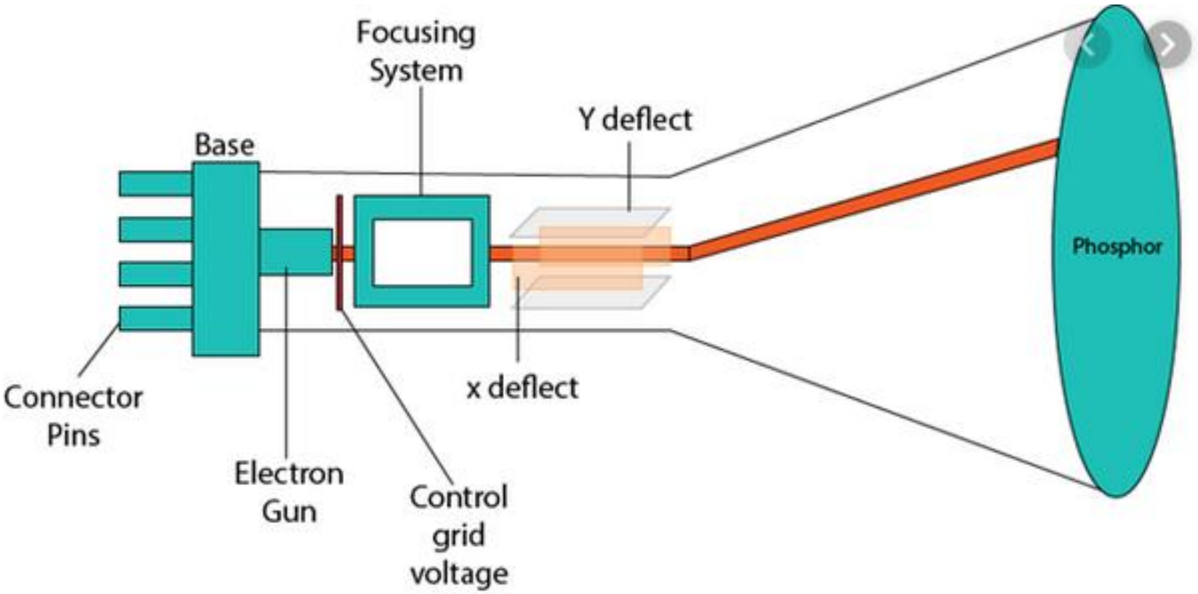
PH 301

ENGINEERING OPTICS

Lecture_Display Devices_30

Cathode Ray Tube

- It is a high vacuum tube that contains one or more electron guns, in which cathode rays produce image on a fluorescent screen.
- It modulates, accelerates, & deflects electron beam onto the screen to create image.
- TV, Computer terminals,….

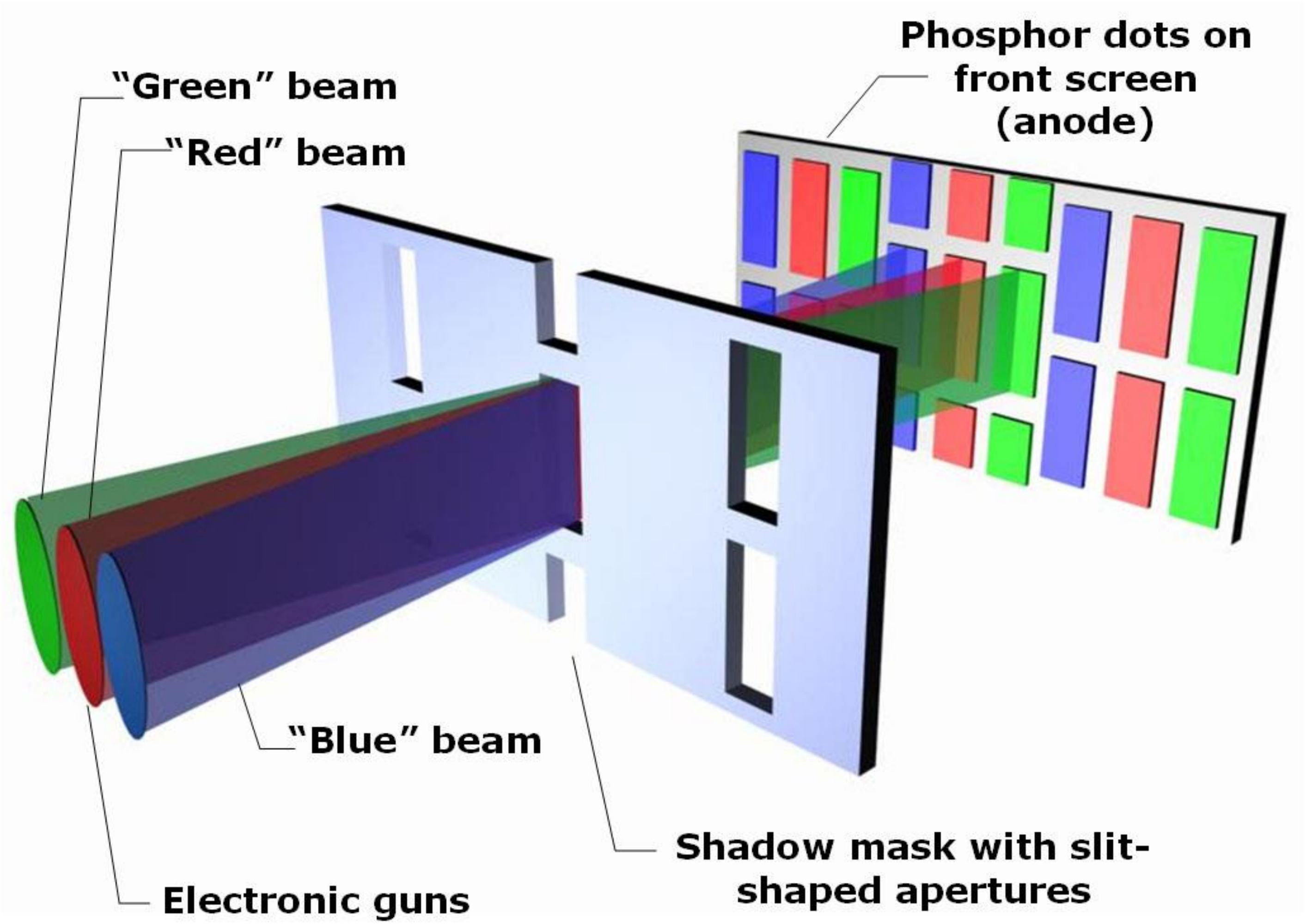


Cathode Ray Tube

CRT Imaging Process

- Low-voltage emission of electrons
- High-voltage anode attracts electrons
- Electrons strike phosphors, causing them to glow brightly
- Color CRTs use three electron guns
- Projection CRTs use single-color phosphors
- Response of CRT is linear for wide grayscales

CRT Imaging Process



CRT performance

Advantages:

- CRTs can scan multiple resolutions
- Wide, linear grayscales are possible
- Precise color shading is achieved
- CRTs have no native pixel structure

Drawbacks:

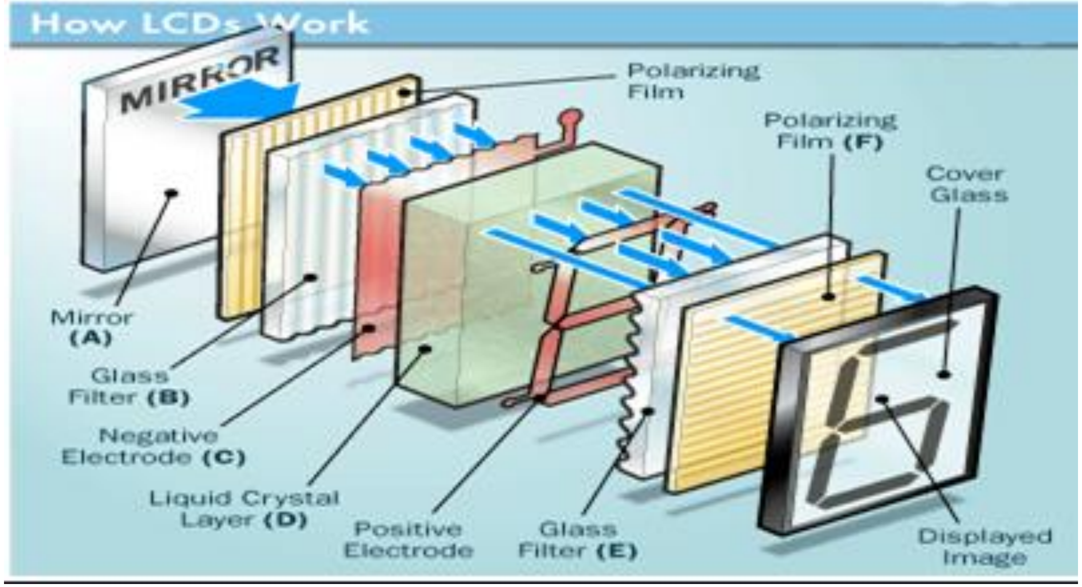
- Brightness limited by tube size
- Resolution (spot size) linked to brightness
- Heavy, bulky displays for small screen sizes

CRT is getting old

- Technology is over 100 years old
- Monochrome CRTs used from 1910s
- Color CRTs developed in early 1950s
- Monochrome tubes were used in front projectors in 1980s – 90s (7”, 8”, 9”)
- Manufacturing has largely moved to China
  - High-volume, low-margin product
  - Thomson TTE, TCL, & others make them

Liquid Crystal Display

Flat-panel displays based on backlit arrays of LCDs.



Liquid Crystal Display

- **LCD is a flat-panel display or other electronically modulated optical device that uses light-modulating properties of liquid crystals.**
- **Liquid crystals do not emit light directly, instead using a backlight or reflector to produce images in colour or monochrome.**
- **LCDs are available to display arbitrary images (as in a general-purpose computer display) or fixed images with low information content, which can be displayed or hidden, such as preset words, digits, & 7-segment displays, as in a digital clock.**
- **Arbitrary images are made up of a large number of small pixels, while other displays have larger elements.**

Applications: **Computer monitors, televisions, instrument panels, aircraft cockpit displays, indoor & outdoor signage, digital cameras, watches, calculators, mobile telephones.**

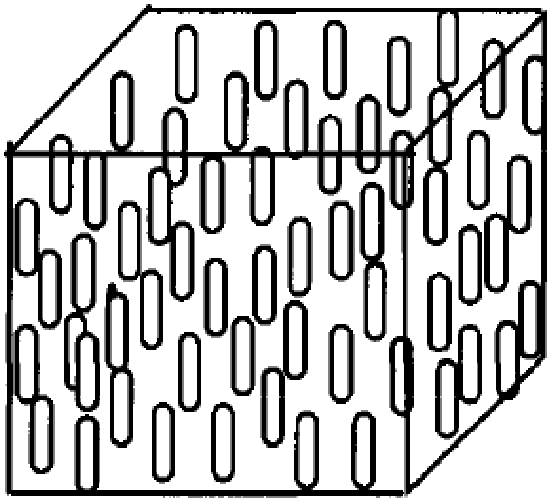
LCD screens are also used on consumer electronic products such as DVD players, video game devices & clocks.

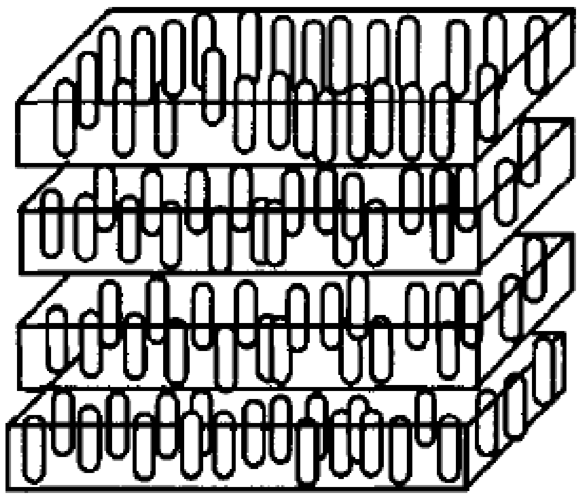
LCD screens have replaced heavy, bulky CRTs in nearly all applications.

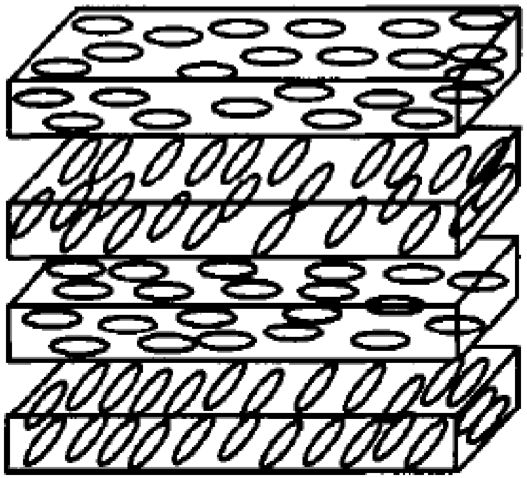
LCD screens are available in a wider range of screen sizes than CRT & plasma displays, with LCD screens available in sizes ranging from tiny digital watches to huge, big-screen television sets.

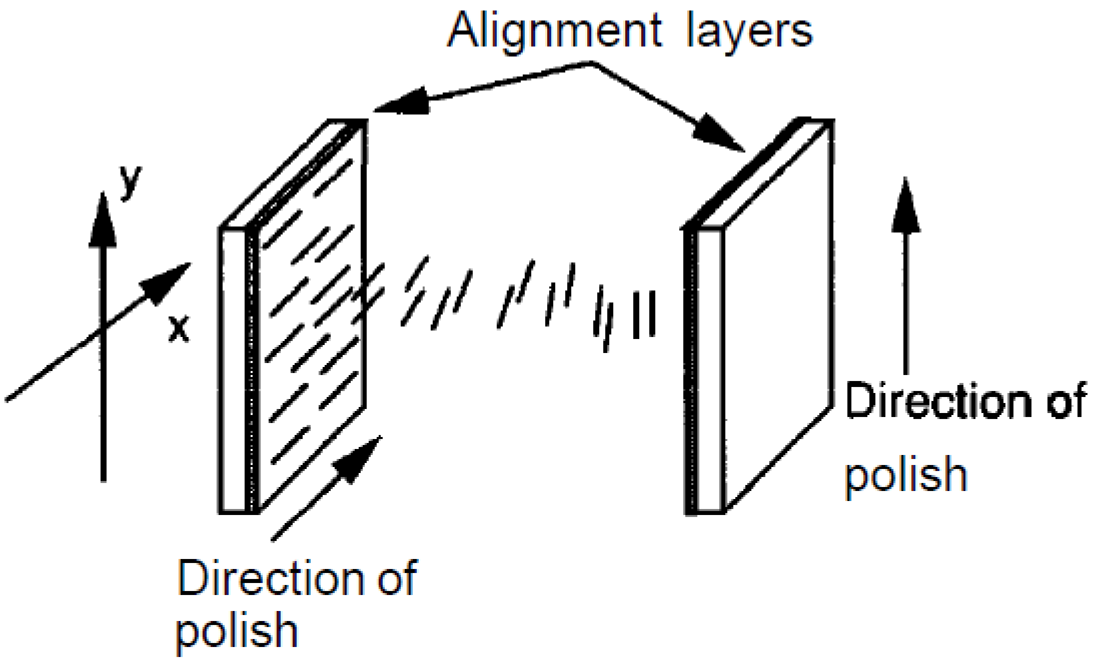
- **Since LCD screens do not use phosphors, they do not suffer image burn-in when a static image is displayed on a screen for a long time (e.g., the table frame for an aircraft schedule on an indoor sign).**
- **LCDs are, susceptible to image persistence.**
- **LCD screen is more energy-efficient & can be disposed of more safely than a CRT can.**
- **Its low electrical power consumption enables it to be used in battery-powered electronic equipment more efficiently than CRTs can be.**
- **By 2008, annual sales of televisions with LCD screens exceeded sales of CRT units worldwide, & CRT became obsolete for most purposes.**

Different types of liquid crystal

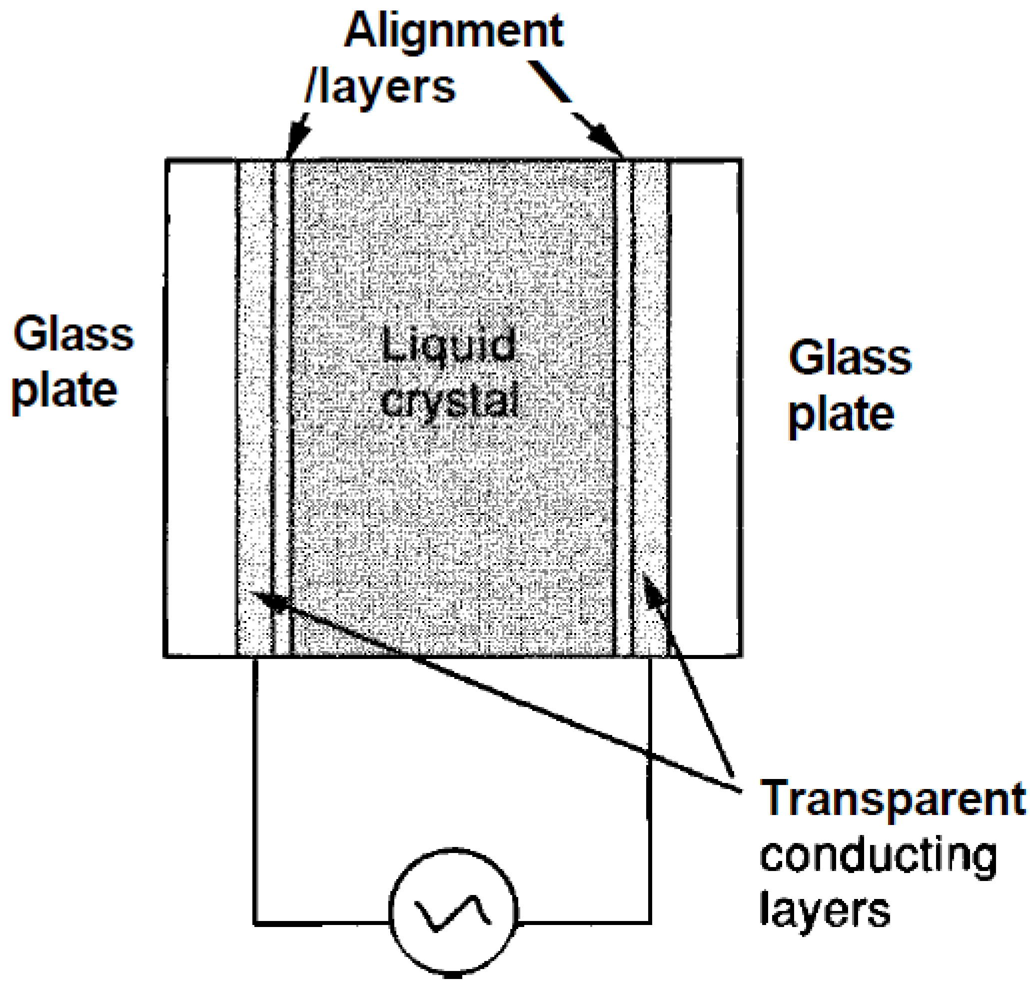

Nematic LC


Smectic LC


Cholesteric LC



Molecular arrangements in a twisted nematic liquid crystal. Lines between direction of alignment layers indicate the direction polish of molecular alignment at various depths within the cell. Only a small column of molecules is shown.

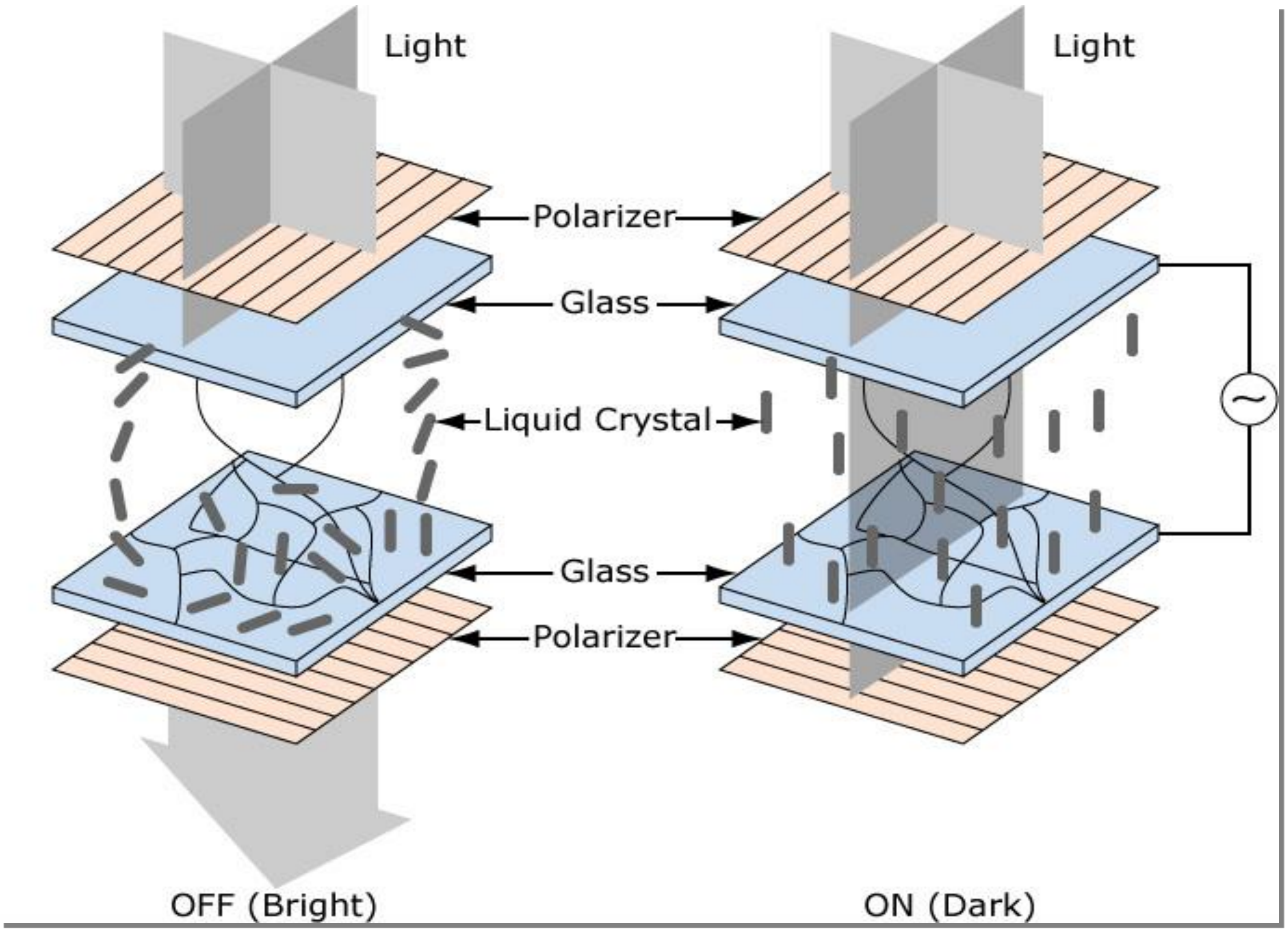


Structure of an electrically controlled light crystal cell.

LCD display technology

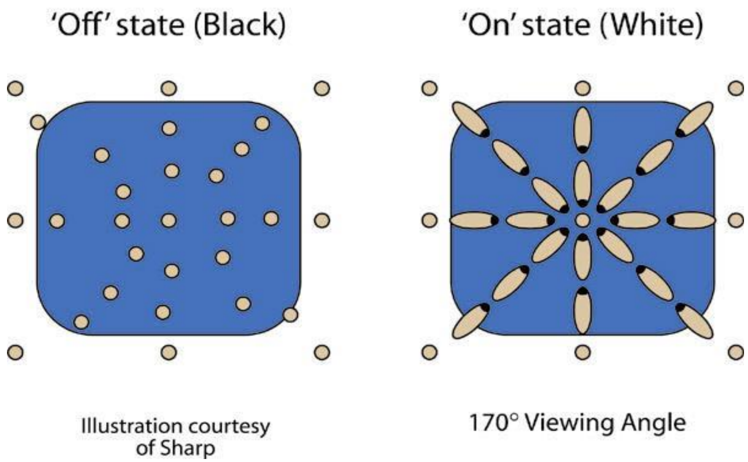
- Liquid-crystal displays are transmissive
- LC pixels act as light shutters
- Current LCD benchmarks:
  – Sizes to 82” (prototypes)
  – Resolution to 1920 × 1080 pixels
  – Brightness > 500 nits
- Power draw < plasma in same size
- Weight < plasma in same size

LCD Imaging Process



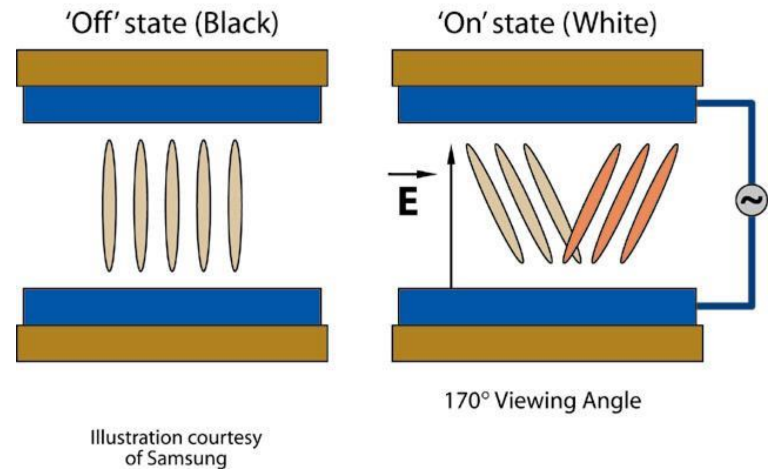
LCD Imaging Process

CPA Mode
(Continuous Pinwheel Alignment)



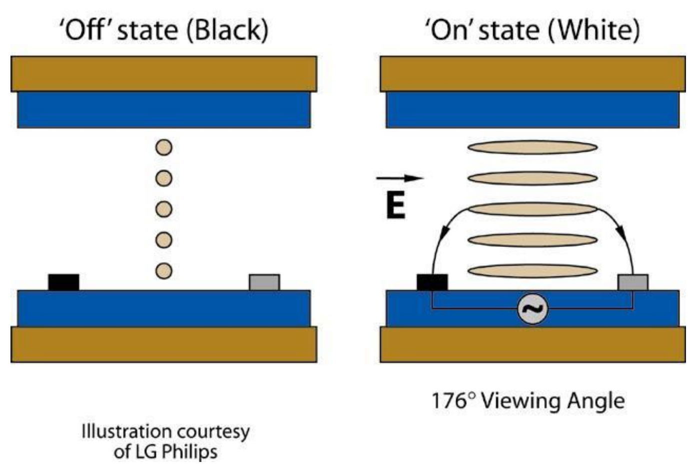
Sharp Approach

PVA Mode
(Patterned Vertical Alignment)



Samsung Approach

Super IPS Mode
(InPlane Switching)



LG Philips Approach

LED TV

- ❖ **Alignment of LCs are altered by applying an electric current to small, specific areas of LC layer. LED can control how the layer transmits light that flows from TV's backlighting.**
- ❖ **In this way, an LED TV can generate on-screen imagery. While a traditional LCD TV relies on same technology, an LED TV utilizes a more advanced form of backlighting.**
- ❖ **LEDs glow during exposure to electric current. Current flows between LED anodes, which are +ve charged electrodes, & LED cathodes, which are -ve charged electrodes.**
- ❖ **Traditional LCD TV utilizes fluorescent lamps for backlighting. These lamps function by using mercury vapory to create UV rays, which in turn cause the phosphor coating of the lamps to glow.**
- ❖ **LEDs have advantages over fluorescent lamps, including requiring less energy & being able to produce brighter on-screen colors.**

LED TV

- Not all LED TVs utilize LEDs in the same way.
- As of 2011, there are two primary forms of LED lighting technology; full-array LED backlighting & edge-lit LED backlighting. Also known as local-dimming technology, full-array technology employs arrays or banks of LEDs that cover the entire back surfaces of LED TV screens.
- In contrast, edge-lit technology employs LEDs only around edges of LED TV screens. Unlike an edge-lit LED TV, an LED TV with full-array technology can selectively dim specific groups of LEDs, allowing for superior contrast ratio & superior overall picture quality.

LED TV

- **As with any TV, an LED TV needs energy in order for its components to function. Specifically, an LED TV needs electric current for stimulating LCs in its LCD panel & for activating its LED backlighting.**

- **In comparison to standard LCD TVs, LED TVs consume less energy, qualifying many of them for the EPA's Energy Star energy-efficiency standard.**

- **An LED TV will typically consume between 20 & 30 percent less energy than an LCD TV with the same screen size.**

Plasma Display Panel Technology

- Plasma displays are emissive
- Current PDP benchmarks:
  - Sizes to 103”
  - Resolution to 1920 × 1080
  - Brightness > 100 nits (FW), 1000 nits peak
- Power draw 15%-20% > same size LCD
- Weight 20%-25% > same size LCD

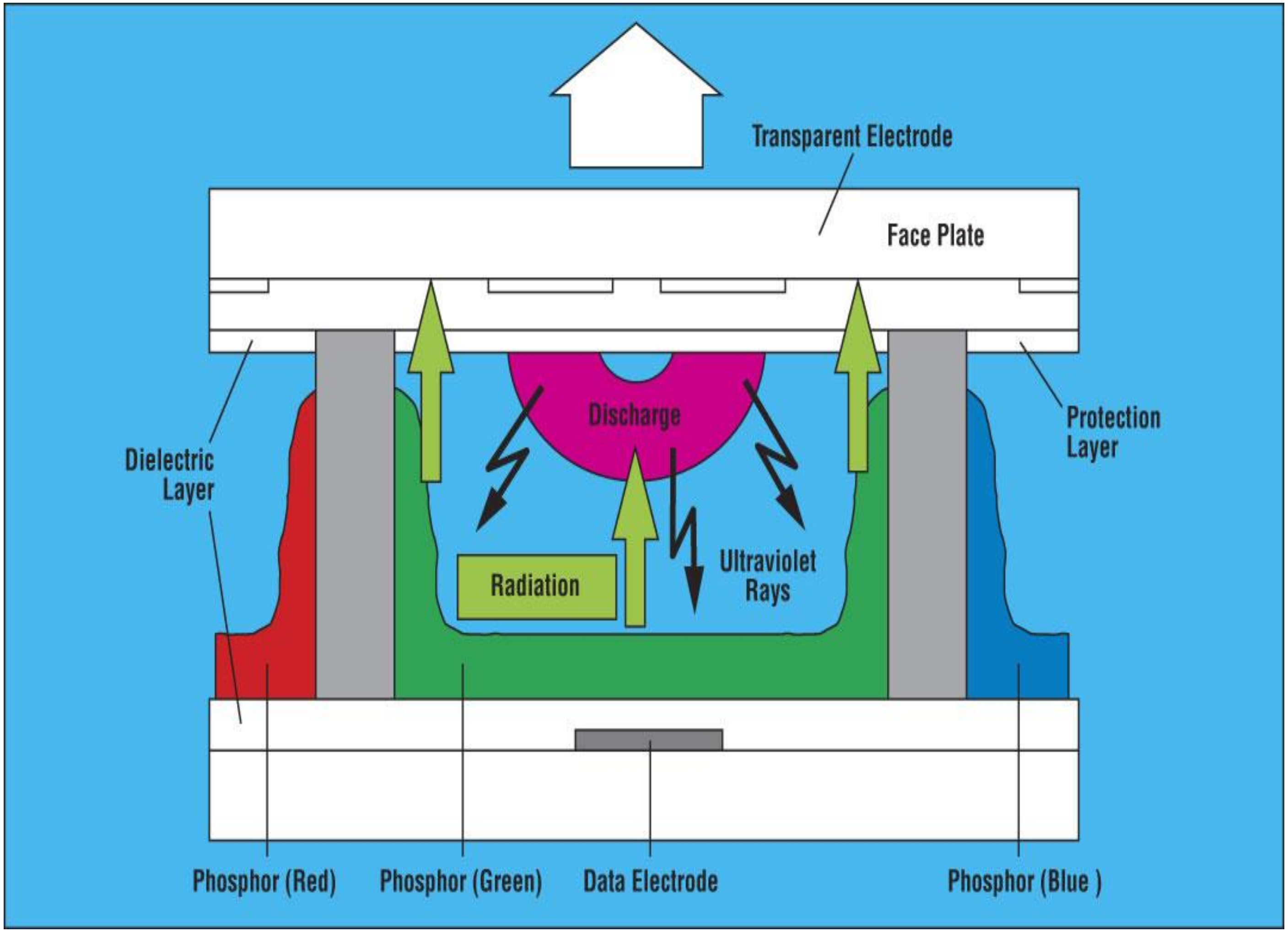
Candela per square metre (cd/m^2) is derived SI unit of Luminance. Nit (nt) is a non-SI unit of Luminance (1 nt = 1 cd/m^2).

Plasma Imaging Process

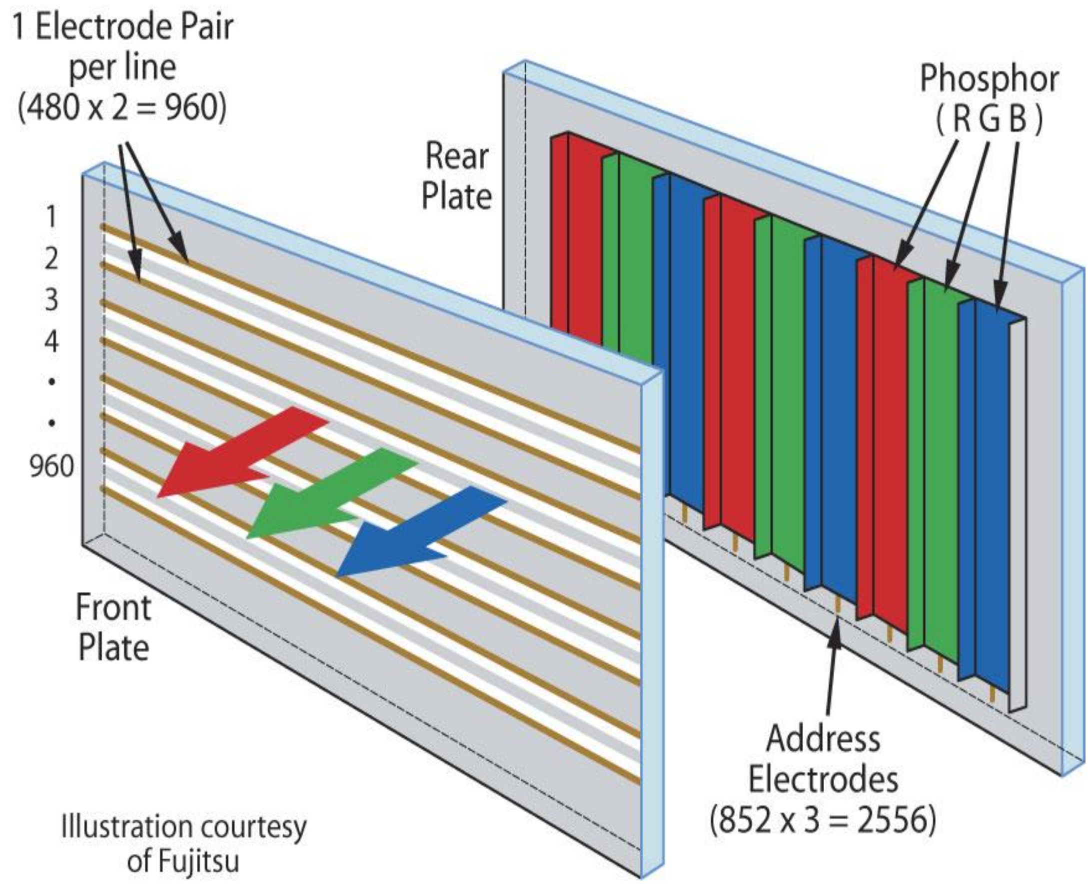
Three-step charge/discharge cycle

- Uses Neon-Xenon gas mixture
- 160-250V AC discharge in cell stimulates UV radiation
- UV stimulation causes color phosphors to glow & form picture elements
- Considerable heat & EMI are released

Plasma Imaging Process

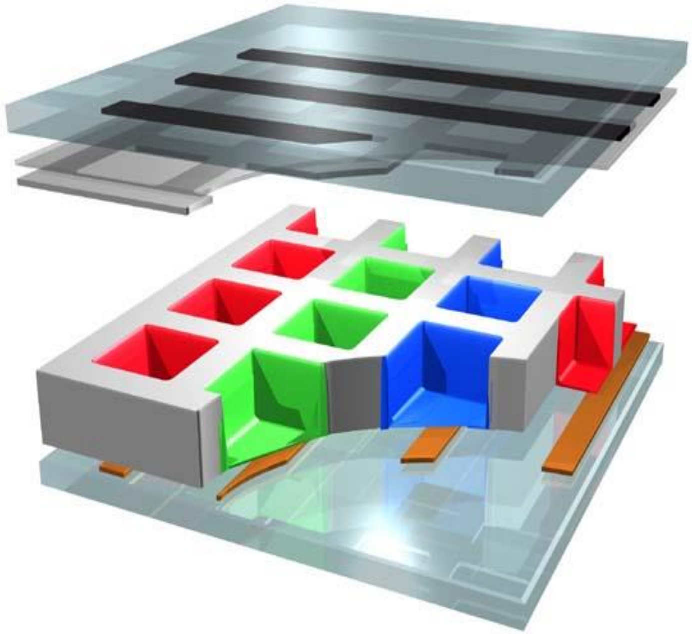


PDP Rib Structure (Simple)



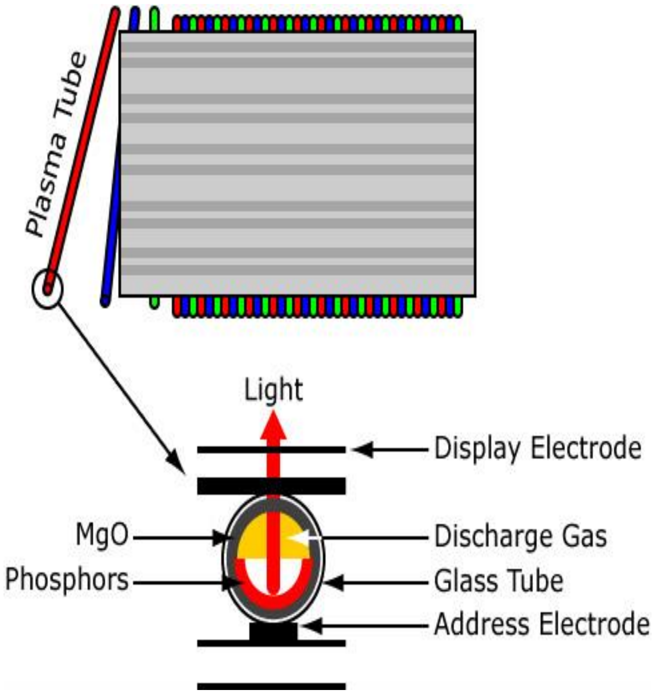
Deep Cell Structure (Advanced)

- Waffle-like structure
- Higher light output
- Less light leakage between rib barriers
- Developed by Pioneer



Plasma Tube Structure (Future?)

- Phosphors, electrodes, & Ne/Xe gas combined into long tubes
- Reduces cost of larger screens
- Flexible displays?
- Developed by Fujitsu



Real-World Plasma Benchmarks

- A review sample 50-inch plasma monitor measured from 93 nits (full white) to 233 nits (small area), with ANSI (average) contrast measured at 572:1 and peak contrast at 668:1
- Typical black level .21 nits (closer to CRT)
- Native Resolution – 1366 × 768
- Power consumption – 411.3 watts over a 6-hour interval (total of 2.089 kWh)

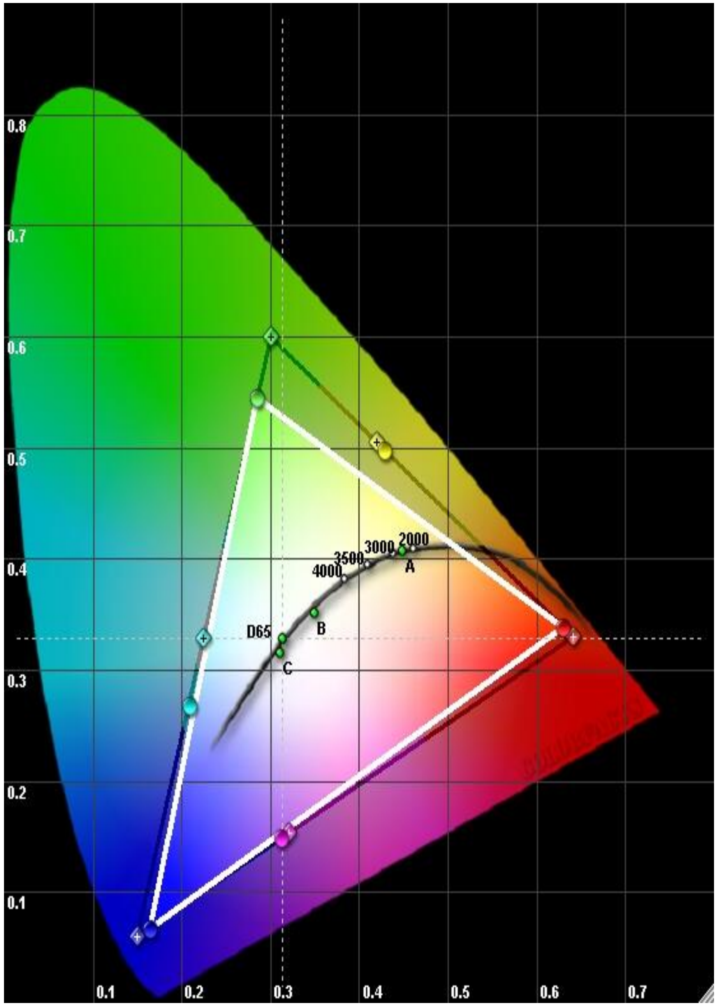
Real-World Plasma Benchmarks

Color rendering

- Gamut is smaller than REC 709 coordinates
- Green somewhat undersaturated
- Red, blue are very close to ideal coordinates

Technology enhancements:

- Wider color gamuts (films, phosphors)
- Improved lifetime (gas mixtures)
- Higher resolution (1920 × 1080 @ 50”)
- Resistance to burn-in (change in gas mixture)



Quantum Dots

- Quantum dots represent 3-D confinement (an electron confined in a 3D quantum box of dimensions from nanometers to tens of nanameters).

- These dimensions are smaller than de Broglie wavelength.

- A 10 *nm* cube of GaAs would contain about 40,000 atoms.

- QD is often described as an artificial atom because electron is dimensionally confined just like in an atom (where an electron is confined near the nucleus) & similarly has only discrete energy levels.

- Electrons in a QD represent a zero-dimensional electron gas.

- Recent efforts have focused on producing quantum dots in different geometric shapes to control shapes of potential barrier confining electrons (& holes).

- **A simple case of a QD is a box of dimensions l_x, l_y, & l_z. Energy levels for an electron have only discrete values,**

$$E_n = \frac{h^2}{8m_e}\left[\left(\frac{n_x}{l_x}\right)^2 + \left(\frac{n_y}{l_y}\right)^2 + \left(\frac{n_z}{l_z}\right)^2\right]$$

where quantum nos. l_x, l_y, & l_z each assuming integral values 1, 2, 3, characterize quantization along x, y, & z axes respectively.

Consequently, density of states for a zero-dimensional electron gas (for a QD) is a series of δ functions at each allowed confinement state energies.

$$D(E) \propto \sum_{E_n} \delta(E - E_n)$$

$D(E)$ has discrete (nonzero) values only at discrete energies. Discrete values of $D(E)$ produce sharp absorption & emission spectra for QDs, even at room temp.

- **QDs have large surface-to-volume ratio of atoms, which can vary as much as 20%. Consequence: surface-related phenomena.**

- **Strong confinement regime represents; when size of QD (e.g., radius *R* of a spherical dot) is smaller than exciton Bohr radius a_B.**

- **Energy separation between sub-bands (various quantized levels of electrons & holes) is much larger than exciton binding energy.**

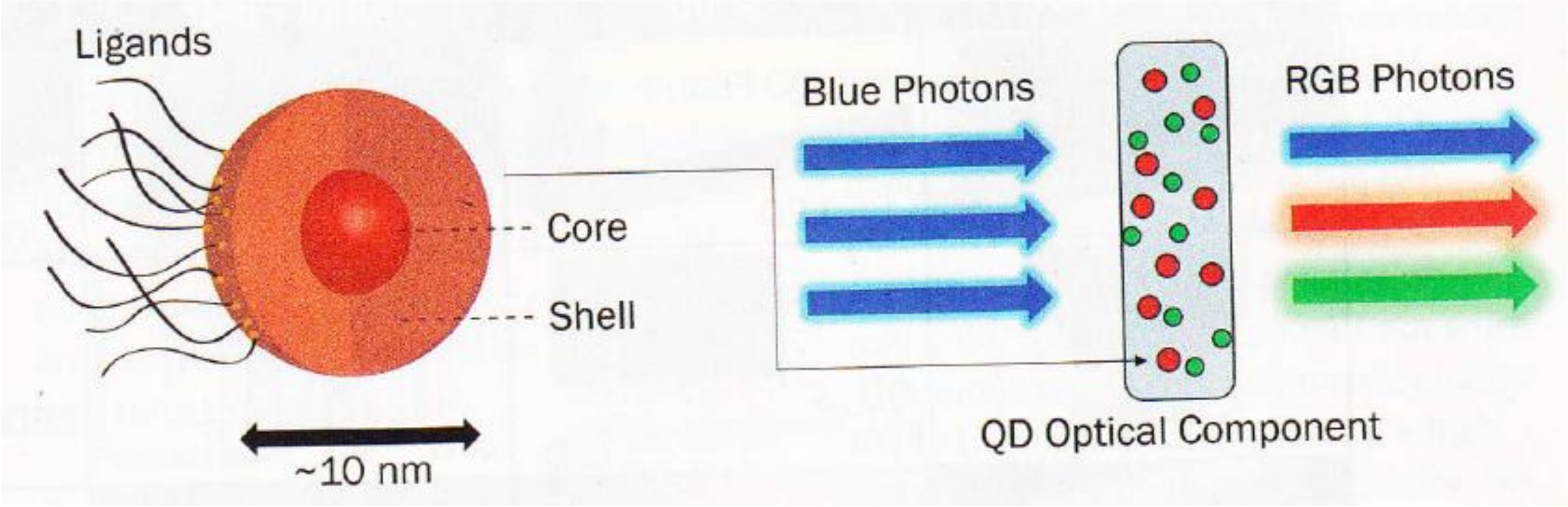
- **Electrons & holes are largely represented by energy states of their respective sub-bands.**

- **As QD size increases, energy separation between various sub-bands becomes comparable to & eventually less than exciton binding energy. Latter represents case of a weak confinement regime where size of quantum dot is much larger than exciton Bohr radius.**

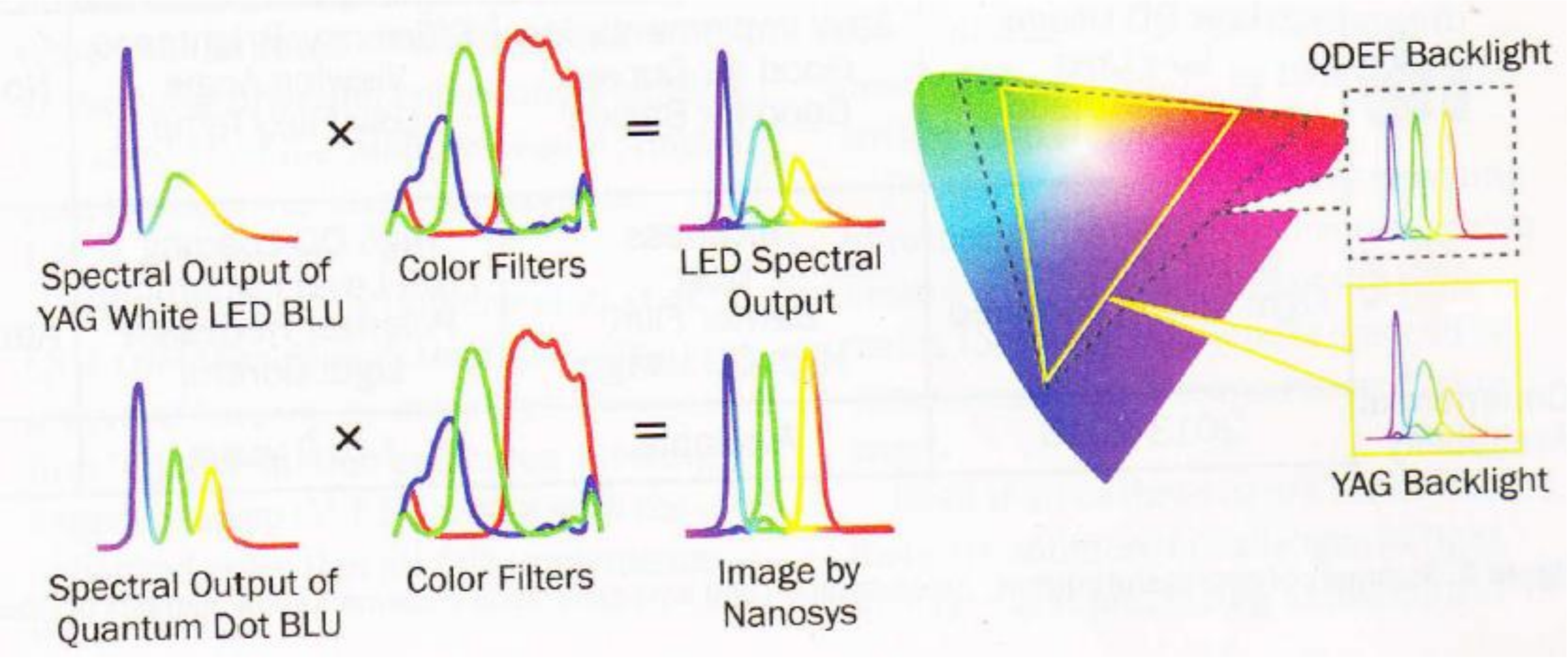
- **Electron-hole binding energy in this case is nearly same as in bulk semiconductor.**

Quantum Dots in Displays

P. Palomaki, Photonics Spectra 52 (May 2018) 42-47.



Composition & function of a QD



Spectral output of blue LED + YAG phosphor (top row) compared to blue LED + QDs (bottom row). Spectra generated by the phosphor/QDs are then passed through a color filter to generate the final LCD spectrum. QD down-conversion approach produces a larger color gamut with less wasted light.

Comparison of CdSe & InP QD technologies

Property				
Technology	FWHM	PLQY	Cost	Regulated
Phosphor (Ce:YAG)	>100 nm	>90%	$	No
CdSe QD[1]	<30 nm	>90%	$$$	Yes
InP QD[4]	40-50 nm	60-85%	$$$$	No

FWHM: Full width half maximum; PLQY: photoluminescent quantum yield;
$ to $$$$: least to most expensive.

	Current Generation		Next Generation		
	Edge Optic	Film	Color Filter	On LED Chip	Electroluminescent
Pros	Low QD Usage Low Cost Fully Hermetic	Easy Implementation Good for Curved Good for Backlit	Efficiency/Brightness Viewing Angle Low Flux/Temp	Drop in Solution No Extra Components	Low QD Usage Efficiency/Brightness Simplifies Display Enable Flexible Display
Cons	Edge-Lit Only Bezel Thickness Light Mixing Required	Thickness Cost Barrier Film High QD Usage	High QD Loading Pixel-Level Patterning Polarizer Redesign Light Control	High-Temp High-Light-Flux Atmosphere Exposure	Poor Lifetime Blue QDs Needed Pixel-Level Patterning
Commercial Availability	2013-2016	Available	1 to 3 years	1 to 3 years	3+ years

Summary of successful current implementation & next-generation implementation methods of QDs in displays.