallel along the grooves.



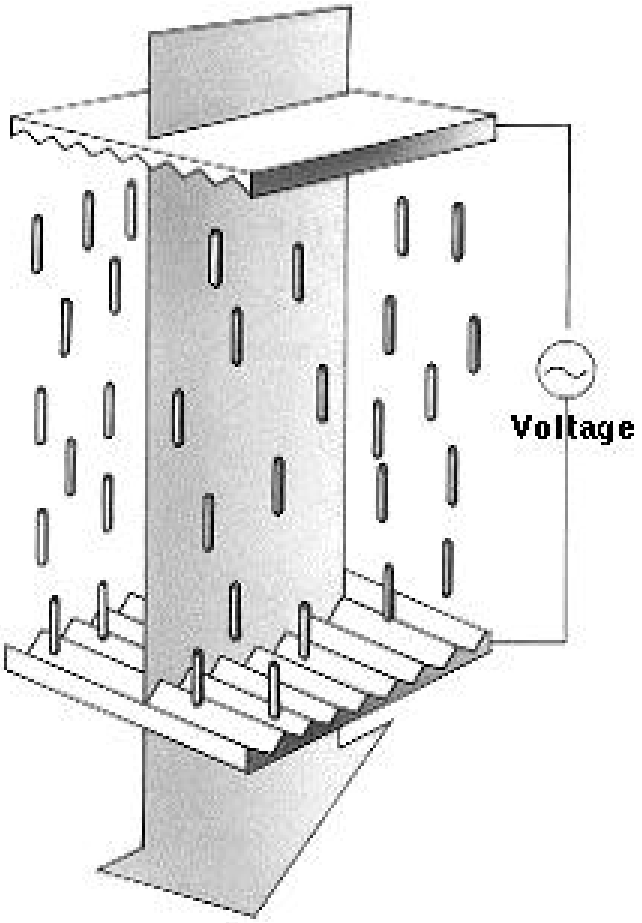
The molecules along the upper plate point in direction 'a' and those along the lower plate in direction 'b,' thus forcing the liquid crystals into a twisted structural arrangement.

The figure shows a 90-degree twist called **twisted nematic (TN)** type liquid crystal

Light travels along the liquid crystal cell:



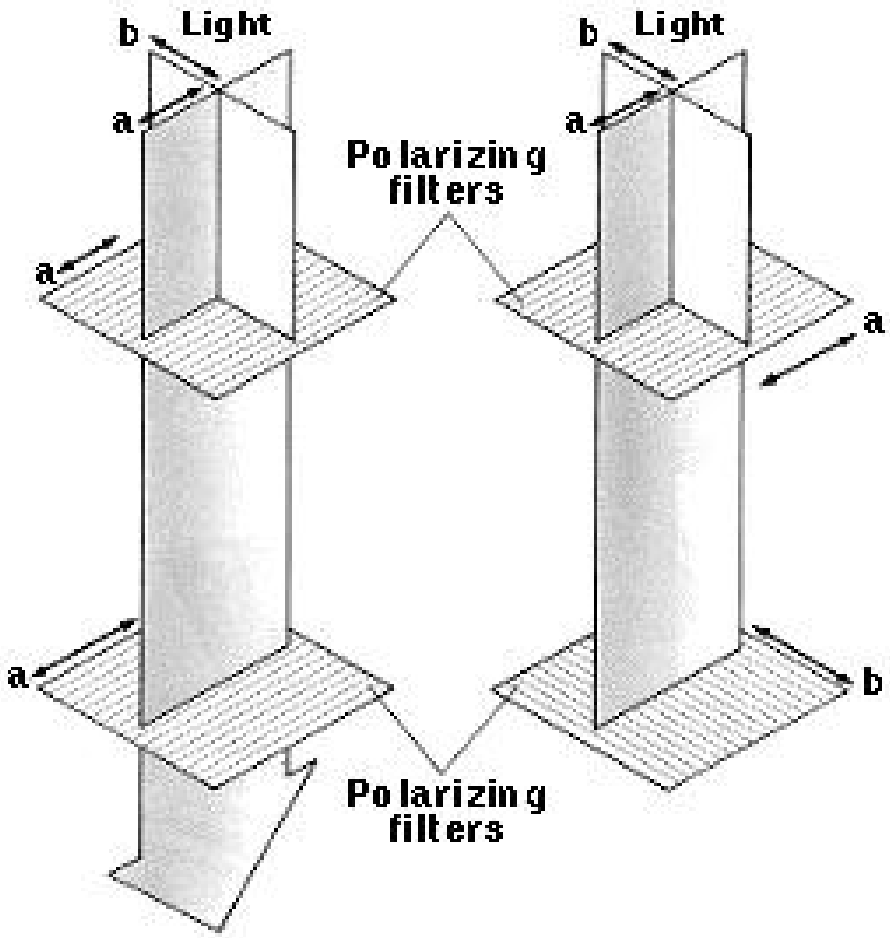
The light also **"twists"** as it passes through the twisted liquid crystals and bends 90 degrees



When voltage is applied to the liquid crystal structure, the twisted light passes straight through.

TN Type LCD:

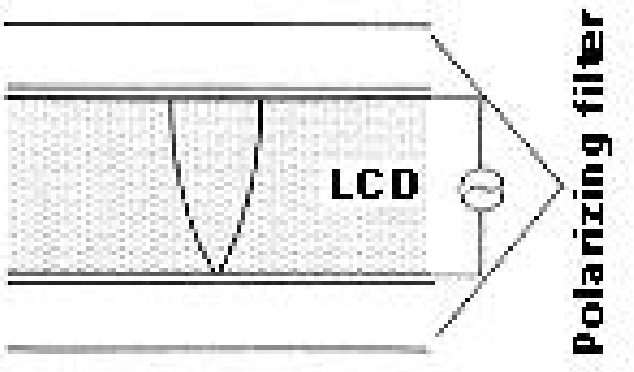
When voltage **is not** applied, light entering from the above is re-directed 90 degrees along the helix arrangement of the liquid crystal molecules so that it **passes** through the lower filter.



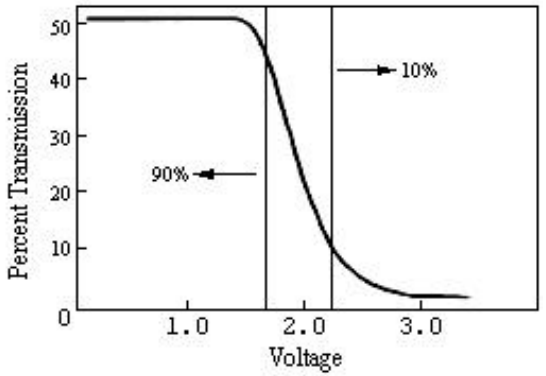
When voltage **is** applied, the liquid crystal molecules straighten out of their helix pattern and stop redirecting the angle of the light, there by **preventing** light from passing through the lower filter.

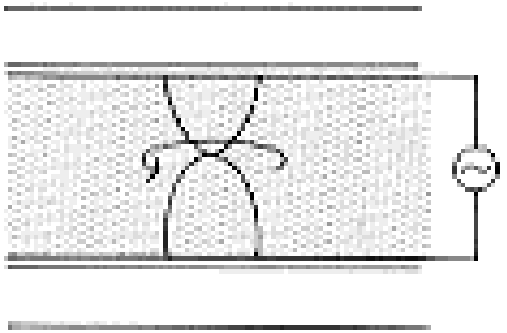
The two polarizing filters are arranged along perpendicular polarizing axes

Different Types of LCDs:

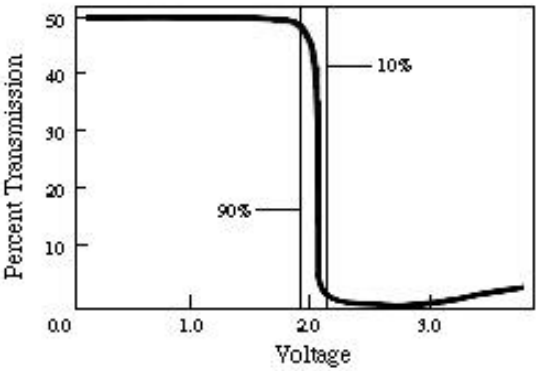


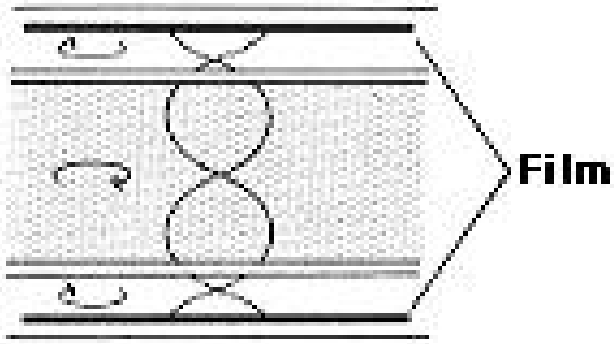
Twisted nematic (TN) 90 degrees twisted





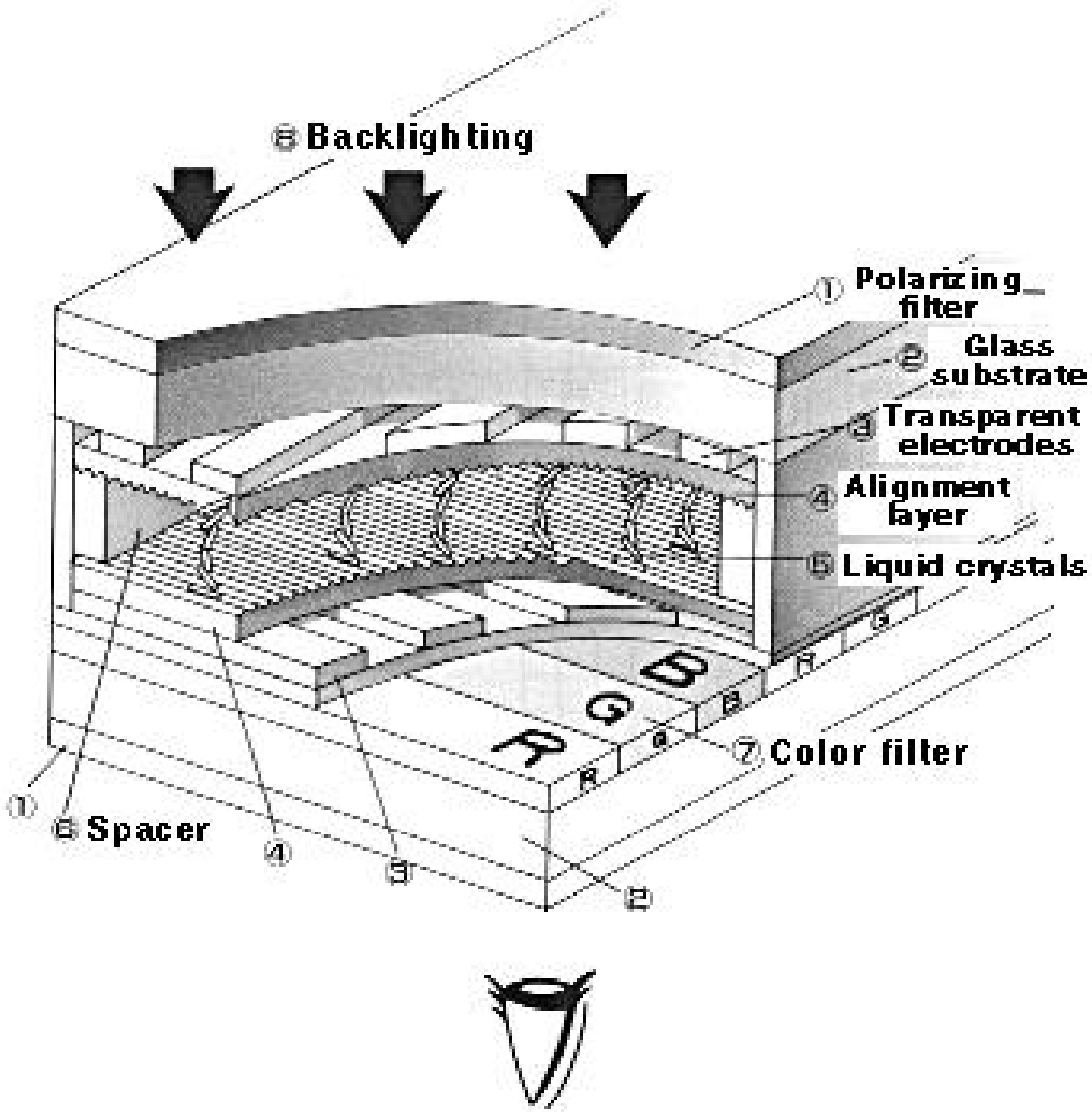
Super twisted nematic (STN) 260 degrees twisted





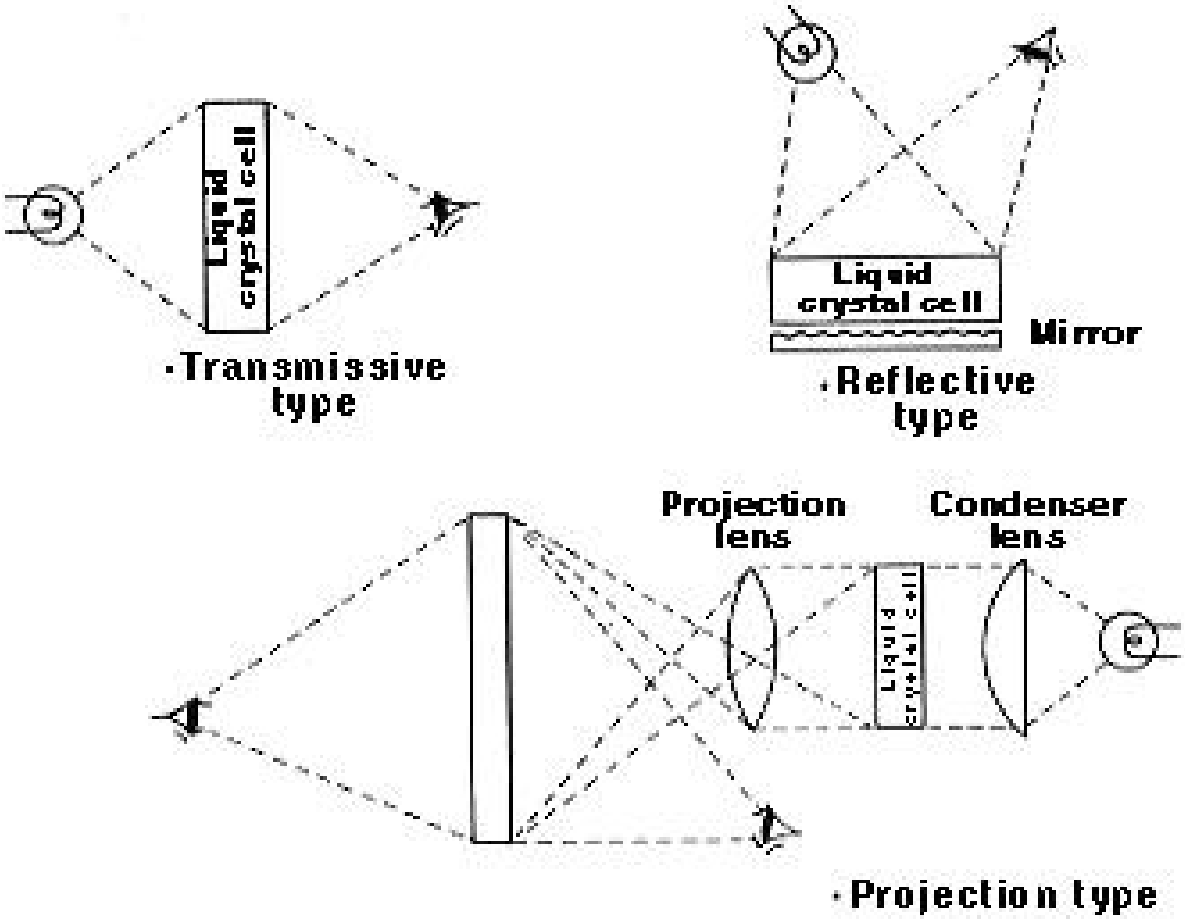
Triple Super twisted nematic (TSTN) with film compensation (FSTN)

LCD Structures:



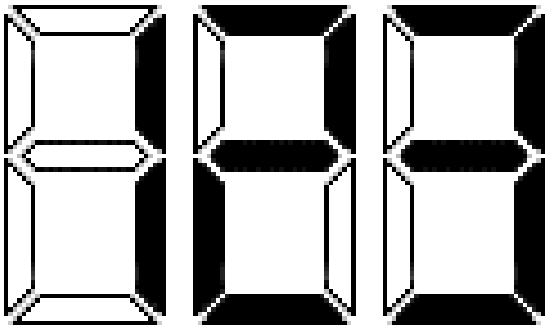
- **Polarizing filter**
  - control light input/output
- **Glass substrate**
- **Transparent electrodes**
  - drives the LCD
- **Alignment layer**
  - aligns the LC in fixed directions
- **Liquid crystals**
- **Spacer**
  - controls the cell gap
- **Color filter**
  - Color is expressed through the use of R, G and B filters.
- **Backlighting**
  - The display is lit from behind to make the screen brighter

Display Systems:

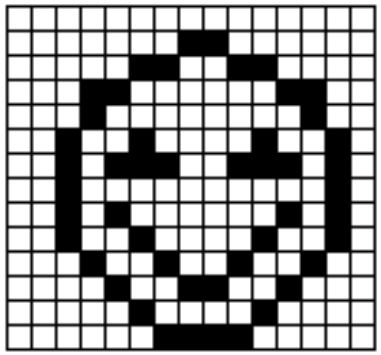


- **Transmissive type:** The notebook computer
- **Reflective type:** LCD calculator and watch
- **Projection type:** LCD projector

Display Principles:

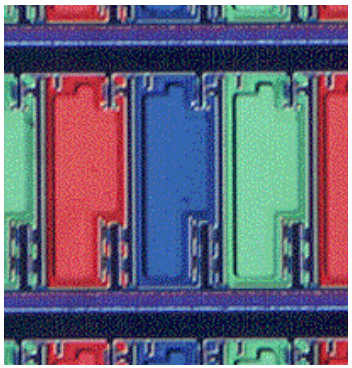


- **Segment system**
  - Long display units are arranged to form a figure '8' to display numbers
  - **Direct driven**
    - » **for TN type LCD**



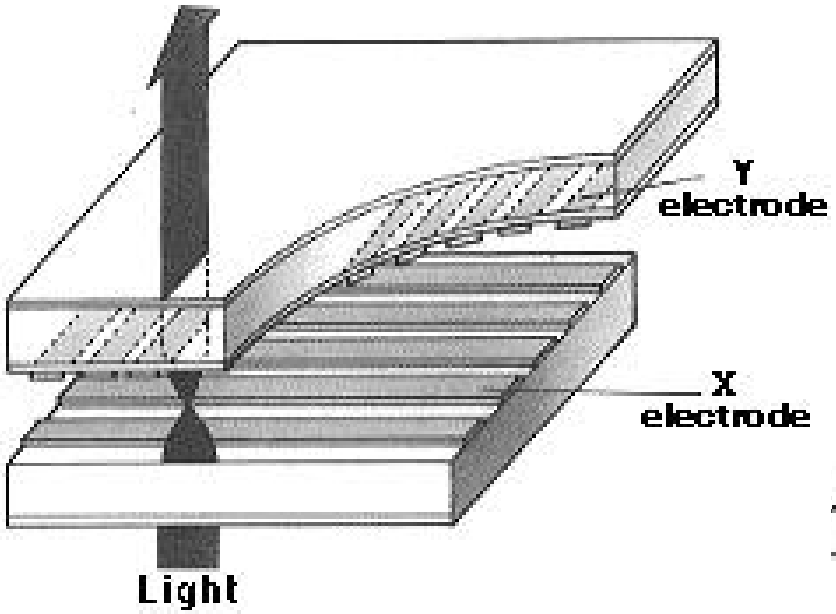
- **Dot matrix system**
  - Display units are arranged in rows and columns to form characters and graph.
  - **Passive matrix**
    - » **for STN type LCD**
  - **Active matrix**
    - » **for TFT LCD**

R	G	B	R	G	B	R
R	G	B	R	G	B	R
R	G	B	R	G	B	R
R	G	B	R	G	B	R
R	G	B	R	G	B	R

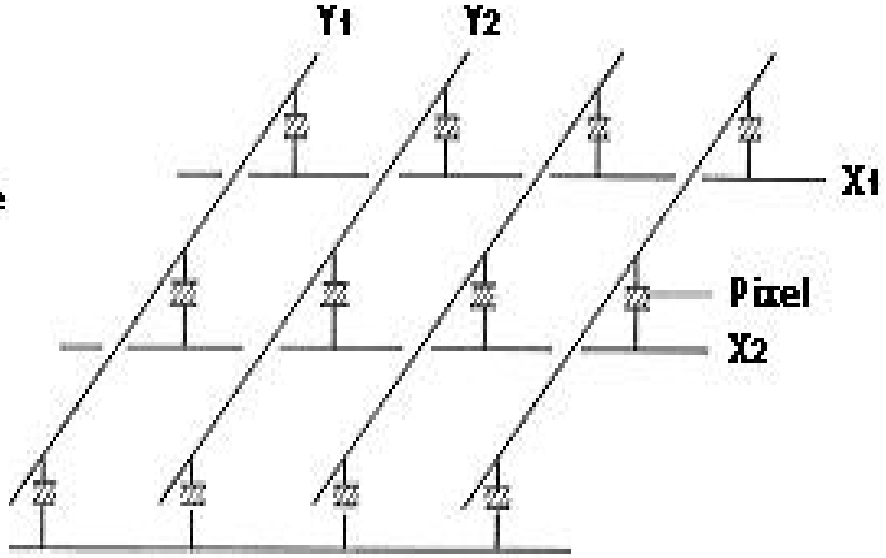


A color display is made possible by placing color filters of red, green and blue over each display unit

Passive Matrix for STN:



Structure



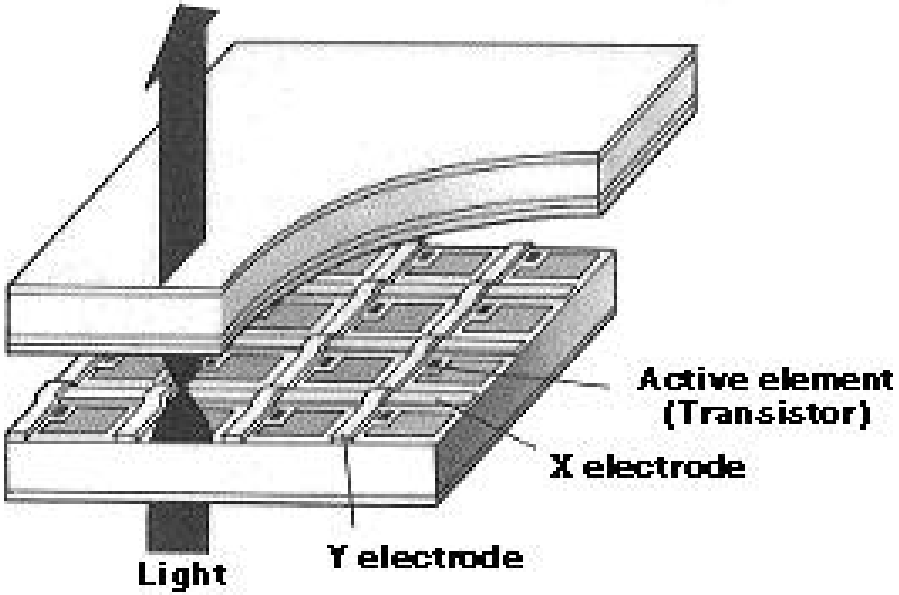
Equivalent Circuit

The X electrodes are laid on the lower substrate of the liquid crystal cell, and the Y electrodes are laid on the upper substrate.

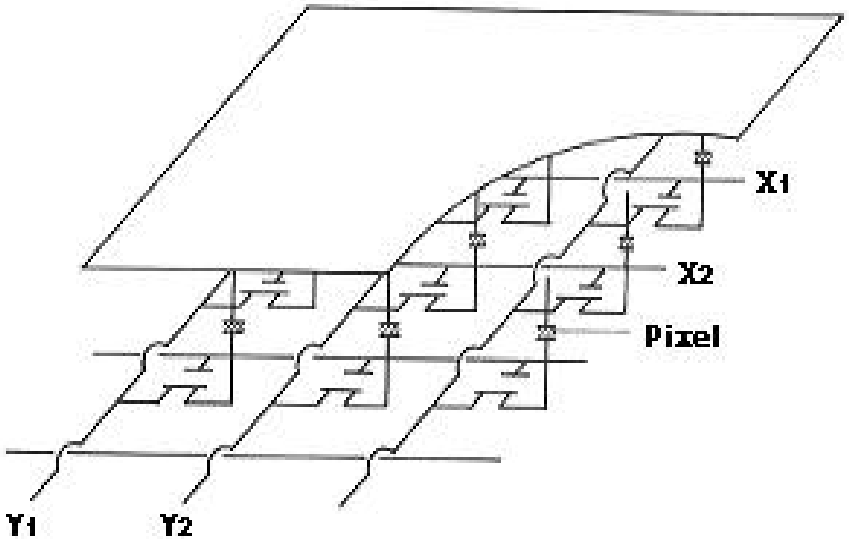
Electrical signals are applied to the X and Y conductors with the proper timing to select the target pixels.

Each intersection of X and Y conductors define a display unit

Active Matrix for TFT:



Structure



Equivalent Circuit

In active matrix LCDs, switching transistors (TFTs) or diodes are attached to each pixel to switch each one on or off.
X and Y electrodes are formed on the same substrate as TFT (Thin-Film Transistor) or diode arrays.

The switching signals are applied to the X electrodes and video signals are then applied to the Y electrodes.

Comparisons of Different Types of LCDs:

Types	TN	STN	TFT (AM-TN)
Contrast	2:1	20:1	200:1
Gray scales	black/white	16	256
Cost	low	moderate	high
Driving	direct drive	passive matrix	active matrix
Major applications	character display	graphic word processor	video display
Manufacturers	China	Hong Kong Taiwan China	Korea (Samsung, LG) Taiwan (Unipac, CMO) Japan (Sharp, Hitachi, ...)

Hong Kong produced 20% of LCDs, but accounted for only 2% sales.
Most LCD products were TN (made in China) and STN (made in HK?)

More LCD Products

Personal Data Assistant (PDA) with handwriting recognition

Notebook computer with 12.4”, 13.1”, *15” (~US$200)* , 17” (~US$400), ...

28” full-color TFT LCD TV (18kg)

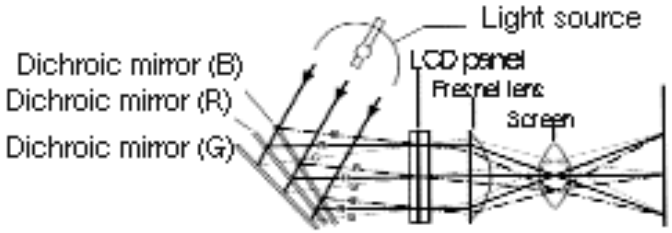
10.4” LCD TV (2.3kg, 47mm thick) used in car navigation

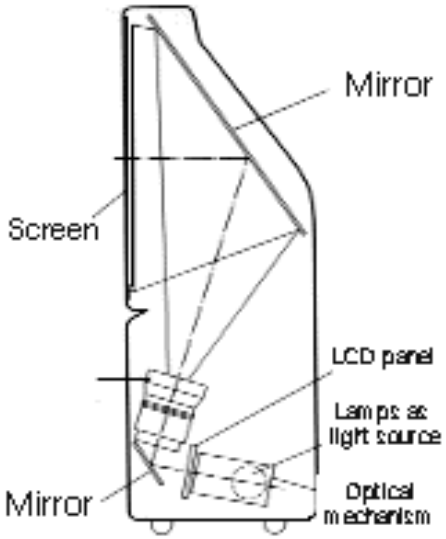
NEC 20” TFT LCD:

- Display area 20.1”
- Aspect ratio 4:3
- Resolution 1280 x 1024
- Pixel pitch 0.31x 0.31 mm
- Contrast 220:1
- Technology a-Si TFT

- Colors 16.7 million
- *Luminance 150 cd /m2*
- *View angle 80 degrees*
- *Power 51 W*
- *Weight 3.5kg*
- Cost ~US$1000

Barco Rear Projection LCD

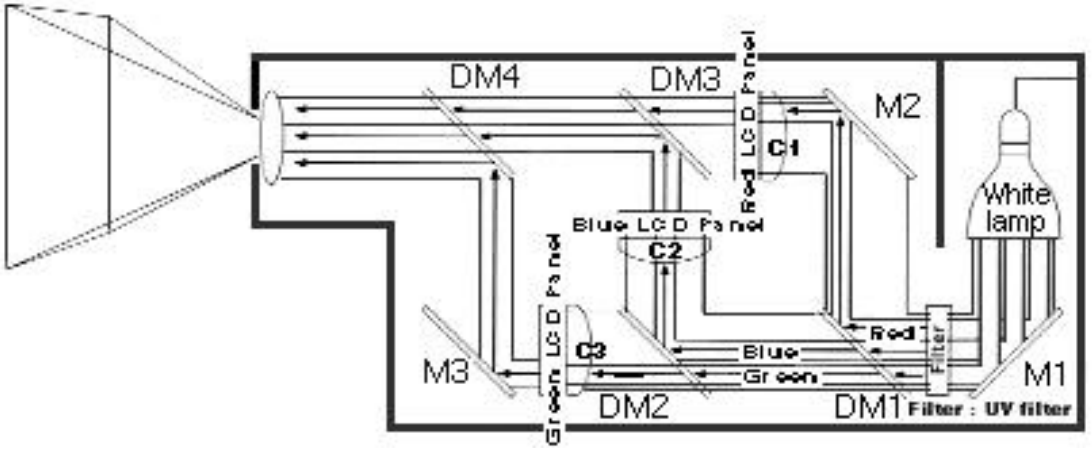




- Display area 67”
- Aspect ratio 4:3
- Resolution 1280 x 1024
- Contrast 300:1
- Luminance 5000 ANSI

- Colors 16.7 million
- Technology 3 x 0.9” poly-Si TFT
- Power 270W (4W)
- Weight 30kg
- Cost ~US4,000

Front Projection LCD

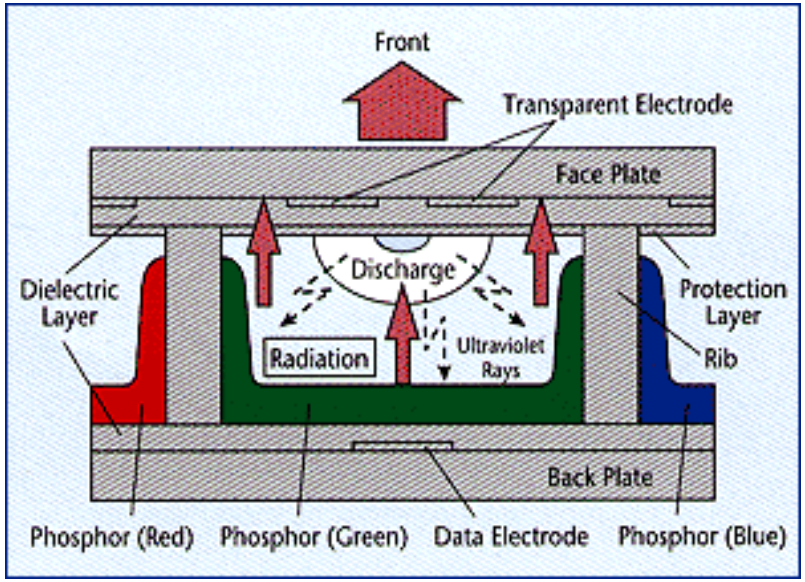


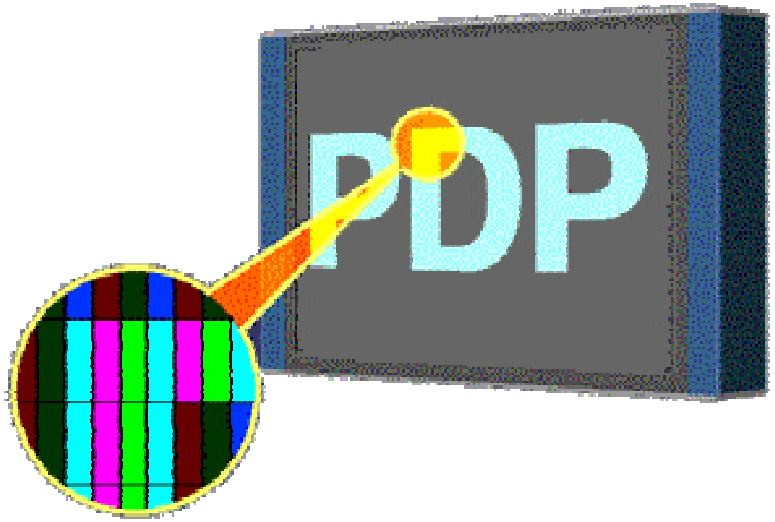
- Display area 40” to 300”
- Aspect ratio 4:3
- Resolution 1024 x 768
- Pixel pitch 0.31x 0.31 mm
- Contrast 220:1
- Luminance 600 ANSI

- Colors 16.7 million
- Technology 3 x 0.9” poly-Si TFT
- Power 270W (4W)
- Weight 4.8kg
- Cost ~US$4000

All Kinds of Displays in Action:

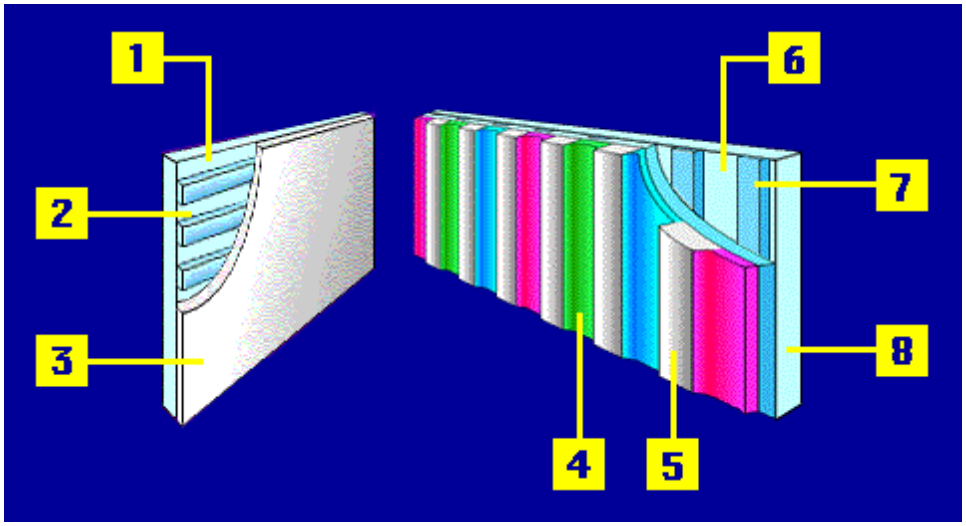
Plasma Display Devices:





- **Structure**
  - The plasma display consists of two thin sheets of glass. A gas is filled into the space between the sheets of glass
- **Function**
  - when a voltage is applied to it, the gas emits ultraviolet light which excites nearby phosphor
  - The color PDP works very similar to a number of small flourescent lamps

NEC Plasma Elements:



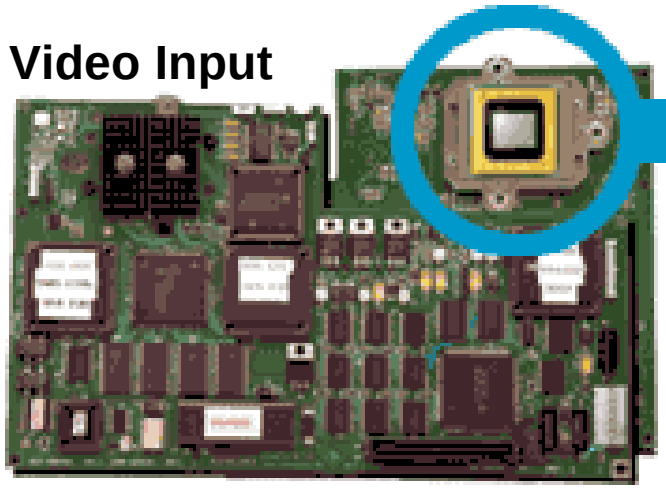
- 1 Front glass surface
- 2 Surface discharge electrode
  - Electrode used in electrical discharge to emit visible light for image.
- 3 Dielectric layer
  - Functions as a capacitor to govern the discharge current.
- 4 Phosphor layer
  - The grooves are alternately coated with the three primary color phospers
- 5 Barrier rib
  - Divide the space between each cell
- 6 Dielectric layer
  - Functions as a capacitor to govern the discharge current.
- 7 Data electrode
  - Electrode used in electrical discharge to write display data in the PDP.
- 8 Back glass substrate

NEC 42”/50” Plasma Display:

- *Display area 42”/50”*
- Aspect ratio 16:9
- Resolution 1,365x768
- Pixel pitch 0.81x0.81mm
- Contrast 250:1
- Colors 16.7 million
- Luminance 250cd /m2
- *View angle 160 degrees*
- *Weight 26kg*
- *Cost ~US$100/inch*

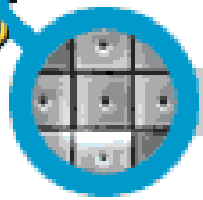
Digital Light Processing (DLP):

Video Input



DMD™

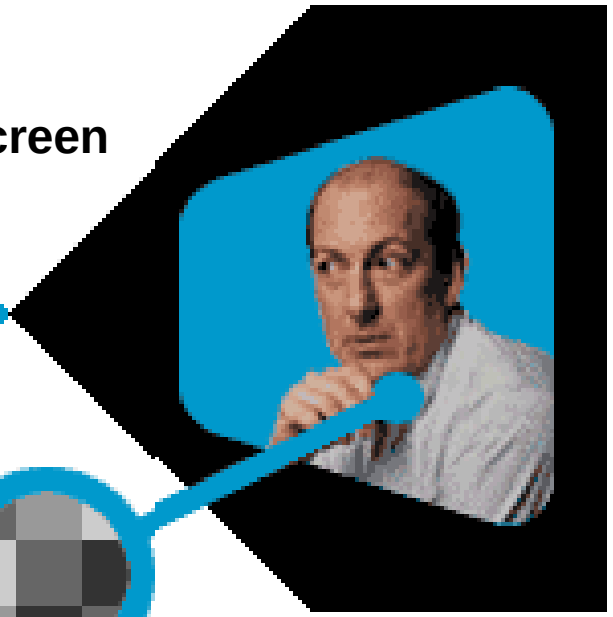
Digital Micro-mirror Device (DMD) : An array of micro mirrors



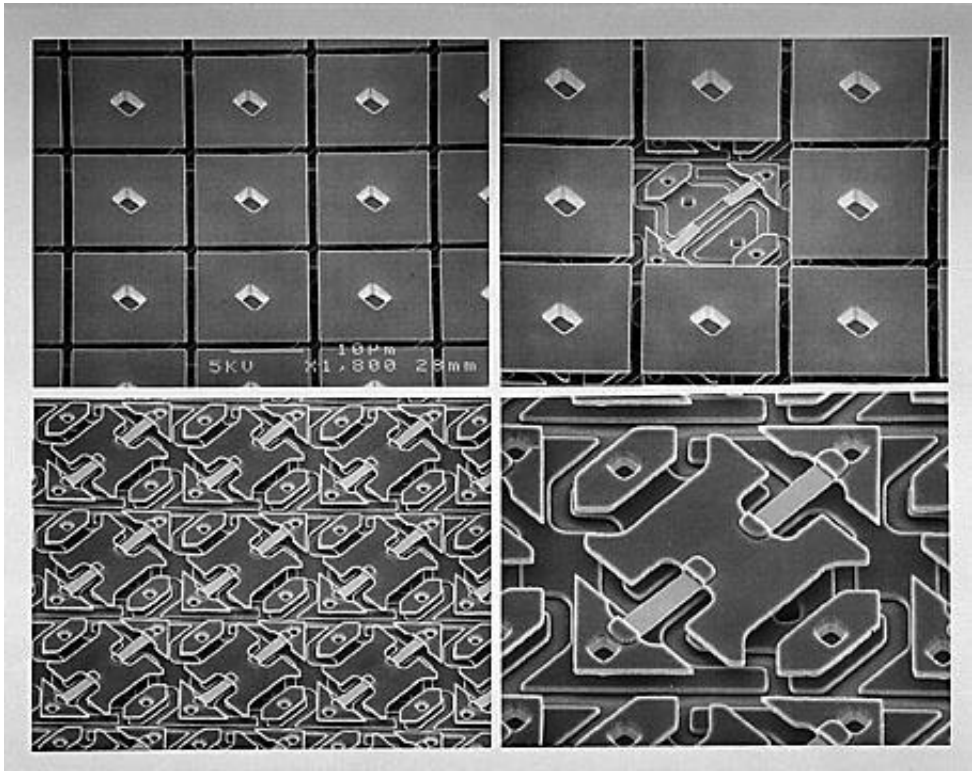
1 mirror = 1 pixel

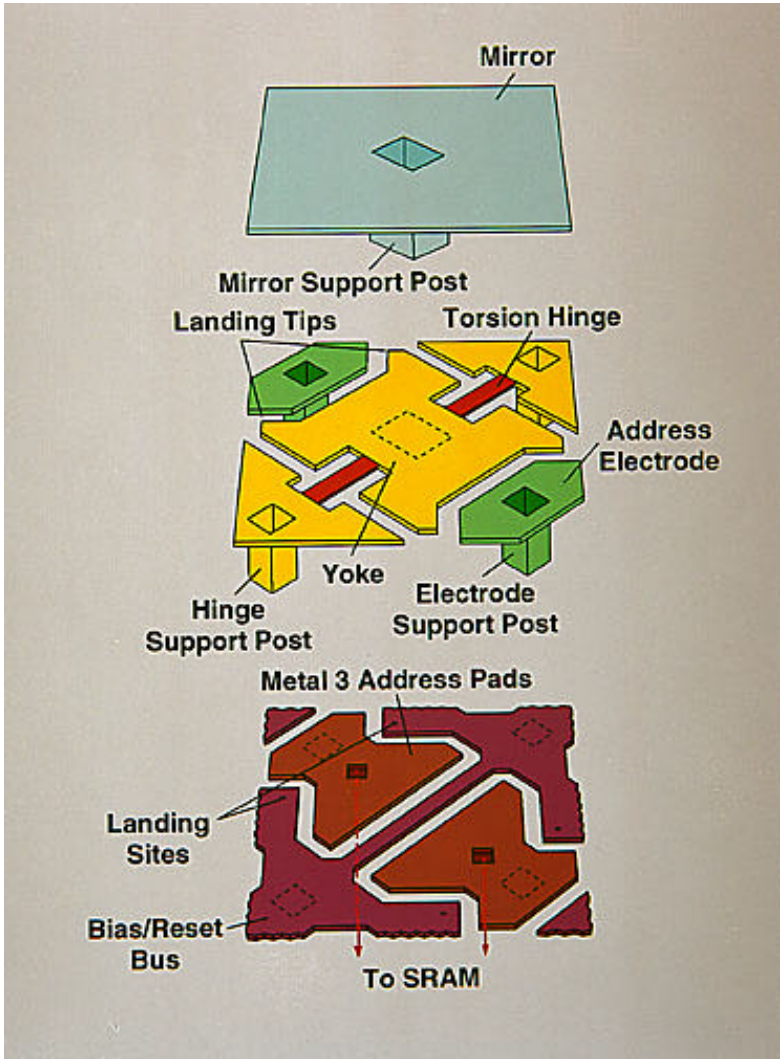
Electronic Image on DMD

By projection onto screen

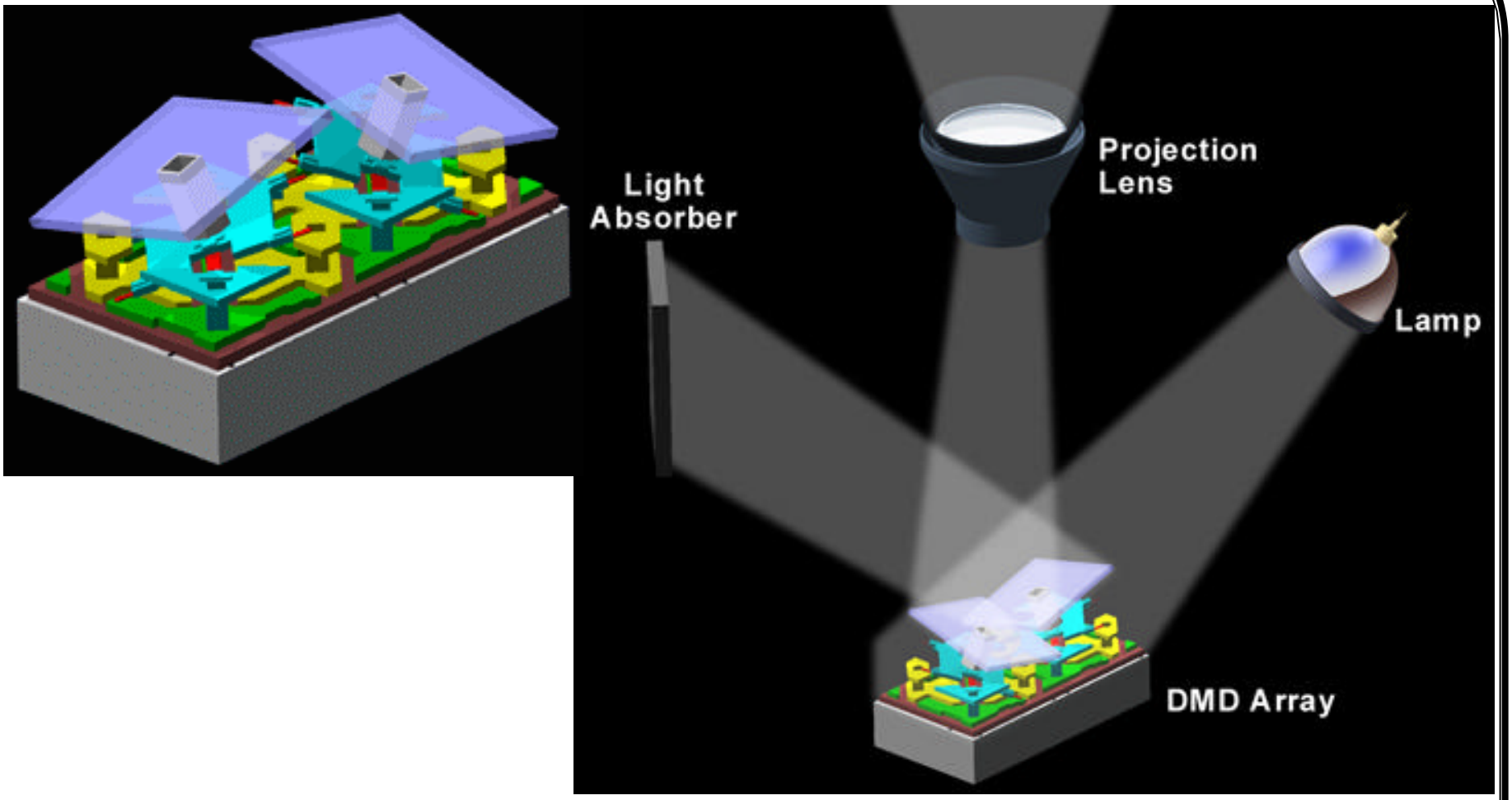


Digital Micro-mirror Device (DMD):

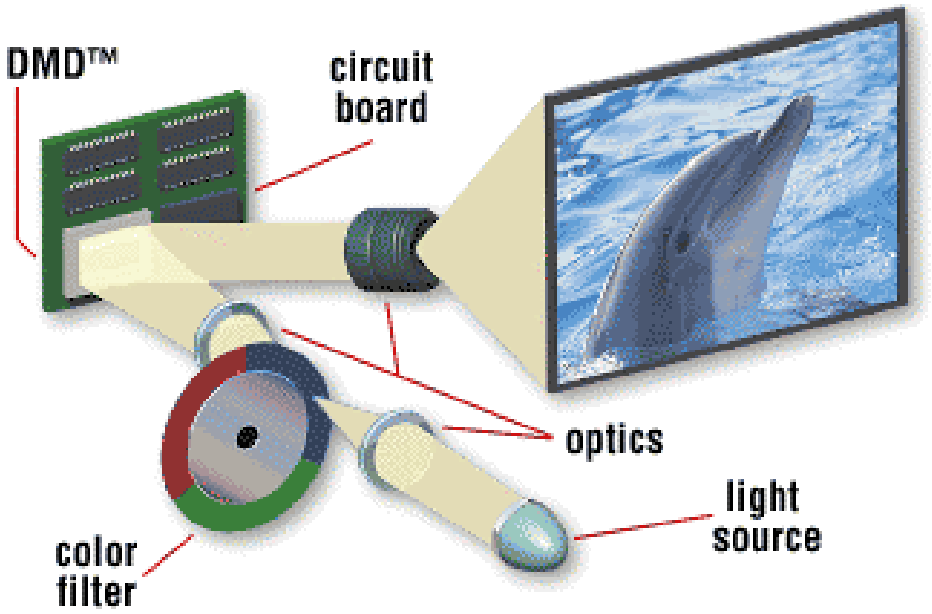


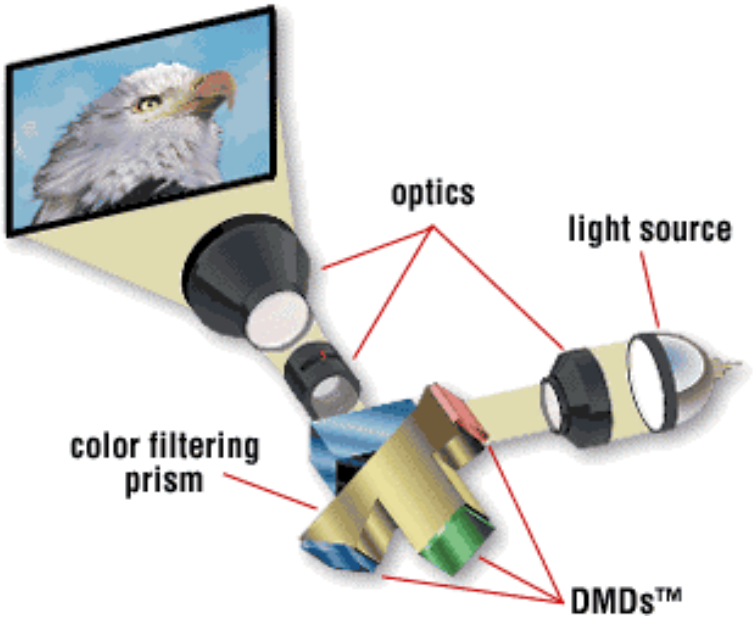


How the DMD Works:



DLP Projectors:

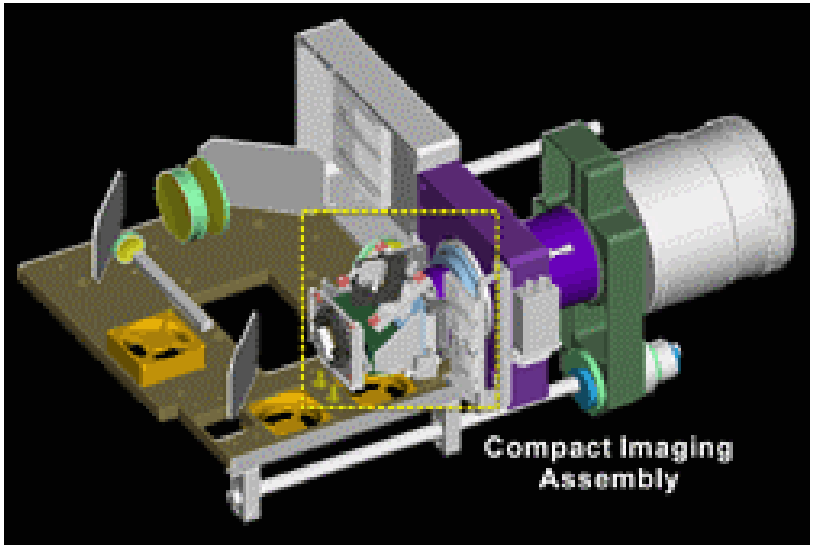


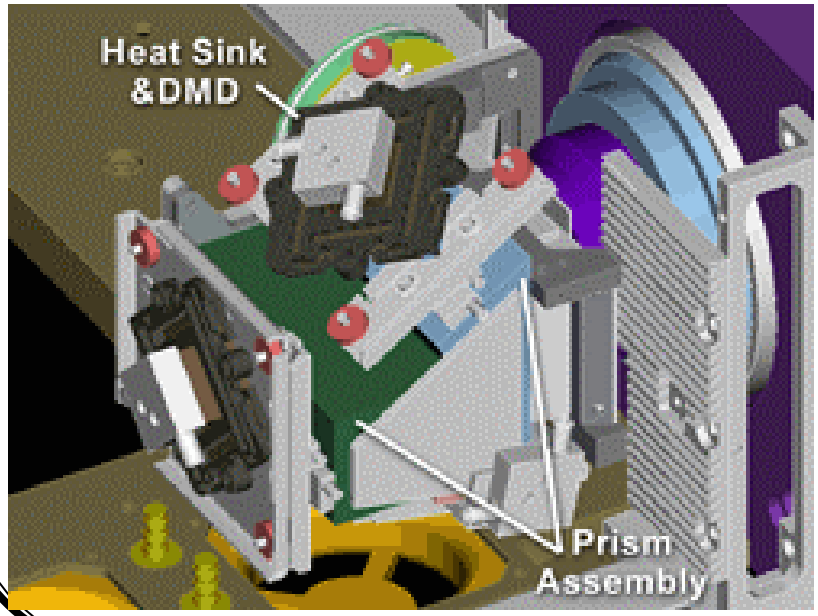


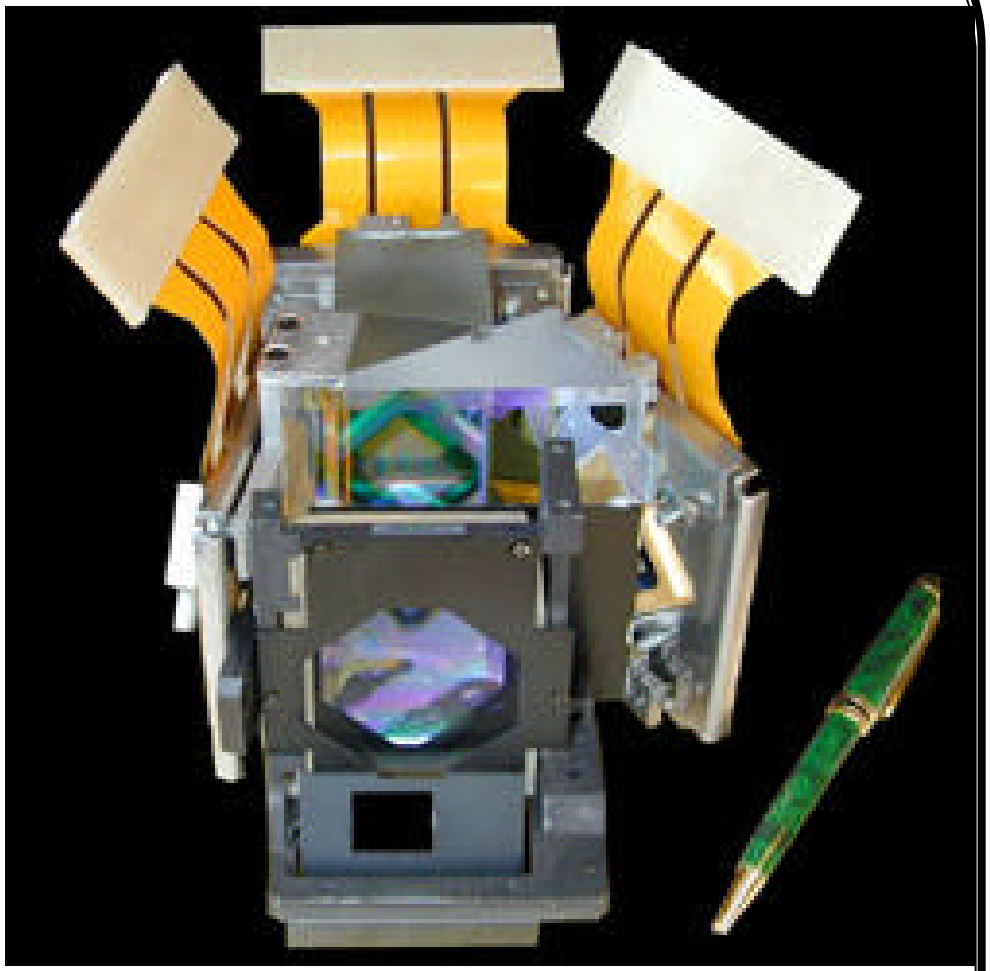
- ***Portable Projector***
- Display area 40” to 80”
- Resolution 1024 x 768
- Contrast 220:1
- Luminance 600 ANSI
- *Weight 2kg*
- ***Cost ~US$4000***

- ***Cinema Projector***
- Display area 300”
- Resolution 1280 x 1024
- Contrast 220:1
- Luminance 5000 ANSI
- Weight 50kg

Inside a 3-panel DLP Projector:





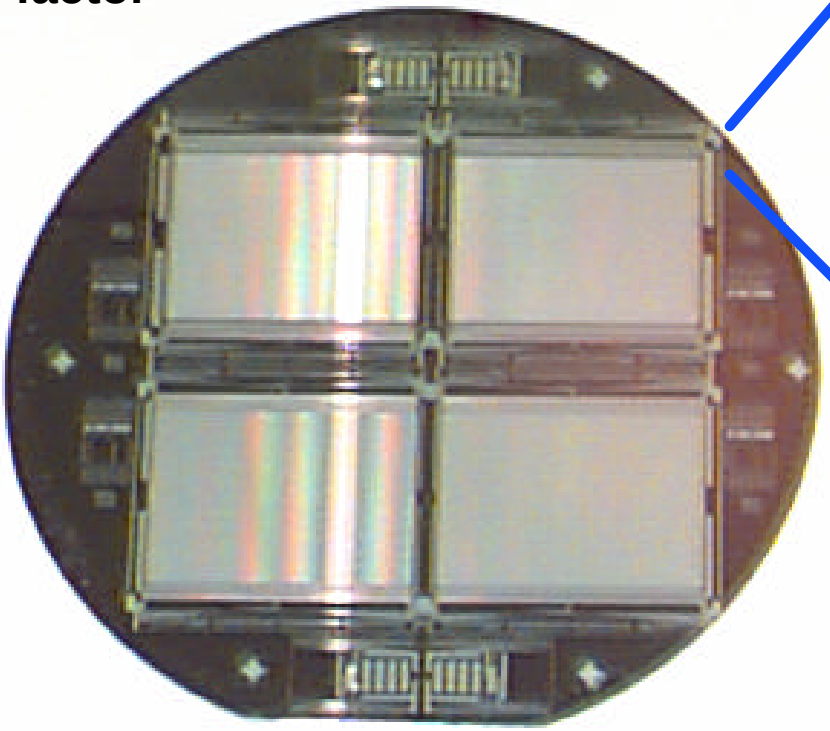


Optical Engine and Prism Assembly

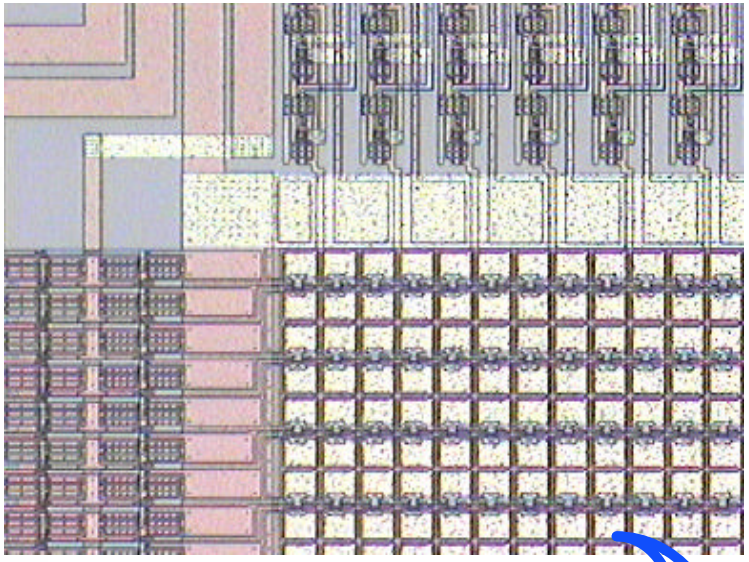
The DMD Advantages:

Silicon Microdisplay:

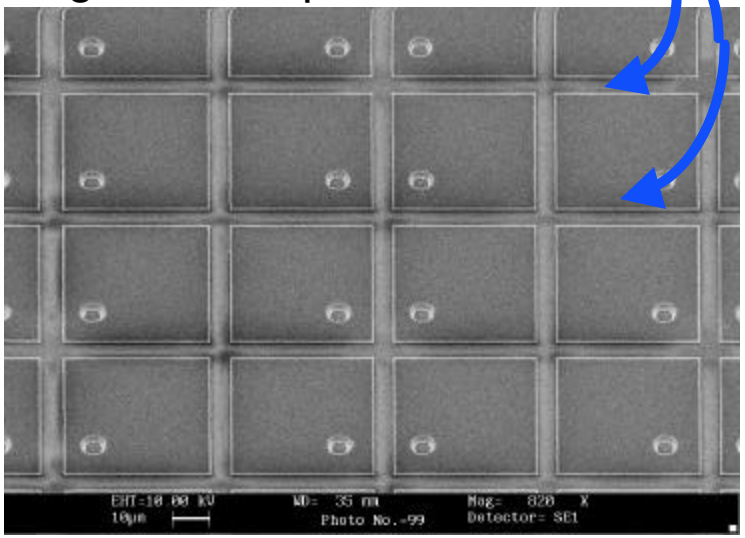
Silicon microdisplay is a miniature LCD, but has advantages of DMD like system integration and high fill factor



Active Matrix on Silicon Wafer Made at HKUST in 1996

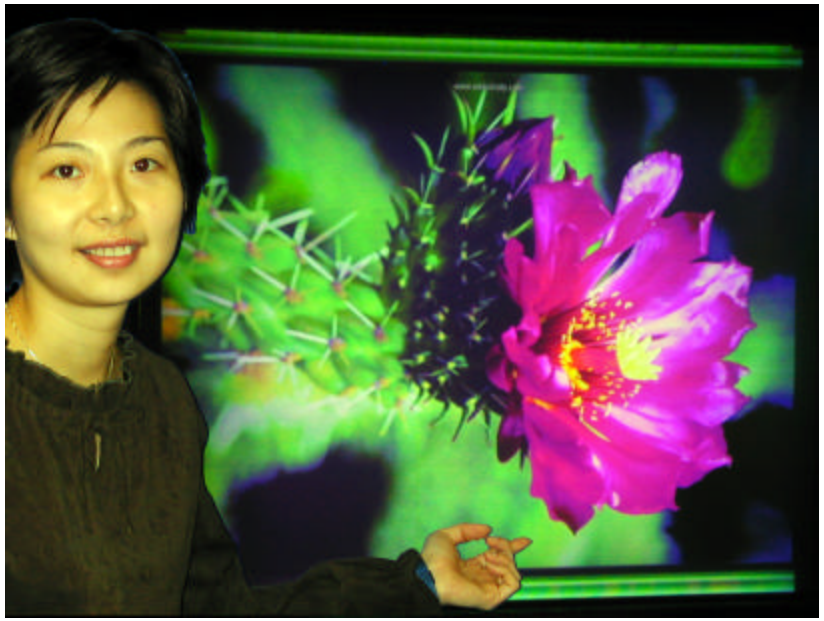


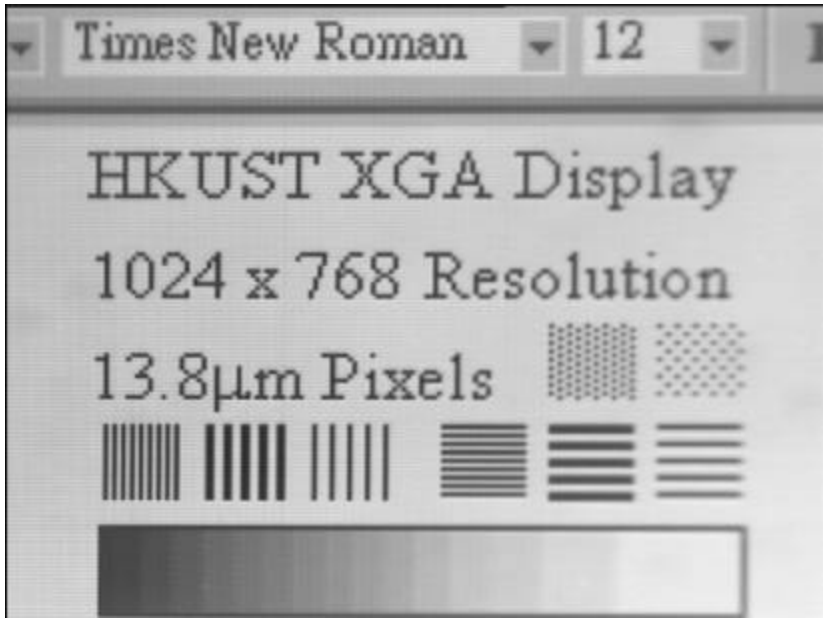
Integrated Peripheral Drivers



Planarized Reflective Pixels

HKUST XGA Projection Display::





- Display area 0.6”
- Aspect ratio 4:3
- Resolution 1,024x768
- Pixel pitch 14x14um
- Contrast 100:1

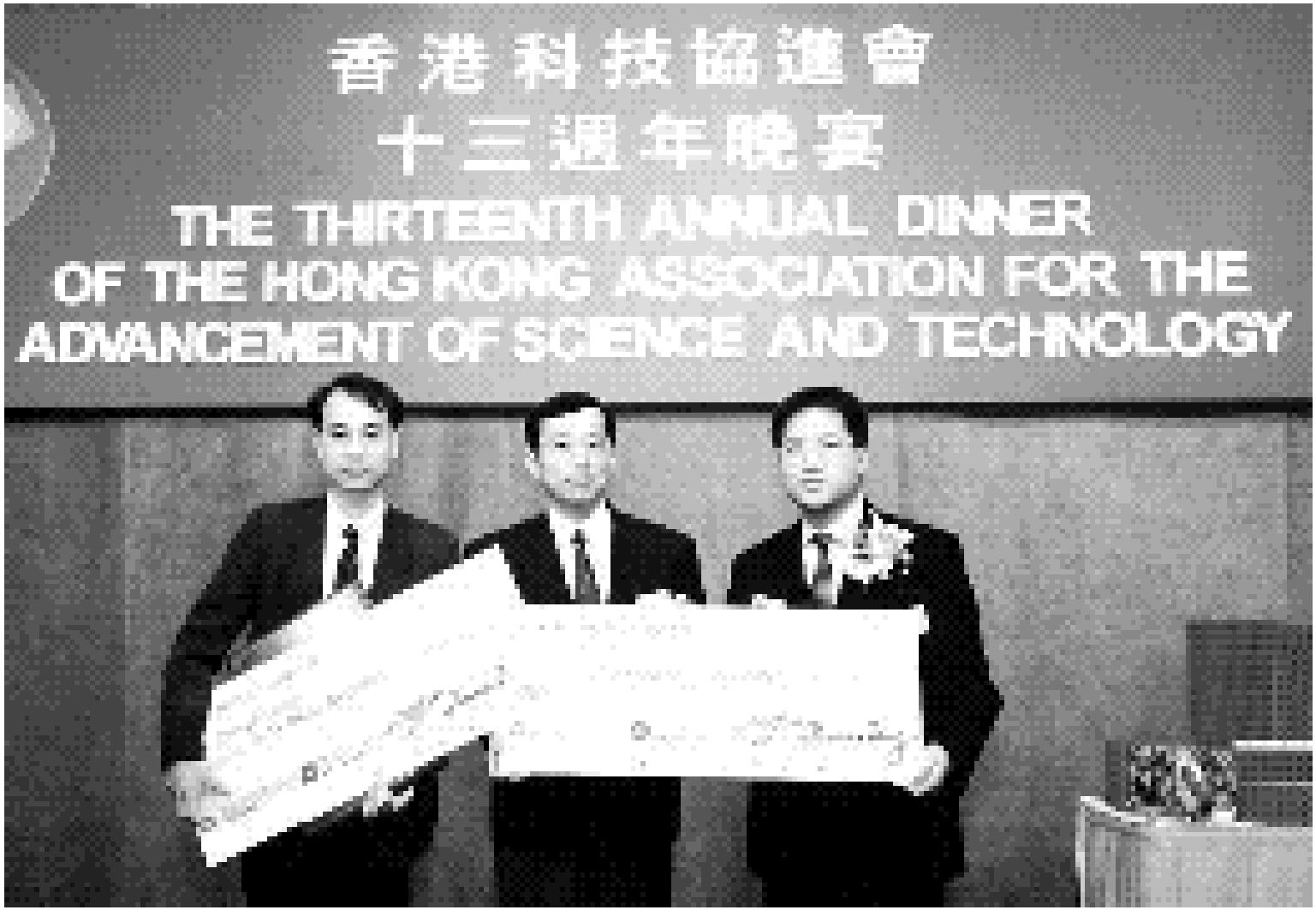
- Colors 16.7 million
- Luminance 100 ANSI
- View angle 20 degree
- *Weight 10kg*
- *Cost very low ?*

HKUST VGA Wearable Display

- Centre for Display Research (CDR)
- Where the LCD was assembled in 1997

- HKUST Campus
- Where the silicon VLSI was designed in 1997

HKUST Silicon Microdisplay won the First Prize in 1998



Commerical Silicon Microdisplays:

Kopin's .24 inch CyberDisplay 320C

Projects a 5.25 inch Virtual Color Image

Mobile Phones:

Dick Tracy's Mobile Phone:

Wearable displays

- *Display area 0.5 ~ 0.9”*
- Aspect ratio 4:3
- Resolution NTSV - DVD
- Pixel pitch 25- 33um
- *For Teenagers*

- View 30 degrees
- *60” virtual image in 2 meters*
- Weight 85g
- Cost US$600 - 2000
- *Do wear for more than 2 hours*

FBI Wearable Displays

Summary:

- **CRT is Matured**
  - It has lasted for more than 100 years
- **LCD is the Display of Choices**
  - TN LCD for alphanumerical display
  - STN LCD for graphics display
  - TFT LCD for high-resolution video display
- **Plasma Display for Wall-Mounted Display**
  - Flat and big for home theatre
- **Digital Light Processing**
  - Portable projector for home theater and cinema projector
- **Silicon Microdisplay**
  - VLSI/TFT LCD with more integration for innovative applications
- **Others**
  - LED for big bulletin board; OLED for hand-held display
  - VFD for audio/stereo Indicators
  - EL for equipment display of wide temperature range
  - FED for equipment display of ultra brightness

How to Select a Flat-Panel Display:

- **Personal Data Assistant (PDA)**
  - STN LCD (low cost and low power)
- **TV/Video Display**
  - Plasma display (bright, high resolution, flat and big)
  - LCD rear projectors
  - North America will start digital video broadcasting in 2004
- **Notebook Computer (Portable Display)**
  - TFT LCD (low power, high resolution)
- **Oscilloscope (Equipment Display)**
  - EL/FED (high speed, wide temperature)
- **Virtual Reality**
  - Silicon Microdisplay (high integration and high resolution)
- **Theatre**
  - Digital Cinema is coming
  - JVC LCD Projectors and TI's DMD Projector
  - Absolute high resolution and dynamic surrounding sounds