Display Wars:
Flat Panels 2005

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Look Out, Here They Come

- Flat-panel display technologies are sweeping through markets all over the world
  - Digital Signage, Home Theater
  - Command and Control, Retail Displays
  - Handheld Electronics (Cameras, PDAs, Phones)
- The Contenders
  - Plasma Display Panels (PDPs)
  - Thin-film Transistor Liquid Crystal Displays (TFT LCDs)
  - Organic Light-emitting Diodes (OLEDs)
  - Electroluminescent and Emissive Displays

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Fighting For Position - 2005

- TFT-LCD Announcements
  - Samsung - 57” TV to retail, 82” panel shown
  - LG Philips - 52” and 55” TVs to retail
  - Sharp - 65” TV to retail
- Major Plasma Announcements
  - Panasonic - 65” TV and monitor to retail
  - LG - 71” TV to retail
  - Samsung - 80” to retail, 102” TV shown

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Fighting For Position: 2004-05

- Price Trends:
  - 42” EDTV “no name” plasma TVs - <$2,000
  - 42” HDTV “no name” plasma TVs - <$3,000
  - 42” LCD TVs (Westinghouse/CMO) - $2,495
  - 37” LCD TVs (rebranded LG) - <$3,000
  - 40” LCD TVs (rebranded Samsung) - <$3,500
  - 46” LCD TVs (CMO) - <$10,000
  - 50” plasma TVs (Samsung) - $4,200
  - 61” plasma monitors - $8,200

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Fighting For Position: 2004-05

- Manufacturer Trends:
  - Fujitsu sells all but 19% of plasma investment, patents, and IP to Hitachi
  - Fujitsu sells LCD business to Sharp
  - Sony - Samsung launch Gen 7 LCD factory
  - Panasonic at 100,000 plasma panels / month
  - Samsung at 250,000 plasma panels / month
  - Panasonic & Hitachi PDP partnership

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Fighting For Position: 2004-05

- Manufacturer Trends:
  - Sony to exit plasma business in favor of LCD
  - Toshiba scales back plasma in favor of LCD
  - Hitachi, Toshiba, and Panasonic joint venture in Gen 6 TFT LCD factory (32” - 42”)
  - Sharp Gen 6 LCD factory on-line (to 65”)
  - Toshiba & Canon demonstrate SED (CES 2005)

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Can’t Tell The Players Without A Scorecard!

Major Plasma Display Manufacturers

- In Japan:
  - Matsushita (Panasonic)
  - Hitachi Electronics (Kyushu FHP factory)
  - Pioneer Electronics (owns former NEC works)
- In Korea:
  - Samsung Electronics
  - LG Electronics
- In China / Taiwan:
  - Chungwha Picture Tube (using ex-Mitsubishi 46” designs)

Plasma TV Market Snapshot

4th Quarter 2004

- Panasonic ends 2004 with 19% WW market share
- LG holds onto #2 with 14.5% WW share
- Samsung takes over #3 spot with 12% WW share
- Philips, Sony, Hitachi, Pioneer ranked #4 - #7
- 42” - 43” screen size dominates market (74%)
- 32” - 37” category climbs to 15%
- 46” - larger sizes drop to 11%
- Dell grabs 10% of 42” - 43” market

Source: DisplaySearch Q4’04 Plasma TV Shipments

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Major TFT LCD Panel Manufacturers

- In Japan:
  - Sharp Electronics (also bought Fujitsu's business 1/05)
  - Hitachi, Sanyo, NEC- Mitsubishi, Kyocera
- In Korea:
  - Samsung Electronics
  - LG - Philips (LGL)
- In China / Taiwan:
  - AU Optronics (AUO), Chi Mei Optronics (CMO)
  - Chungwha Picture Tube (CPT)

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LCD Panel Market Snapshot

Large-Area Panels 4th Quarter 2004

- LG Philips holds 23% market share (size, capacity)
- Samsung right behind at 22.5%
- AUO in #3 spot (14.9%), CMO #4 (11.6%)
- 20” VGA, 15” XGA, 32” WXGA sizes #1-#2-#3
- 30” and larger up to 21% share WW
- Samsung #1 in LCD TV modules shipped
- LG Philips, CMO at #2, Sharp at #4

Source: DisplaySearch Q4’04 Plasma TV Shipments

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LCD Display Technology

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Everyone Wants A Piece of the Action

- LCD manufacturing is expanding and maturing
  - "Sweet spot" is from 26 inches to 42 inches for the home
  - LCD can provide HD resolution in all sizes; 1280x768 pixels through 42-inch sizes, 1920x1080 pixels > 42 inches
  - Gen 6 fabs now on line in Japan, Korea, China
  - Typical Gen 6 motherglass is 1500 x 1800mm (Sharp), approximately 70 inches by 59 inches
  - Gen 6 glass can yield (6) 37-inch or (12) 26-inch panels
  - Samsung, Sony (S-LCD) launch Gen 7 in 2006 (1870 x 2200mm)

LCD Display Technology - A Recap

- Mature technology (first developed in 1960s)
- Liquid-crystal monitors and TVs are **transmissive** in operation. Their pixels act as shutters to control the amount of light from a fluorescent backlight
- Current LCD benchmarks include sizes to 82” (prototypes) and brightness exceeding 400 nits FW
- Power consumption less than plasma for given size
- Weight less than plasma for given size

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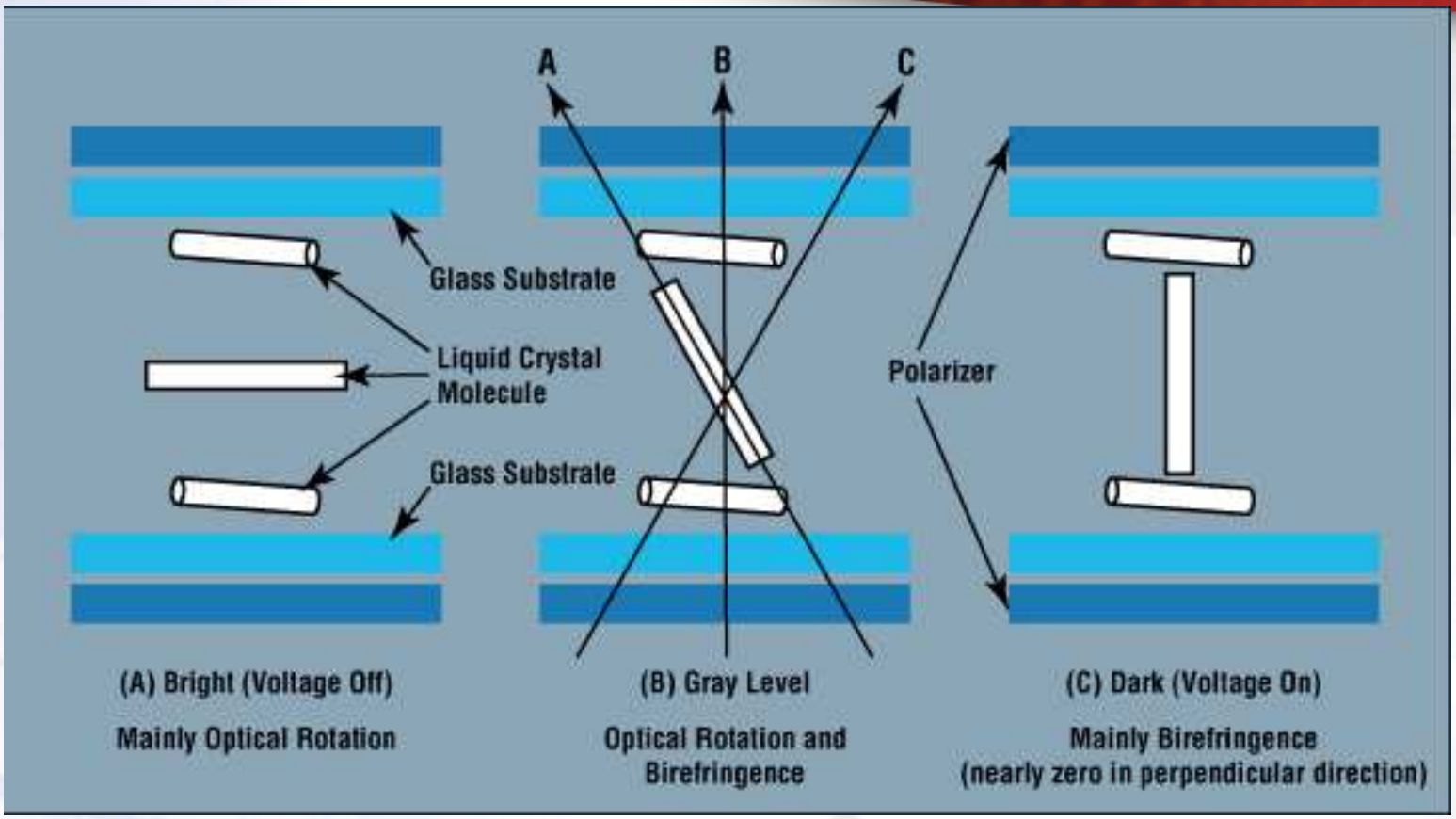
The Birefringence Principle

- Randomly-arranged LCs pass light normally (“off” state)
- Liquid crystals arranged to block light (“on” state)
- Light beams are polarized (split into two planes) when passing through LC field
- The polarizing effect is known as “birefringence”
- Important to remember: Source of illumination is independent of individual LC pixels

LCD Imaging Process



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LCD Imaging Process

- TFT LCD monitors have individual R, G, B pixels with micro color filters
- Each pixel addressed by small thin-film transistor (TFT) made from amorphous silicon
- Addressing is usually active matrix (AM TFT)
- Variations include TN, STN, TSTN, homeotropic, and daisywheel/vertical LC alignments (better contrast)

A Close Cousin?

(Venetian Blinds)

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Real World LCD Benchmarks

- A review 45-inch LCD TV delivered from 156 to 284 nits (45.6 to 83 foot-Lamberts) with ANSI (average) contrast measured at 147:1 and peak contrast at 170:1
- Typical black level = 1.7 nits (8 x CRT)
- Adjustable backlights help with lower black levels and better contrast numbers
- Predicted life of backlight: 60,000 hours @ 200 nits (not in full power mode)

Source: Roam Consulting Tests 2004

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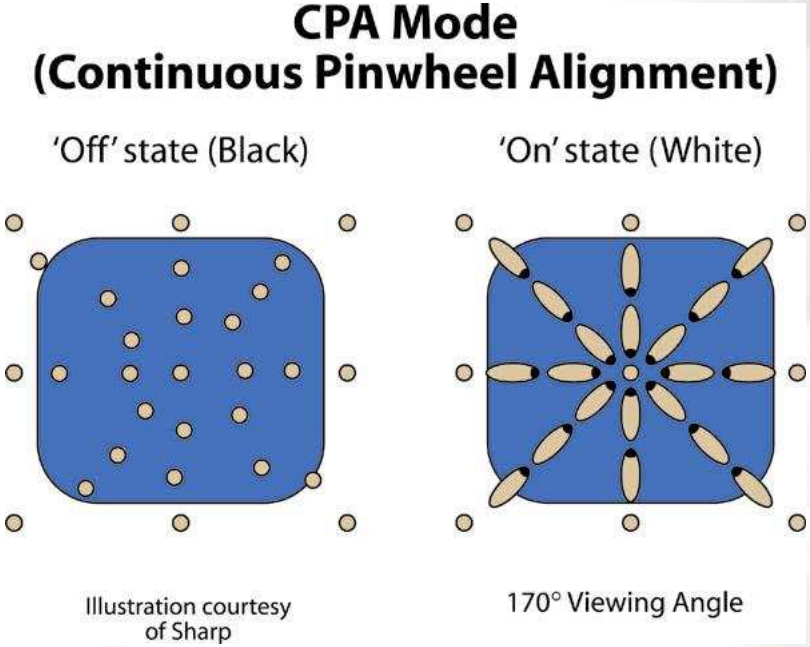
Continuous Pinwheel Alignment

- CPA - Developed by Sharp Electronics
- LC alignment optimized for wide viewing angles (typically 150° H/V)
- Improved contrast
- High brightness



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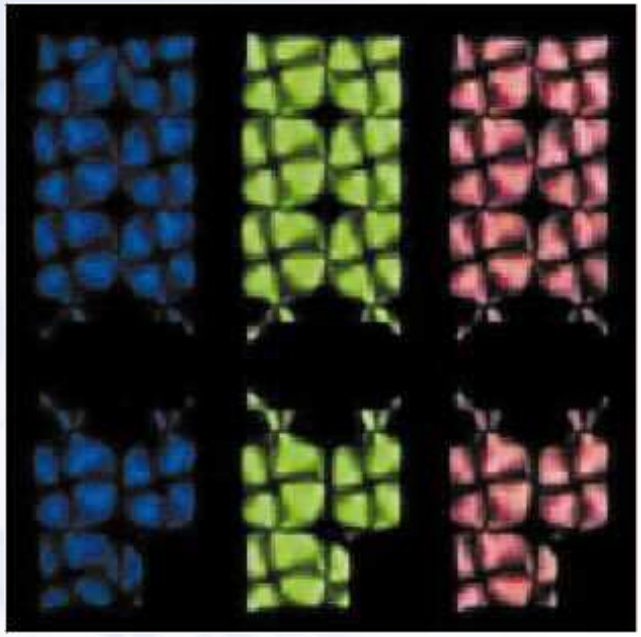
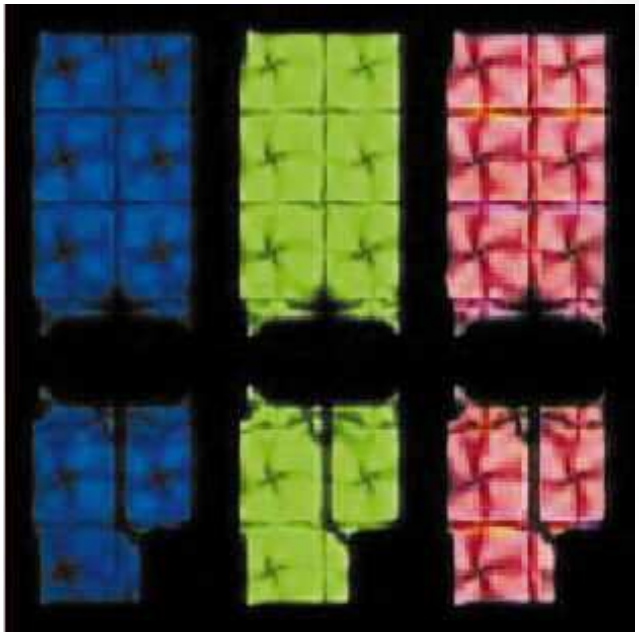
CPA / Advanced Super View in Action





Illustrations courtesy Sharp Electronics

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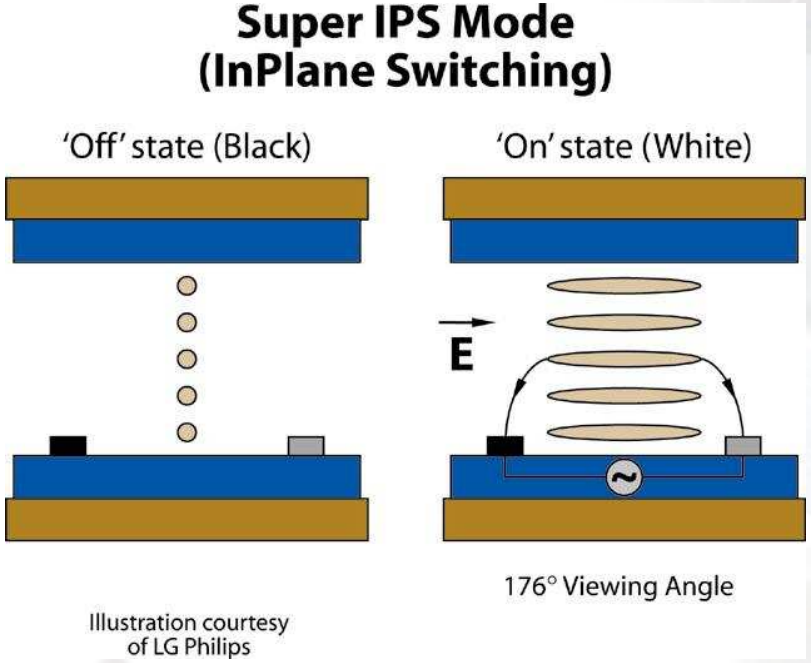
Super In-Plane Switching

- Super IPS - Developed by LG Philips LCD
- LC alignment optimized for wide viewing angles (typically 150º H/V)
- Improved contrast
- High brightness



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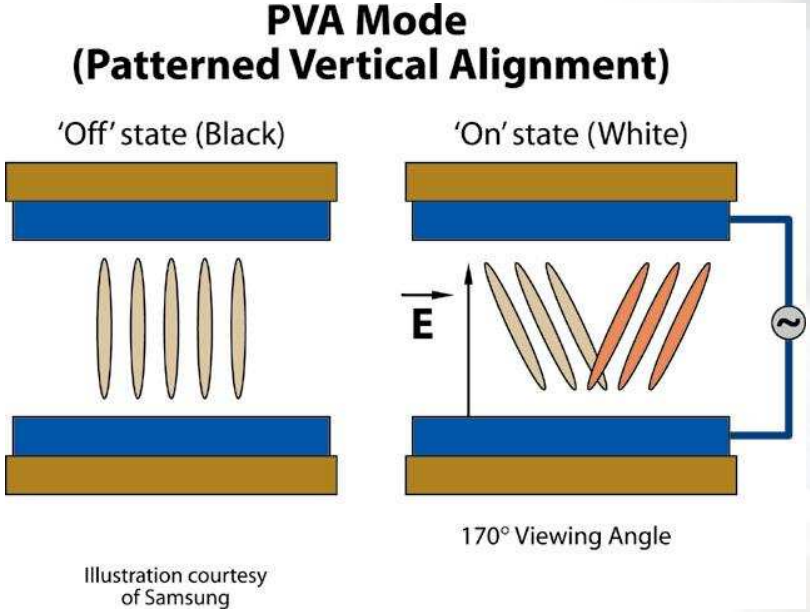
Patterned Vertical Alignment

- PVA - Developed by Samsung Electronics
- LC alignment optimized for wide viewing angles (typically 150° H/V)
- Improved contrast
- High brightness



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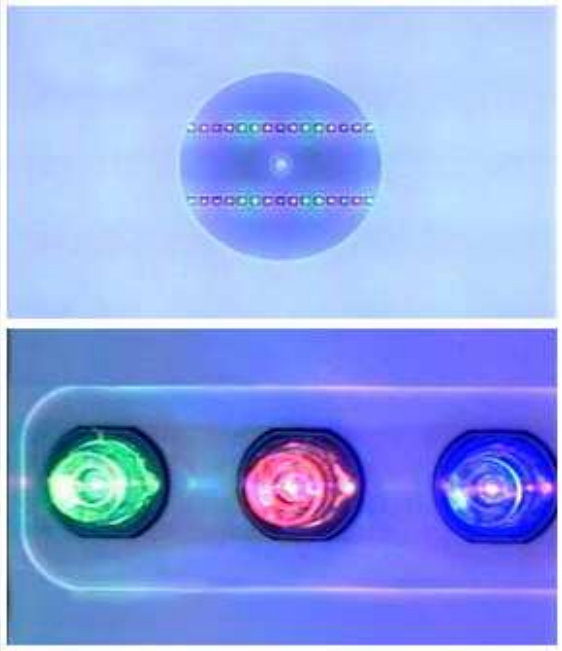
How Do They Handle Video?

- LCD panels are analog RGB displays (0-255 levels of gray), so they work best with RGB inputs
- LC response time is still slow for video (claimed 16 mS), some manufacturers now claim 8 ms switch time
- LCD displays have trouble with low-level shadow detail (video) resulting in crushed grayscales
- They look best with RGB and DVI input connections

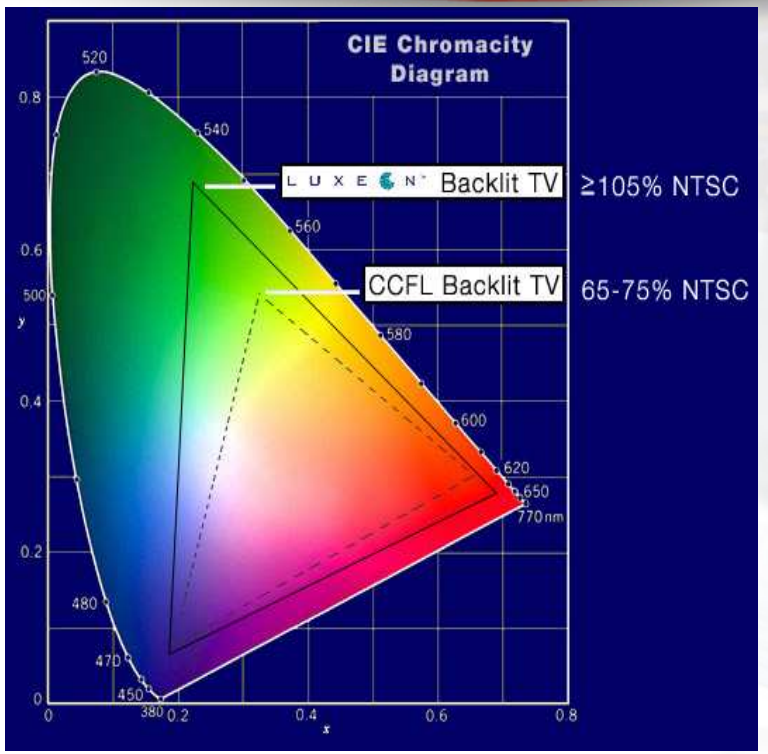
LCD Color Accuracy Issues

- Ditch the CCFL, use LEDs instead!
- Samsung (LNR460D) 46-inch LCD TV
- Sony (Qualia 005) 46-inch LCD TV
- Both use LumiLEDs RGB LED stripes for color
  - Line array is 26 red, 26 green, 13 blue
  - 65 diodes by 7 rows = 455 total LED ‘elements’
  - Brightness spec tentatively set at 450 nits
  - LED life estimated between 50,000 - 100,000 hours
- But they draw a lot of current!

LED Matrix and Color Gamut



Close-up of LED Array



Claimed LED Color Gamut

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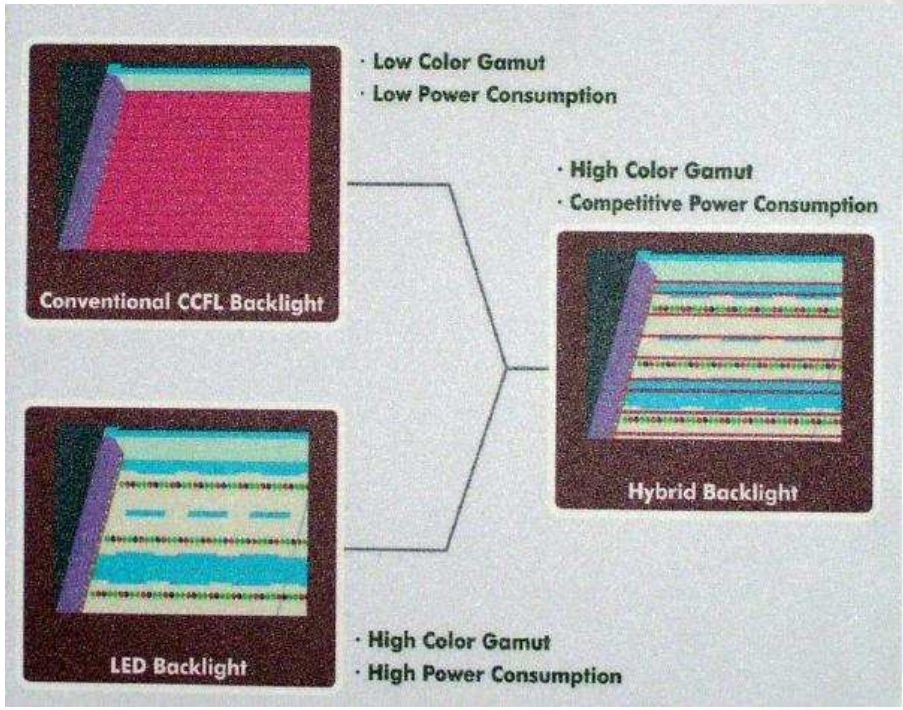
Hybrid Color Backlight System

- Combines CCFL / HCFL with LED stripes
- Hybrid system has many advantages:
  - Gamut exceeds SMPTE C
  - CCFL / HCFL creates white light (pulsed)
  - Current consumption lower
  - Power draw is reduced!



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LCD Versus Plasma: The 'Skinny'

- Drawbacks of TFT LCD:
  - Contrast (about 1/4 - 1/2 plasma)
  - Motion Smear (LC twist times)
  - Color Saturation (transmissive, not emissive)
- Advantages of TFT LCD:
  - Higher pixel density (HDTV in smaller screen size)
  - Brightness (3x - 5x comparable plasma)
  - No burn-in, only TFT or backlight burn-out

What's Ahead for TFT LCDs

- Size - 82" TFT LCD panels achieved
- Resolution - 1920x1080 has been achieved
- LCD has taken over the flat panel market to 32"
- 32" - 42" is the current LCD - plasma battleground
- Market prices falling as new, larger fabs start up
- Some plasma manufacturers hedging bets with LCD (Samsung, LG, Panasonic, Hitachi, CPT)

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Plasma Display Technology

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Playing A Strong Hand

- Plasma is gunning for CRTs
  - "Sweet spot" is from 26 inches to 42 inches
  - Plasma in true HD resolutions only above 42 inches
  - New plasma fabs from Samsung, CPT, Panasonic
  - New gas mixtures (neon + xenon) = longer panel life
  - Materials cost for plasma fabs lower than LCD (about 1/3 of price, LCD is 1/2 of price) - larger is cheaper!
  - > 25 companies now manufacturing or marketing plasma in all sizes (this number changes every week)

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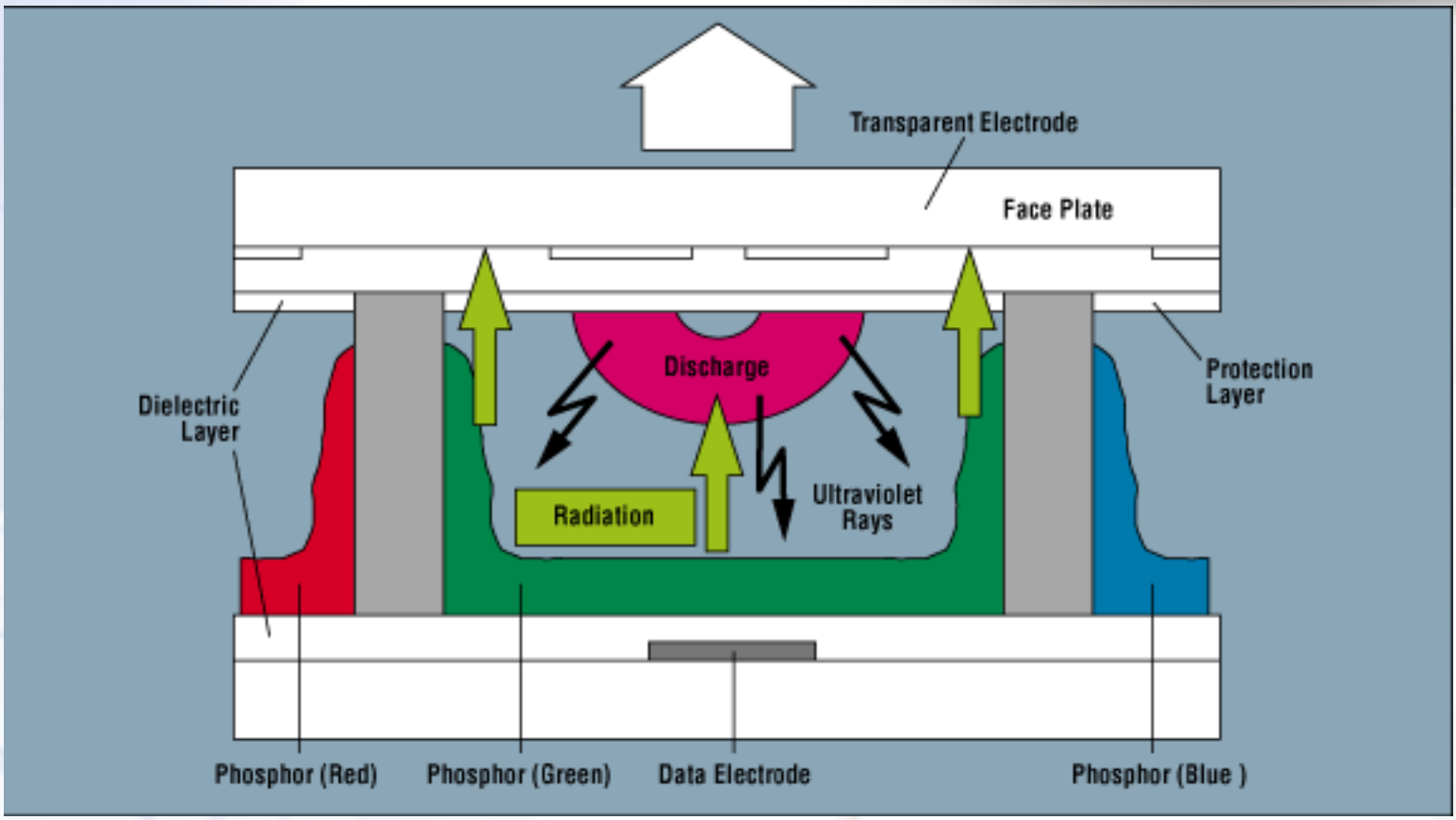
PDP Technology - A Recap

- Plasma monitors and TVs are **emissive** in operation
- Image brightness directly related to intensity at which individual pixels are driven
- Current PDP benchmarks include sizes to 102” (prototypes) and brightness exceeding 100 nits (FW)
- Power draw 15-20% more than LCD for given size
- Weight 20-25% more than LCD for given size
- Mature technology since early 1960s

Plasma Imaging Process

- CHARGE / DISCHARGE CYCLE
  - Uses mix of rare gases (neon, argon, etc)
  - 160 - 250V AC discharge in cell stimulates ultraviolet (UV) radiation
  - UV stimulation causes color phosphors to glow and form picture elements
  - Yes, PDPs get warm!

Gas Plasma Discharge Principle



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A Close Cousin?

(Fluorescent Lamps)

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PDP Rib Structure (Simple)

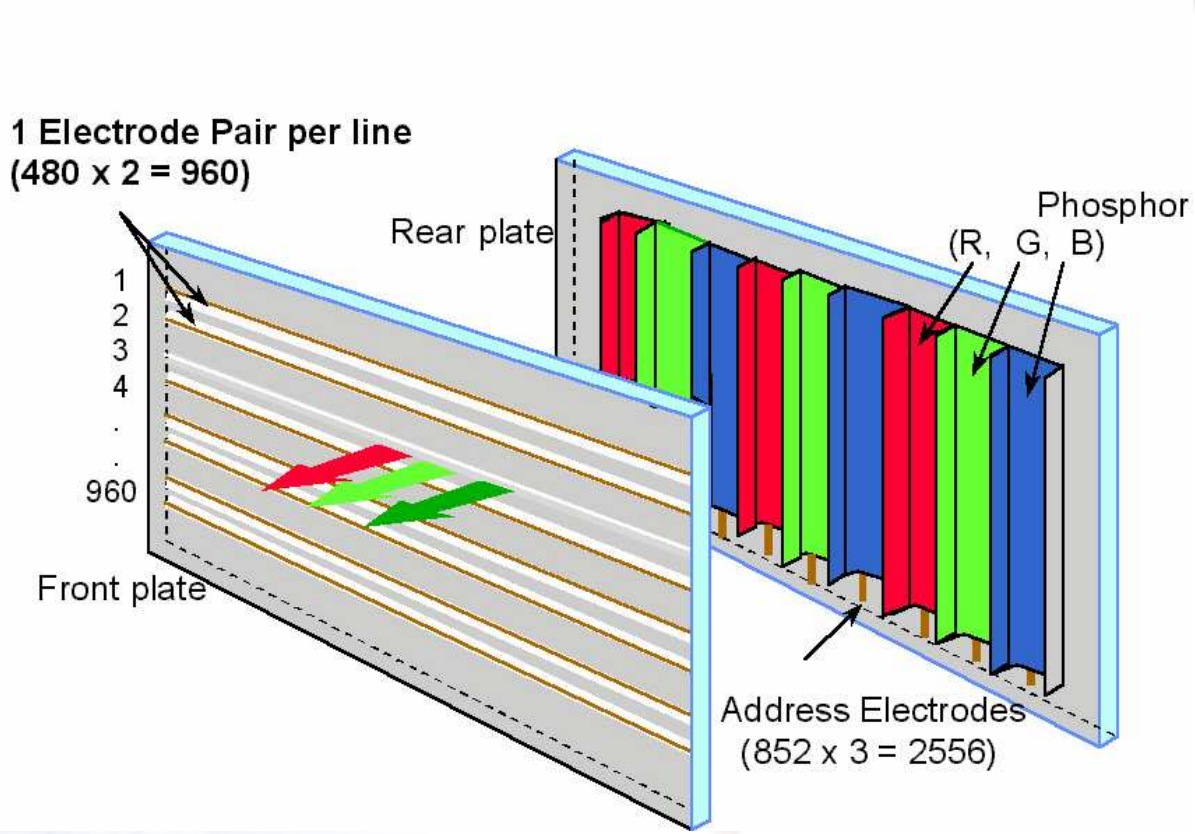

Illustration courtesy of Fujitsu

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Real World Plasma Benchmarks

- A review 42-inch plasma TV delivered from 72 to 299 nits (21 to 87.4 foot-Lamberts) with ANSI (average) contrast measured at 596:1 and peak contrast at 772:1
- Typical black level = .21 nits (same as CRT)
- Deep cell structure, improved filters both enhance contrast
- Predicted life of phosphors: 60,000 hours @ 80 nits (not in full power mode)
- Burn-in still a concern, picture orbiting and low power modes are standard menu selections now

Source: Roam Consulting Plasma Tests 2004

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Deep Cell Pixel Structure

- Waffle-like pixel structure for higher light output
- Improves luminous efficiency
- Black levels higher
- Viewing angles the same as conventional “ribs”
- More complex to manufacture than ribs

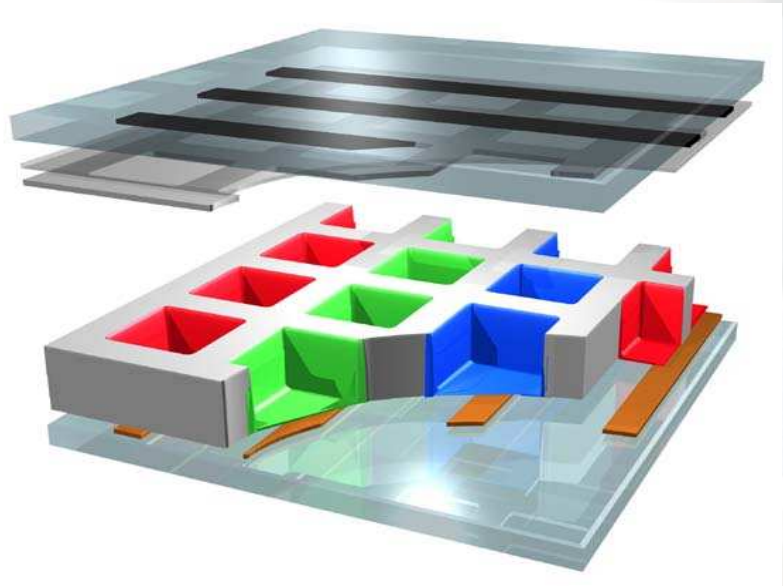

Illustration courtesy of Pioneer

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Alternate Lighting of Surfaces

- Segmented pixel scanning system
- Higher light output with reduced power
- Not an interlaced system
- High pixel density in smaller panel sizes
- FHP developed it

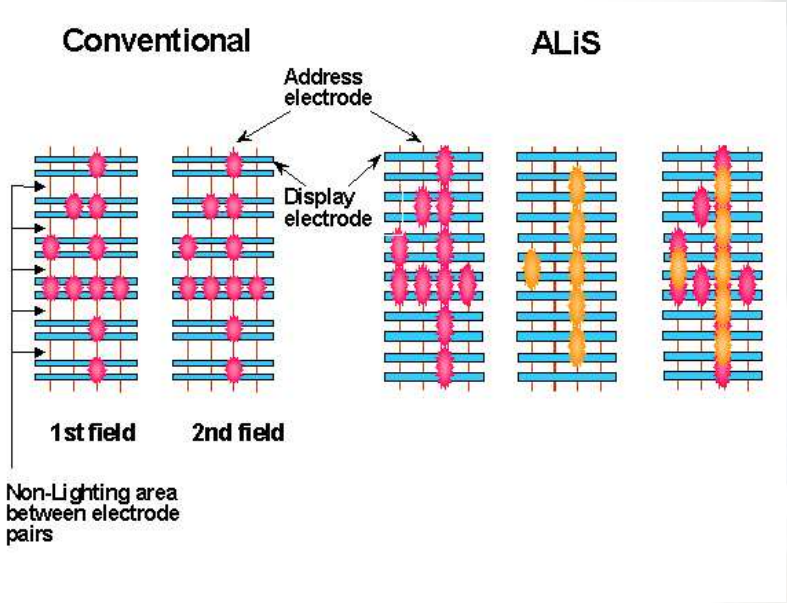

Illustration courtesy of Fujitsu

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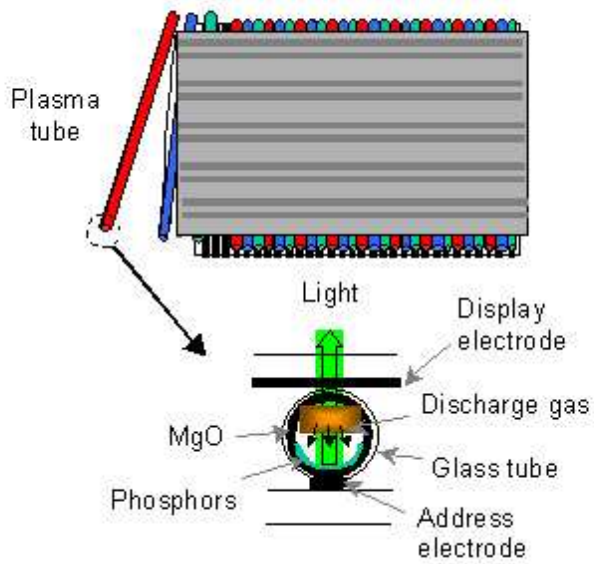
Plasma Tube Technology

- Tubes less expensive to make than unified PDP
- Allows much larger panel sizes
- Tubes can be cut to specific lengths
- Developed and patented by Fujitsu (will Hitachi continue?)

▪ Figure 1:



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How Does Video Look?

- Plasma panels are RGB devices (0-255 levels of gray)
- Plasma displays have trouble with high- and low-level shadow detail (video) resulting in false contours
- They work best with RGB input signals and video scalars to achieve 1:1 pixel map
- Best to use RGB or DVI input connections
- No problems with fast motion, progressive sources are the best to display (480p, 576p, 720p, PC rates)

Plasma Versus LCD: The 'Skinny'

- Drawbacks of Plasma:
  - Phosphor burn-in (overdrive)
  - Power consumption and heat dissipation
  - Pixel pitch is coarse (.8mm - 1 mm)
- Advantages of Plasma:
  - Wider viewing angles (160 degrees H&V)
  - Saturated colors, lower gray levels
  - Faster video switch times (full motion 60 Hz)
  - Lower cost!!!

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What's Ahead for Plasma

- Has conceded 32" and smaller market due to prices and mass availability of LCD
- Longevity - est. 30,000 - 60,000 hours*
- Size - 80" current production max, >100" possible
- Resolution - HDTV (1920x1080) at 65" and above
- 42" EDTV plasma was the 'hot' product for 2004 holiday selling season
- Gradual shift to 42-inch HD plasma from ED models

* - Range of PDP manufacturer's claims

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Not So Fast, There!

Other Contenders (or Pretenders?)
To The Flat-Panel Throne

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Other Contenders and Pretenders

- Organic Light-emitting Diodes (OLEDs)
  - Low voltage, super thin analog display devices
  - Saturated, bright colors and wide viewing angles
- Surface-conduction Electron-emitter Displays (SEDs)
  - Super-flat version of a CRT
  - Bright colors, wide viewing angles
- Field Emissive Displays (FEDs)
- Electroluminescent Displays (ELs)
- Super Flat CRTs
- Salad Dressing Light Valves (SDLVs)

OLEDs: Displays You Can Print

- Construction uses anode and cathode, organic film layer divides ‘noble’ and ‘base’ electrodes
- ‘Holes’ and electrons meet in organic layer, energy from collisions is released as photons
- High contrast under normal to high ambient light
- Fast response for video, wide viewing angles standard
- No need for backlight or front-light!

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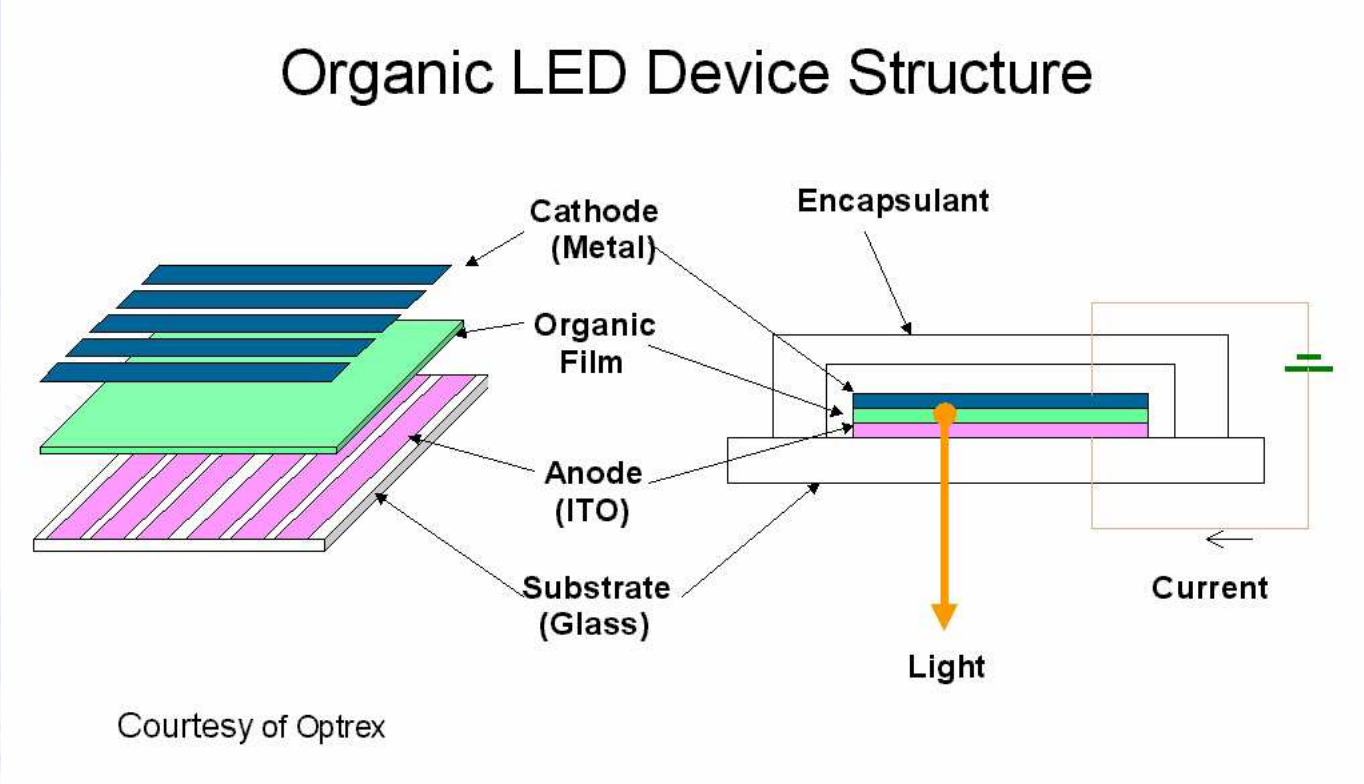
OLED Device Structure



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OLEDs: Displays You Can Print

- Manufactured in small molecule (SM-OLED) and dispersed polymer (P-OLED) designs
- Both are low-voltage semiconductors that emit light when current flows through an organic film layer
- Poised to take over the handheld display market

Photo courtesy Cambridge Display Technologies

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OLEDs: Displays You Can Print

- Organic LED displays are emissive in operation
- Individual LEDs activated to form picture elements
- OLEDs operate in 4 - 20 VDC range
- Full color RGB, ‘white’, and monochrome available
- Largest size manufactured to date - 40” (Epson, Samsung)

Samsung 40” AM OLED TV

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OLEDs: Displays You Can Print

- Yes, OLEDs are very, VERY thin! (< 5mm for film layer)
- Samsung 40-inch active matrix OLED shown at SID
- Polymer-based colors are developed with Dupont
- Issues remain with white balance and motion image sharpness

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OLED Benchmarks

- Brightness of 100-200 cd/m^2, contrast 200:1 - 400:1
- Resolutions to WXGA 1280x768
- They can be ink jet printed using polymer (P-OLED) deposition process
- Blue polymers now have 10,000 hour lifespan

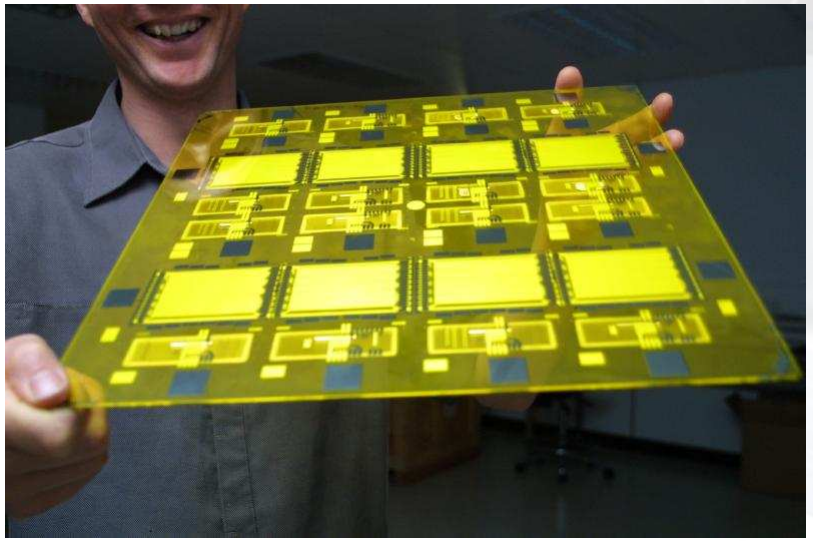

Photo courtesy Cambridge Display Technologies

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OLED Ink Jet Printing Technique

- Yes, you can literally ‘print’ a display using ink jets
- Precise alignment required for R, G, B channels
- Precise metering of polymers is required (no overfills or splash into adjoining cells)
- P-OLEDs only made this way

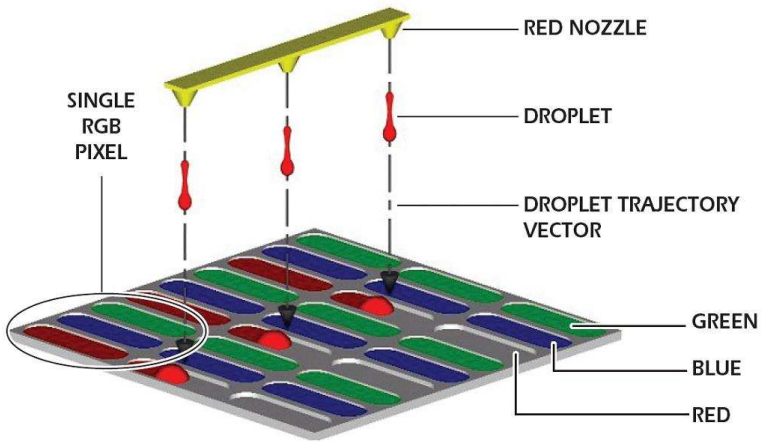

Photo courtesy Spectra / Information Display

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SED: The Plasma - LCD 'Killer'?

- SED = Surface-conduction Electron-emitter Display
- Uses high anode voltage, phosphors like CRT
- Emitter 'scans' from electrodes using low voltages
- Display is very thin, uses about 30% * less power than PDP
  - Color gamut exceeds SMPTE 'C' phosphors *
  - Peak brightness specification - 300 nits (87.7 ft-L) *
  - Contrast ratio specification (dark room) - 10,000:1 *
  - Wide viewing angle, fast response time (no smear)
- Developed by Canon, marketed with Toshiba

* - Manufacturer's claimed specs, not mine!

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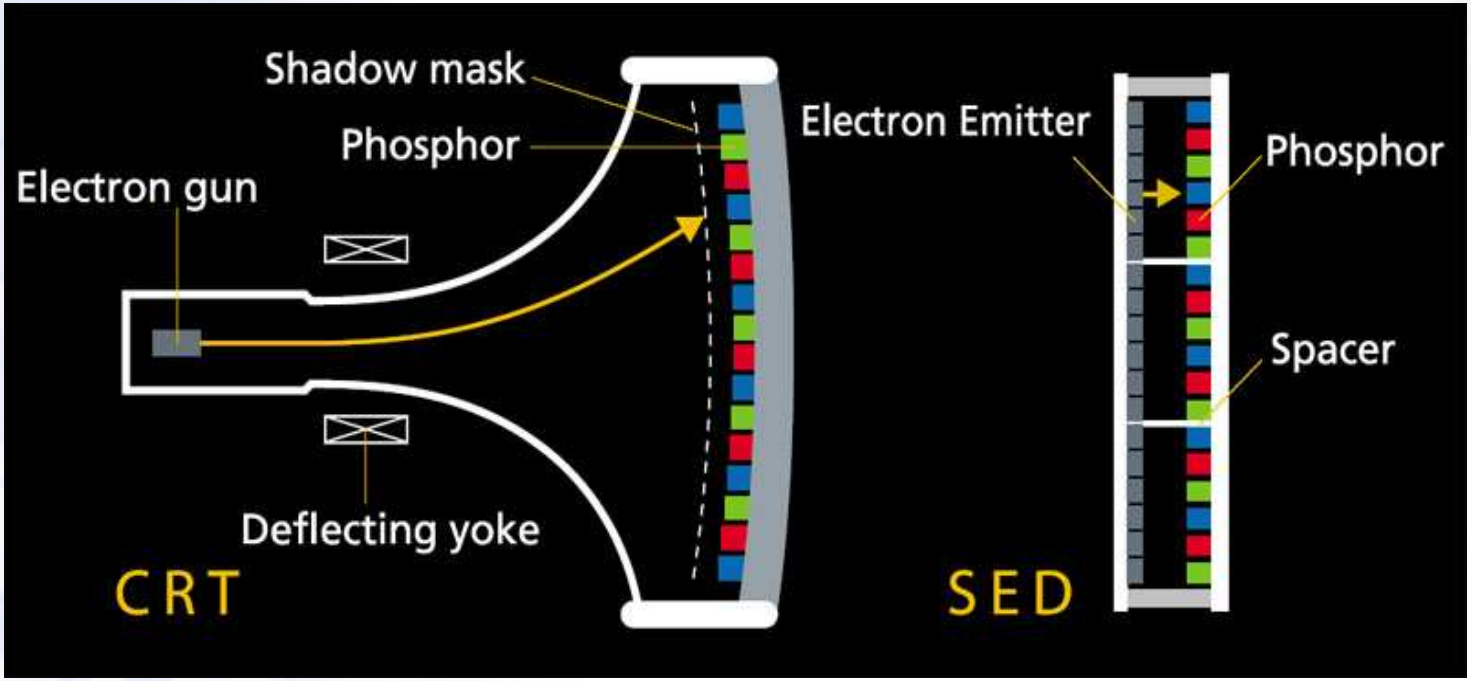
SED: The Plasma - LCD 'Killer'?



If you squashed a CRT, would it look and perform like this?

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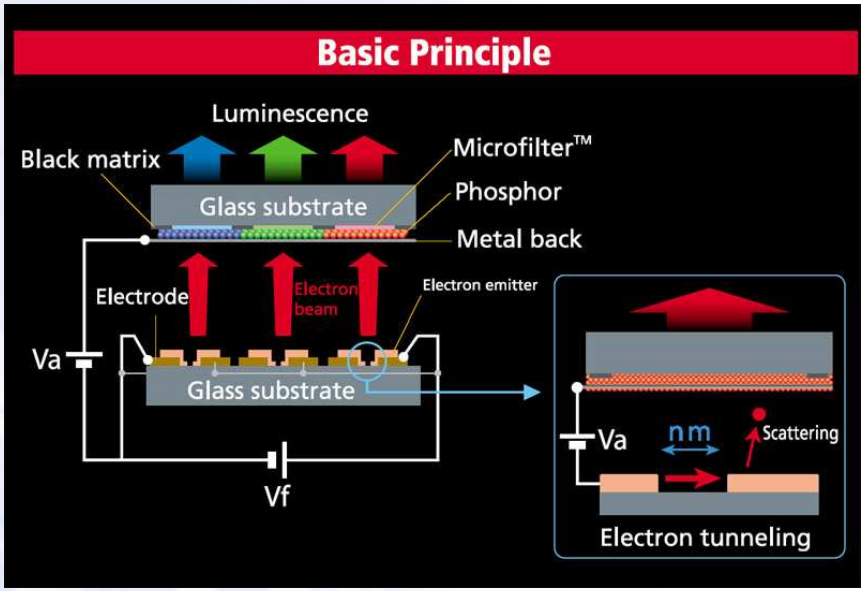
SED: The Plasma - LCD 'Killer'?



SED Pixel Structure

36-inch SED TV (1280x768)

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SED Benchmarks

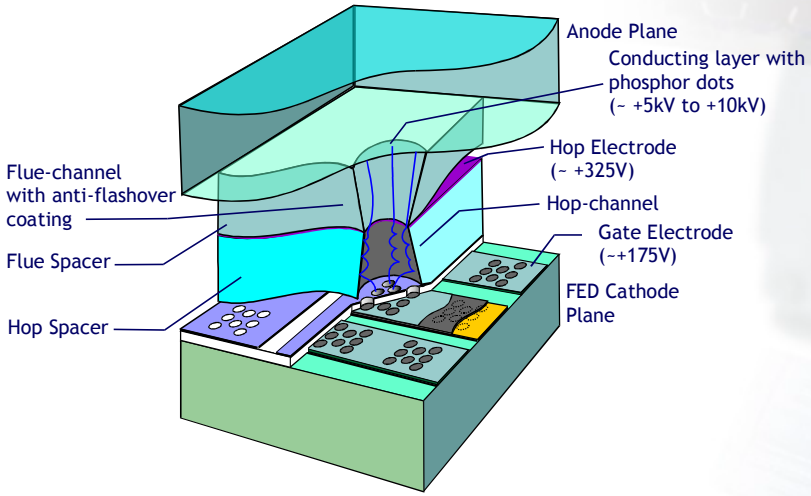
- Low power consumption (5 lumens/watt or better)
- Film layers can be printed using ink jet method
- A 40-inch SED panel would weigh less than 45 lbs and consume around 60W
- Super-flat screen possible (< 1/4 inch)
- Black level and grayscale performance of a CRT

FEDs: Always A Bridesmaid…

- Field Emissive Displays were once heir to CRT throne
- Super-small emitters of electrons attracted to front glass
- Super-fine pixel pitch (comparable to OLEDs)
- High brightness, wide viewing angles, saturated color
- The newest wrinkle, carbon nanotube emitters, may be able to resuscitate FEDs from their doldrums

FEDs: Always A Bridesmaid...

MIMIV 5.7” Color FED panel



Cross section of FED Pixel

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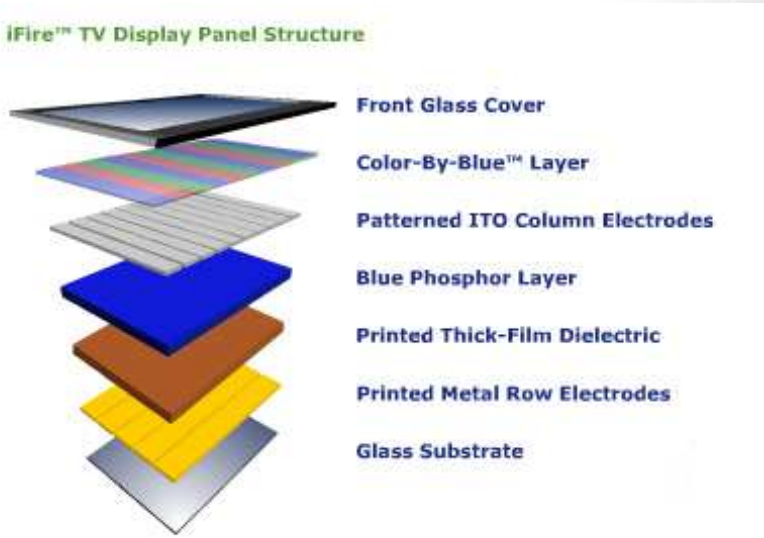
EL Displays: One Color Fits All

- Electroluminescent display uses a common-color phosphor emitter (blue)
- Color filters (stripes) provide R, G, B imaging
- Matrix of electrodes for pixel activation
- Bright display, wide viewing angles
- Similar to LCD with single-color backlight
- Similar to plasma with emissive operation

EL Displays: One Color Fits All

- iFire TDEL 34-inch display
- 1280x720 resolution
- Full color display
- Developed with DNP in Japan as lower-cost flat panel
- Est. 30 - 50% cost savings over plasma manufacturing



iFire Panel Structure

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Super Flat CRTs: Hanging In There

- CRT designs use extreme deflection yokes
- Neck is super thin, length reduced by 30%
- Bright displays with wide viewing angles
- Saturated and accurate colors
- Resolution limited to beam spot size (pitch)
- Developed by Samsung and LG

Super Flat CRTs: Hanging In There

Samsung 26-inch SF CRT Demo

LG 30-inch SF CRT Demo

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ELVs: Displays You Can Eat?

- Electrowetting light valve display uses oil and water mixture to shutter light
- Change in voltage potential causes oil to shift position
- Light source is individual RGB LEDs
- Bright transmissive display, wide viewing angles
- Initial tests with monochrome displays only

ELVs: Displays You Can Eat?

- Difference in viscosity is what makes the ELV work
- Any two liquids with opposites in viscosity may also work in ELV
  - One must be opaque
  - One must be transparent
- Possibilities: Combinations of salad dressings or liquors?

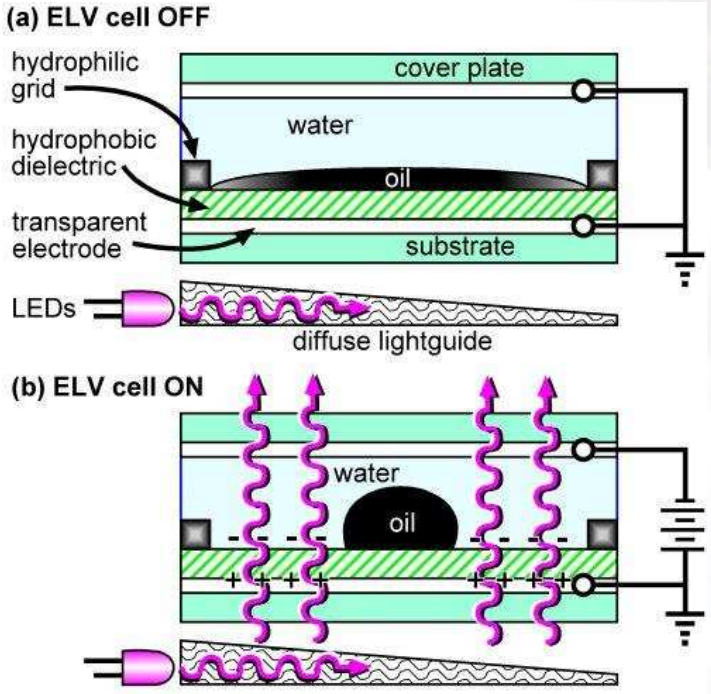

Photo courtesy Extreme Photonics / Univ. of Cincinnati

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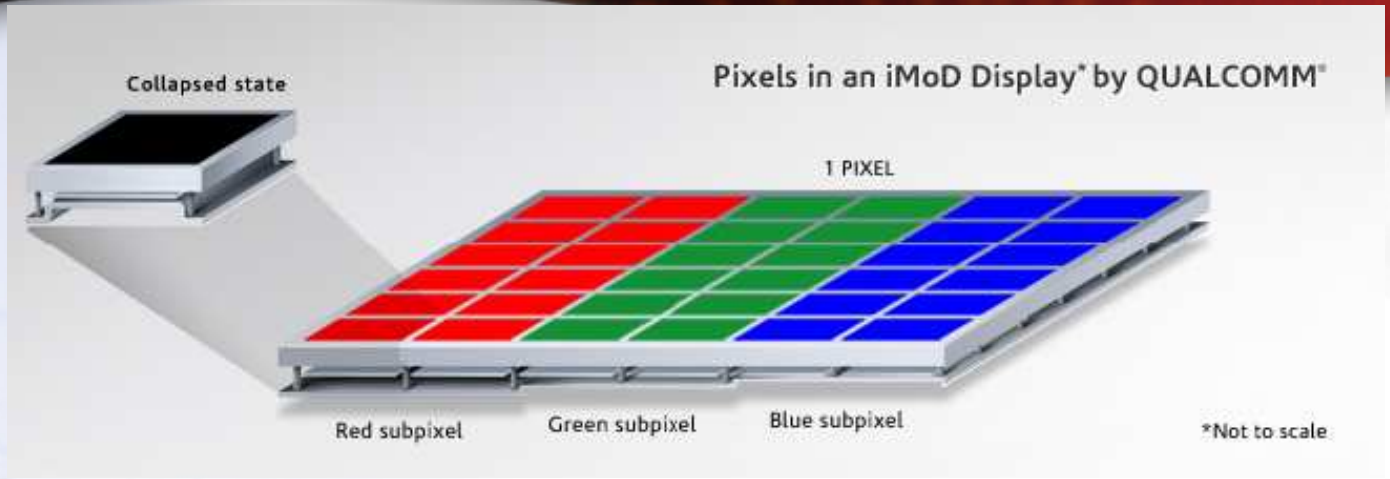
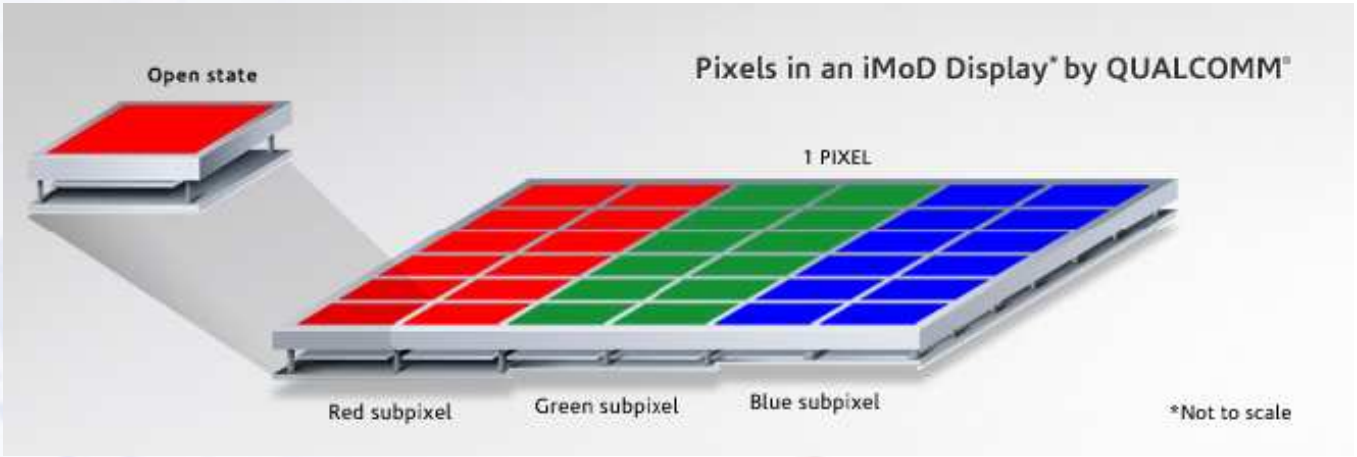
iMod: Inspired By A Butterfly

- Interferometric Modulator uses natural refractive principles (interferometer)
- Two-position pixel reflects or absorbs light
- RGB stripes are used for color imaging
- Initial target is handheld electronics, near-to-eye
- Developed by Qualcomm and Iridigm

iMod: Inspired By A Butterfly





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OK, Time For A Recap

- LCD pushing up in size, owns market <32”, battling plasma for 32” - 42” ‘sweet spot’; still has motion issues
- Plasma holding 42” and up market for now, thanks to low cost - burn-in; power consumption still an issue
- OLEDs still not in mass production yet, best targeted at handheld displays with short life cycles (10,000 hrs)
- SED has potential to be disruptive, pricing, screen sizes, and distribution are still issues to be resolved
- FEDs still on sidelines, EL looks promising, ELVs best served with bacon bits and cheese
- Super Flat CRTs may stave off extinction

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Audience Participation Time

(Otherwise Known As Q&A)