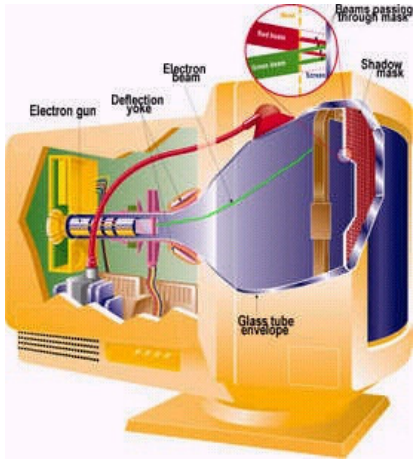



# Display Technologies

## CMSC 435

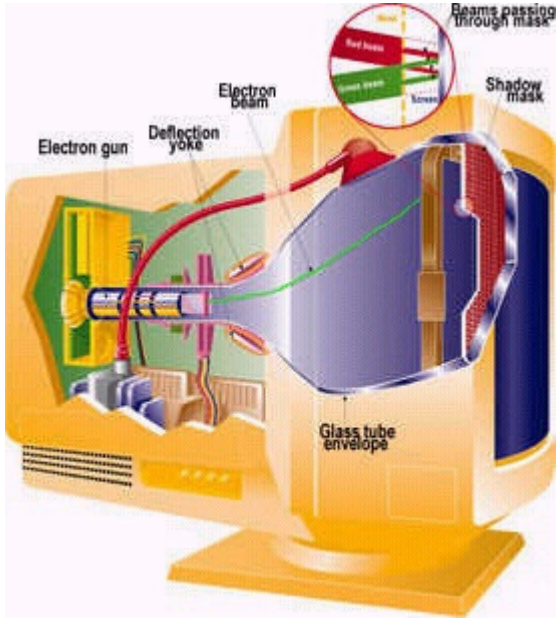
Slides based on Dr. Luebke's slides

# Recap: Transforms

- Basic 2D Transforms: Scaling, Shearing, Rotation, Reflection, Composition of 2D Transforms
- Basic 3D Transforms: Rotation, Shearing, Translation
- Homogeneous Coordinates
- Windowing Transforms: 3 Steps
- Coordinate Transforms

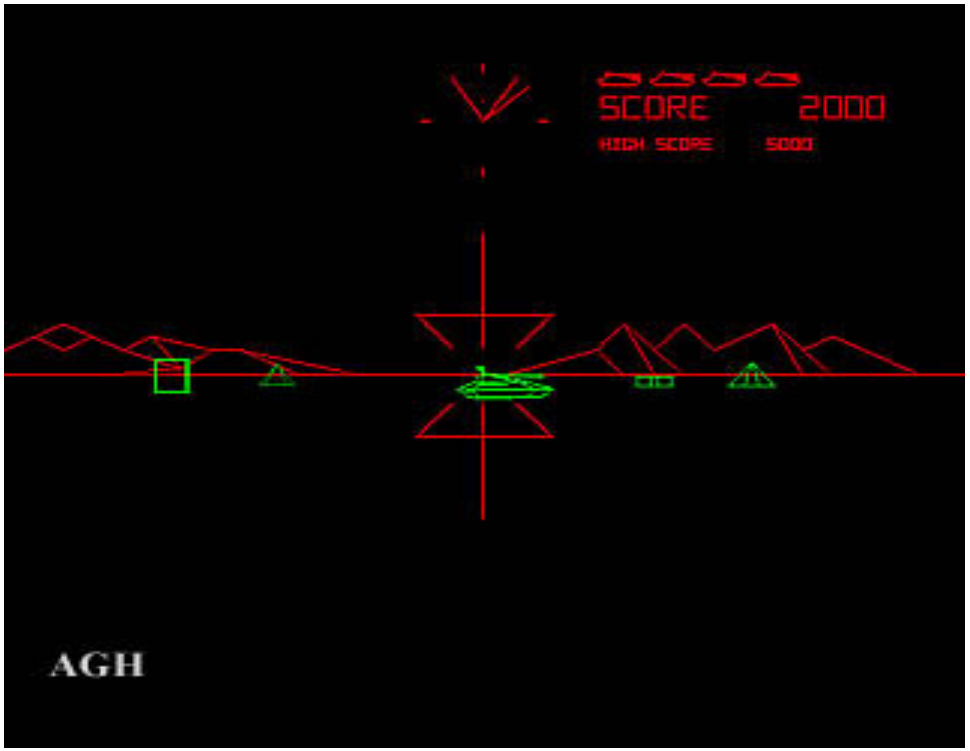
# Display Technologies

- Cathode Ray Tubes (CRTs)
  - Most common display device
  - Evacuated glass bottle (last of the vacuum tubes)
  - Heating element (filament)
  - Electrons pulled towards anode focusing cylinder
  - Vertical and horizontal deflection plates
  - Beam strikes phosphor coating on front of tube



# Display Technologies: CRTs

- Vector Displays
  - Anybody remember *Battlezone*? *Tempest*?




# Display Technologies: CRTs

- Vector displays
  - Early computer displays: basically an oscilloscope
  - Control X,Y with vertical/horizontal plate voltage
  - Often used intensity as Z
  - Show: *http://graphics.lcs.mit.edu/classes/6.837/F98/Lecture1/Slide11.html*
- *Name two disadvantages*

  Just does wireframe

  Complex scenes ⇗ visible flicker

# Display Technologies: CRTs

- Black and white television: an oscilloscope with a fixed scan pattern: left to right, top to bottom
  - Paint entire screen 30 times/sec
    - Actually, TVs paint top-to-bottom 60 times/sec, alternating between even and odd *scanlines*
    - This is called *interlacing*. It's a hack. *Why do it?*
  - To paint the screen, computer needs to synchronize with the scanning pattern of raster
    - Solution: special memory to buffer image with scan-out synchronous to the raster. We call this the *framebuffer*.

# Display Technologies: CRTs

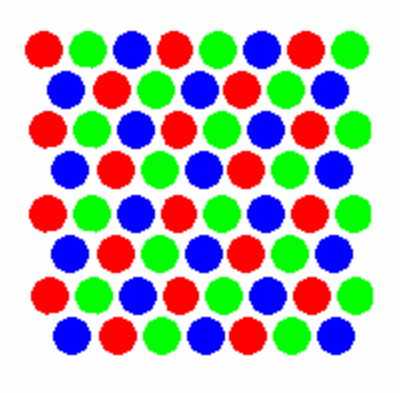
- Raster Displays
  - *Raster*: A rectangular array of points or dots
  - *Pixel*: One dot or picture element of the raster
  - *Scanline*: A row of pixels
  - *Rasterize*: find the set of pixels corresponding to a 2D shape (line, circle, polygon)

# Display Technologies: CRTs

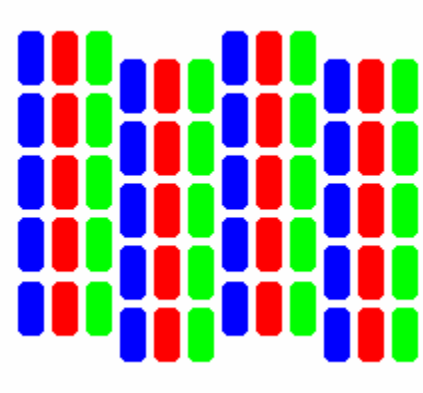
- Raster Displays
  - Frame must be “refreshed” to draw new images
  - As new pixels are struck by electron beam, others are decaying
  - Electron beam must hit all pixels frequently to eliminate flicker
  - Critical fusion frequency
    - Typically 60 times/sec
    - Varies with intensity, individuals, phosphor persistence, lighting...

# Display Technology: Color CRTs

- Color CRTs are *much* more complicated
  - Requires manufacturing very precise geometry
  - Uses a pattern of color phosphors on the screen:



Delta electron gun arrangement

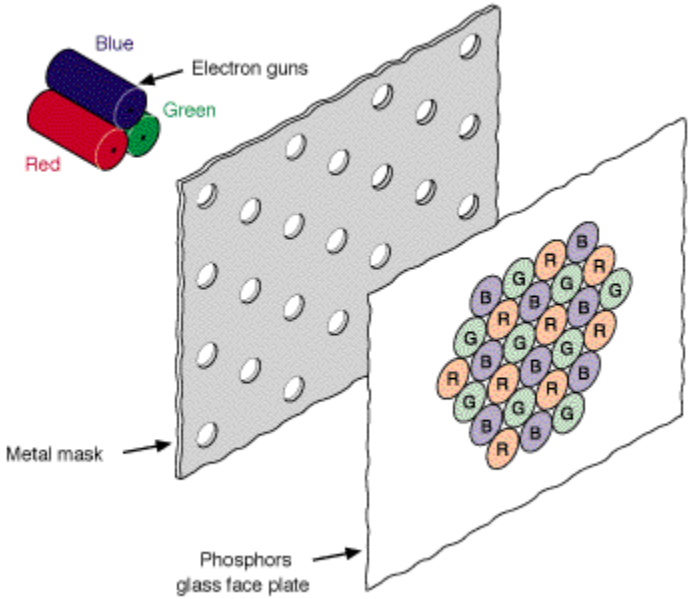


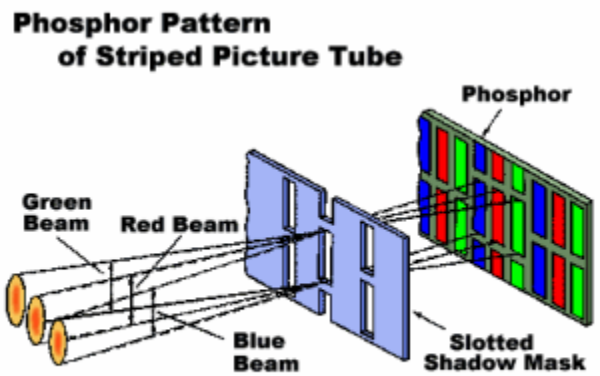
In-line electron gun arrangement

  - *Why red, green, and blue phosphors?*

# Display Technology: Color CRTs

- Color CRTs have
  - Three electron guns
  - A metal *shadow mask* to differentiate the beams



# Display Technology: Raster CRTs

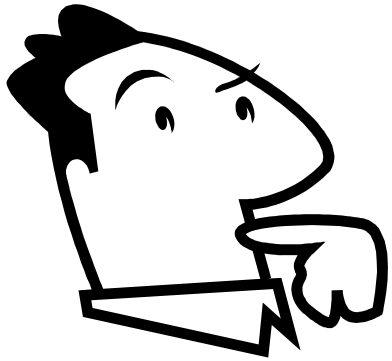
- Raster CRT pros:
  - Allows solids, not just wireframes
  - Leverages low-cost CRT technology (i.e., TVs)
  - Bright!  Display *emits* light
- Cons:
  - Requires screen-size memory array
  - Discreet sampling (pixels)
  - Practical limit on size (call it 40 inches)
  - Bulky
  - Finicky (convergence, warp, etc)

# CRTs – Overview

- CRT technology hasn't changed much in 50 years
- Early television technology
  - high resolution
  - requires synchronization between video signal and electron beam vertical sync pulse
- Early computer displays
  - avoided synchronization using 'vector' algorithm
  - flicker and refresh were problematic

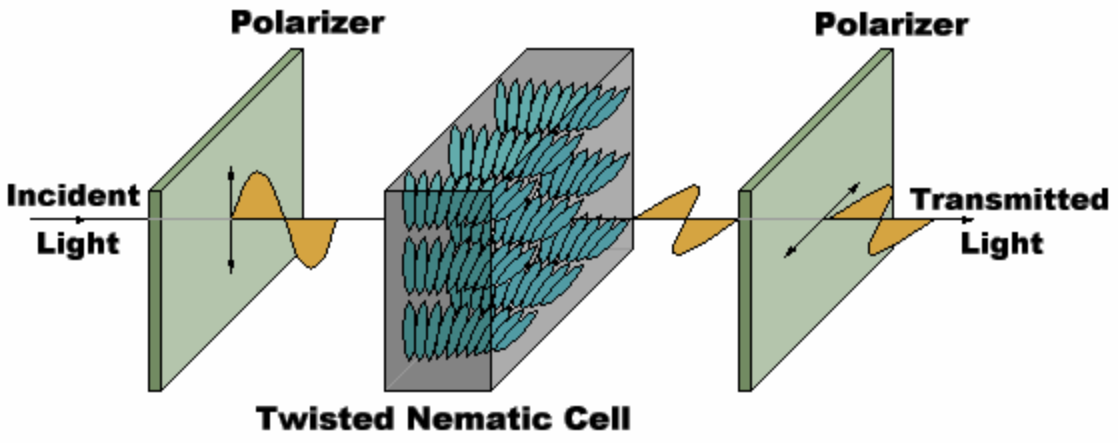
# CRTs – Overview

- Raster Displays (early 70s)
  - like television, scan all pixels in regular pattern
  - use frame buffer (video RAM) to eliminate sync problems
- RAM
  - ¼ MB (256 KB) cost $2 million in 1971
  - Do some math…
    - 1280 x 1024 screen resolution = 1,310,720 pixels
    - Monochrome color (binary) requires 160 KB
    - High resolution color requires 5.2 MB



# Display Technology: LCDs

- Liquid Crystal Displays (LCDs)
  - LCDs: organic molecules, naturally in crystalline state, that liquefy when excited by heat or E field
  - Crystalline state twists polarized light 90º.



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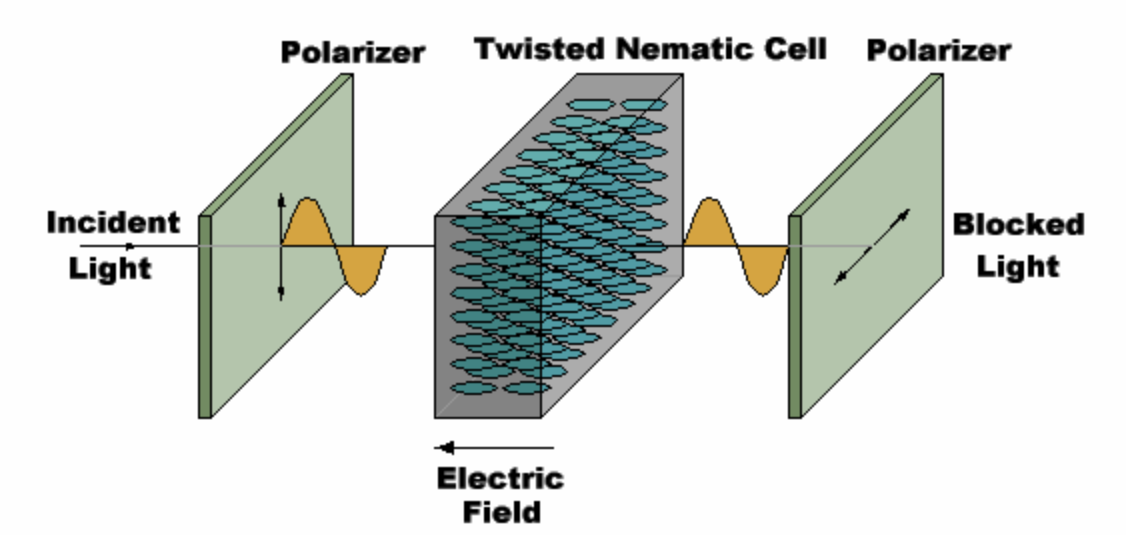
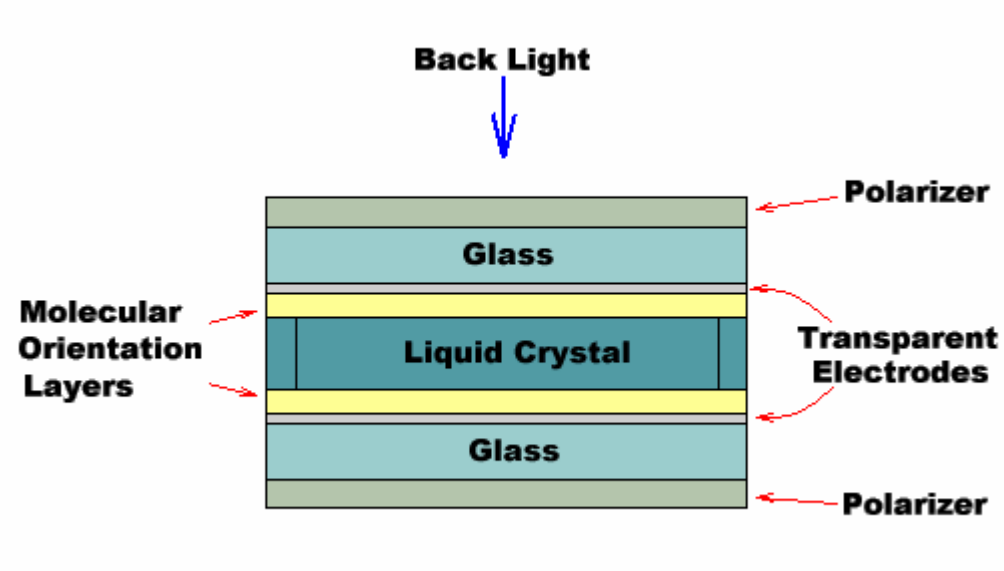


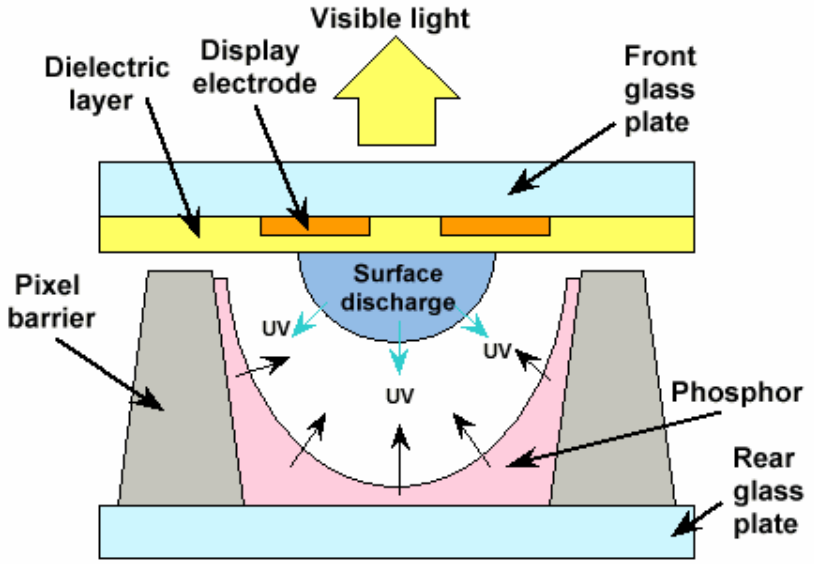
# Display Technology: LCDs

- Transmissive & reflective LCDs:
  - LCDs act as light valves, not light emitters, and thus rely on an external light source.
  - Laptop screen: backlit, *transmissive display*
  - Palm Pilot/Game Boy: *reflective display*



# Display Technology: Plasma

- Plasma display panels
  - Similar in principle to fluorescent light tubes
  - Small gas-filled capsules are excited by electric field, emits UV light
  - UV excites phosphor
  - Phosphor relaxes, emits some other color

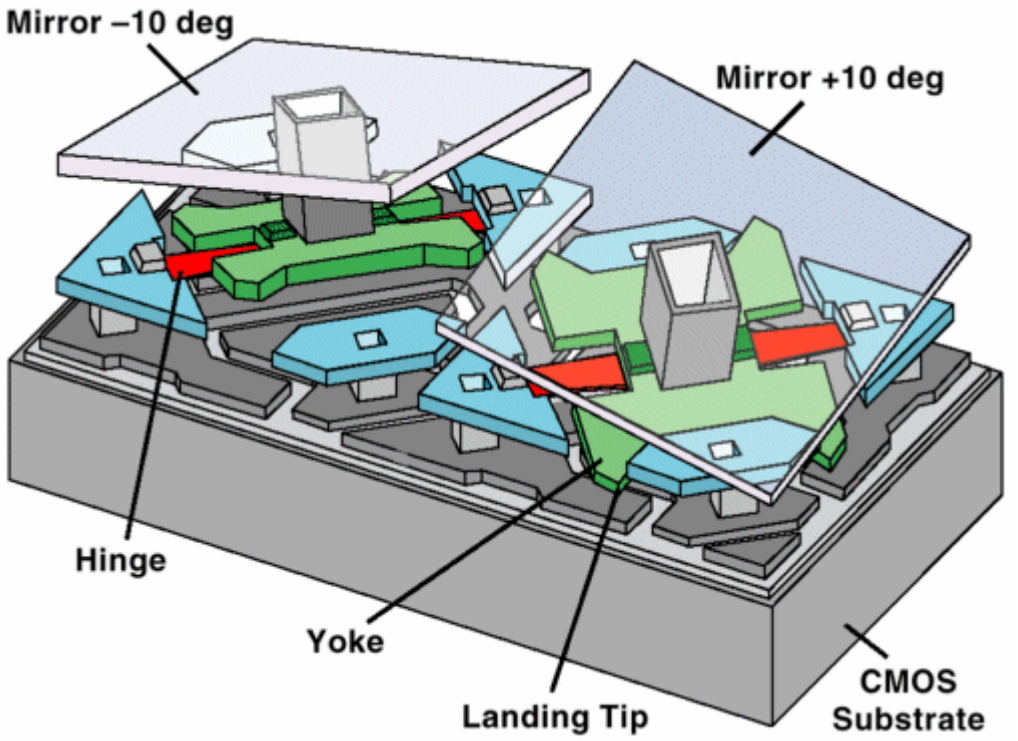


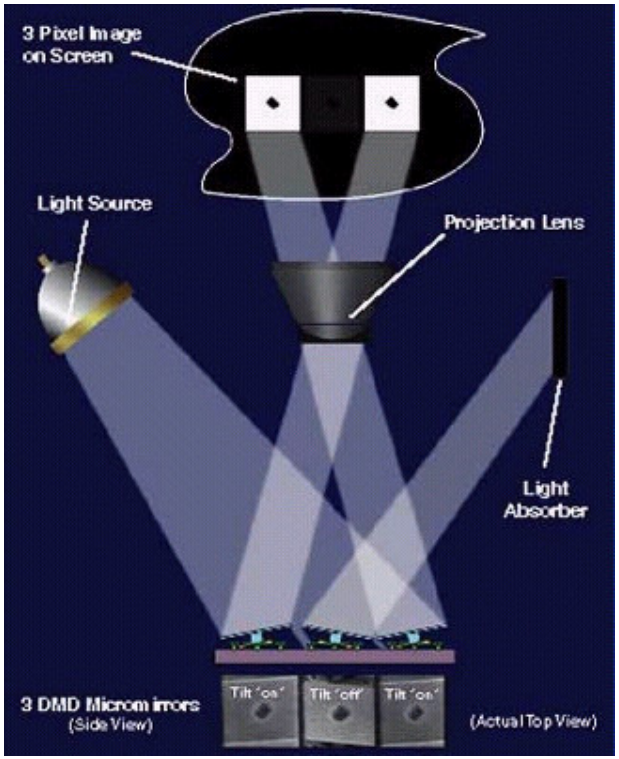
# Display Technology

- Plasma Display Panel Pros
  - Large viewing angle
  - Good for large-format displays
  - Fairly bright
- Cons
  - Expensive
  - Large pixels (~1 mm versus ~0.2 mm)
  - Phosphors gradually deplete
  - Less bright than CRTs, using more power

# Display Technology: DMDs

- Digital Micromirror Devices (projectors)
  - Microelectromechanical (MEM) devices, fabricated with VLSI techniques



# Display Technology: DMDs

- DMDs are truly digital pixels
- Vary grey levels by modulating pulse length
- Color: multiple chips, or color-wheel
- Great resolution
- Very bright
- Flicker problems

# Display Technologies: Organic LED Arrays

- Organic Light-Emitting Diode (OLED) Arrays
  - The display of the future?  Many think so.


# Display Technologies: Organic LED Arrays

- OLEDs function like regular semiconductor LEDs
  - But with thin-film polymer construction:
    - Thin-film deposition of organic, light-emitting molecules through vapor sublimation in a vacuum.
    - Dope emissive layers with fluorescent molecules to create color.
    - Not grown like a crystal, no high-temperature doping
    - Thus, easier to create large-area OLEDs

# Display Technologies: Organic LED Arrays

- OLED pros:
  - Transparent
  - Flexible
  - Light-emitting, and quite bright (daylight visible)
  - Large viewing angle
  - Fast (< 1 microsecond off-on-off)
  - Can be made large or small

# Display Technologies: Organic LED Arrays

- OLED cons
  - Not quite there yet (96x64 displays) except niche markets
    - Cell phones (especially back display)
    - Car stereos
  - Not very robust, display lifetime a key issue
  - Currently only passive matrix displays
    - Passive matrix: Pixels are illuminated in scanline order (like a raster display), but the lack of phosphorescence causes flicker
    - Active matrix: A polysilicate layer provides thin film transistors at each pixel, allowing direct pixel access and constant illumination
  - Hard to compete with LCDs, a moving target

# Framebuffers

- So far we've talked about the physical display device
- How does the interface between the device and the computer's notion of an image look?
- *Framebuffer*: A memory array in which the computer stores an image
  - On most computers, separate memory bank from main memory (why?)
  - Many different variations, motivated by cost of memory

# Trivia


- How many workstations were used to Render images for Pixar's Toy Story?
- Pixar cre PARC workstat microproc
- Using or er "Toy Story" w performa
- Each of t nd 114,000 Farm, a task that duce the final cut. of data and requ cessing.