

Images and Displays

Computer Graphics
Instructor: Sungkil Lee

Today

- **Digital Images**
- **Raster Graphics**
- **Vector Graphics**
- **Displays**

Images

- **Image:**

- (**continuous**) 2D distribution of intensity or color, defined as a 2-D function $f(x, y)$ at spatial coordinates (x, y)
- $f(x, y)$ is the intensity (or gray level) or the amplitude of light.



Lena: the most famous test image in image processing community

Digital Images

- **Digital image:** a *finite*, *discrete* quantities of image
 - finite range: e.g., 0-255
 - discrete quantities: e.g., 0, 1, 2, ..., 255 (integer only here)
 - usually has 3 channels: RGB (red, green, and blue)
 - motivated by 3 types of cone cells (L, M, S) in the retina
- **Pixel (picture element):**
 - A single element of a digital image
 - For multi-channel images, three channel elements form a pixel.
 - c.f., voxel (volume element), texel (texture element)

Digital Images: Example

- **3-channel RGB format**

- Intensity of the red channel is stronger than the other two in the example.



red

+



green

+



blue

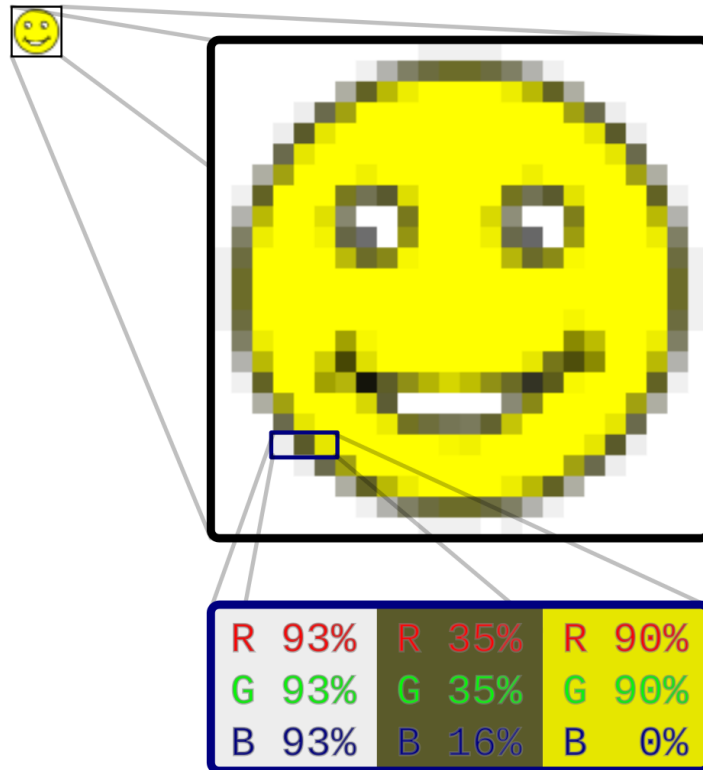
=



RGB

Raster Graphics

- A raster graphics representation (also called the **bitmap**)
 - *2D array* structure that represents a rectangular grid of pixels.
 - When enlarged, a blocky structure is visible

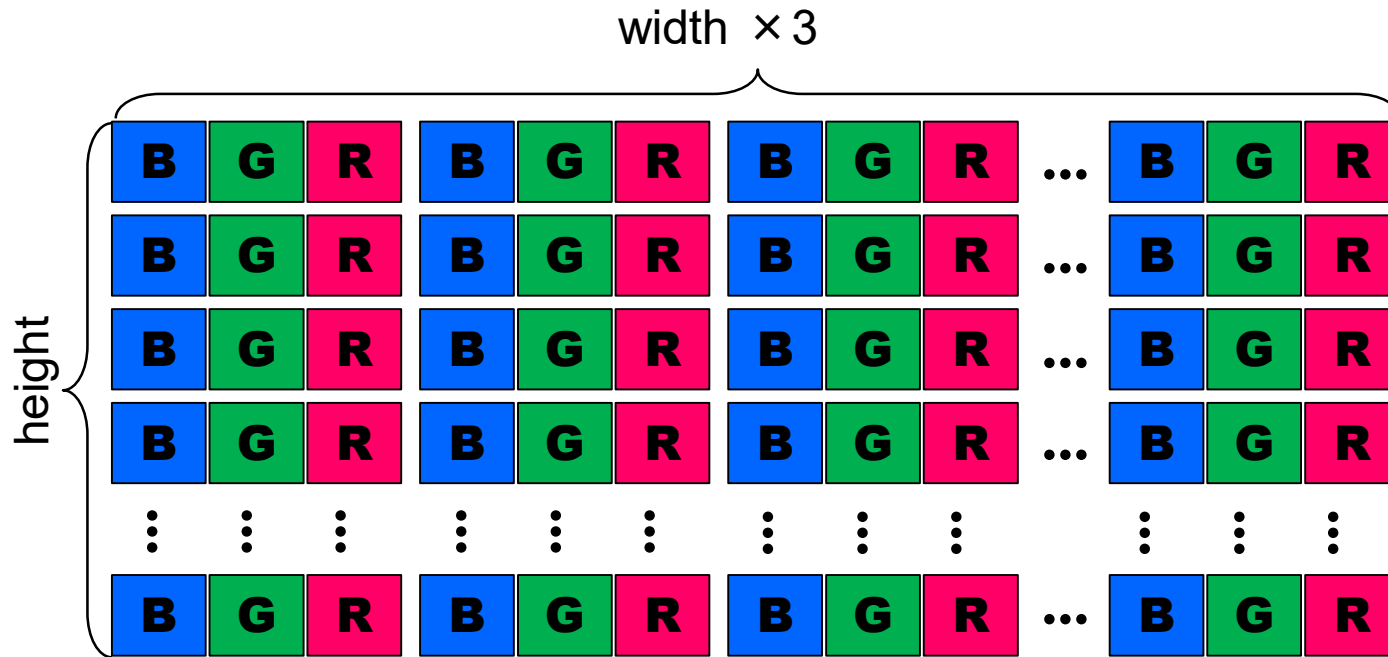


Raster Graphics

- Memory structure

```
unsigned char image[height*width*3];    // as a 1D array
```

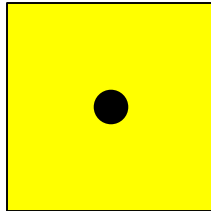
- e.g., BGR format in Windows BMP



Raster Graphics

- **Implication of a raster image**

- **approximation** (sampled representation) of a real intensity distribution
 - c.f., a float-point number in computer is always an approximation.
- A single pixel represents **the color of the pixel center**, not on the whole area of a pixel.
 - example: the yellow color of the center approximates the whole pixel area.



- **Advantages:**

- Brute-force sampling can represent arbitrary images; memory is cheap.
- Quality becomes higher with increasing resolution (denser sampling)
- 2D array can easily be mapped to display devices.

Raster Graphics: Data Types

- **Bitmaps:**
 - boolean per pixel (black or white); e.g., fax, (old) newspaper
- **Grayscale:**
 - integer per pixel (gray levels)
 - Precision: usually 8-bits per pixel (bpp), but often 10, 12, 16 bpp
- **Color:**
 - 3 or 4 integers per pixel (RGBA for 4 integers)
 - "A" means "alpha" or opacity
 - Precision: usually 24 bpp (RGB) or 32 bpp (RGBA)
- **Floating-point**
 - Floating-point format is often used for high-dynamic range (48 or 96 bpp)
 - Exposure effects can be captured with HDR formats

Raster Graphics: Storage Requirements

- **1024 × 1024 image (1 Megapixel) example**
 - bitmap: 128 KB
 - grayscale 8bpp: 1MB
 - grayscale 16bpp: 2MB
 - color 24bpp: 3MB
 - floating-point HDR color: 12MB
- **Think about:**
 - how many memory is required for an arbitrary resolution and bpp.

Raster Graphics: File Containers

- **Compression of image files**

- When images are stored into disks with particular formats, they are usually compressed. So, you see much smaller file sizes for them.

- **Typical containers**

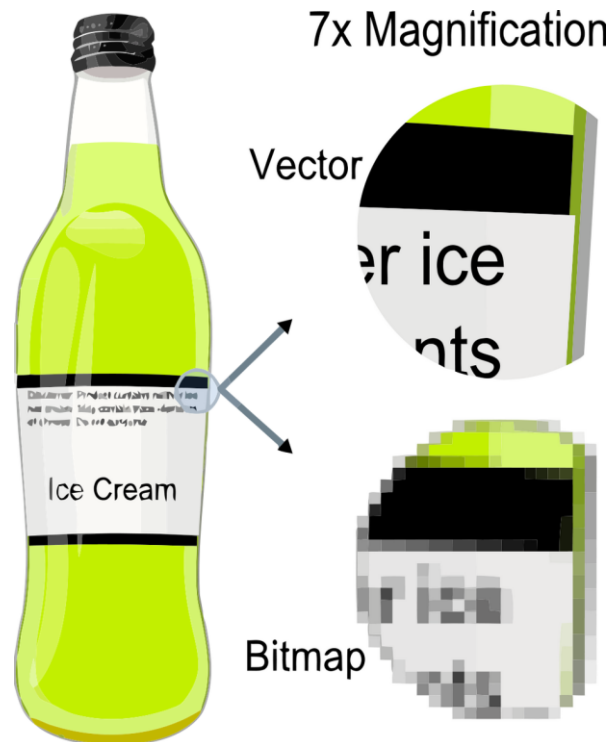
- BMP: Lossless raw format
- JPEG: Lossy compression (pronounced as "Jay-Peg")
 - Using DCT (discrete cosine transform for compression)
- PNG: Lossless compression (pronounced as "Ping")
 - Using ZLIB for compression
- TIFF, GIF, ... (obsolete)
- WebP (recent container/compression by Google)

Vector Graphics

- **Unlike the raster graphics, vector graphics uses geometrical primitives such as points, lines, triangles, curves, etc.**
 - The primitives are represented as a mathematical expressions.
 - "Vector", in this context, is more than a straight line.
- **Common tools/formats to manipulate 2D vector graphics**
 - Adobe illustrator
 - Adobe Acrobat
 - SVG (Scale Vector Graphics; recently available on the web)
 - Postscripts (for printers or printer file)

Vector Graphics

- **Vector graphics representations are usually independent of the output resolution.**
 - Because they are **rasterized on the fly** at the output stage to be displayed.
 - Still, most of display devices use raster display.



3D Graphics and Images

Vector Graphics to Raster Graphics

- **Input: vector representation**

- Graphics uses vector graphic formats as an input
- Points, lines, triangles, quads, polygons, curves, ...

- **Output: raster representation**

- Raster images whose dimension is identical to the window resolution

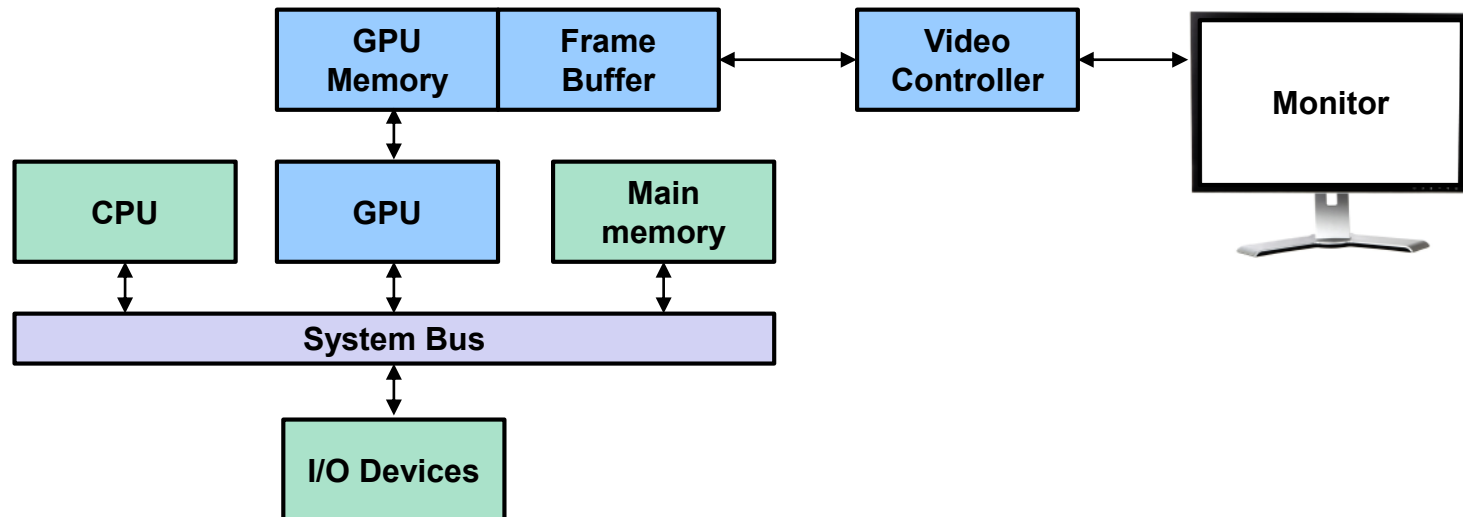
Graphics Terms

- ***"capture images" means:***
 - record the light distribution on the sensor (using cameras)
- ***"represent images" means:***
 - encode images numerically (normally binary)
- ***"display images" means:***
 - realize the encoded images as actual intensity distribution on the display devices (e.g., monitors)

Displays

Raster Display System

- **Screen image is defined by a 2D array in RAM**
 - The memory area is called the *frame buffer*.
 - Nowadays, the most system has it in Graphics Processor Unit (GPU) memory.
- **Architecture of raster display system**



Display Devices

- **Computer displays**

- CRT (Cathode Ray Tube)
- LCD (Liquid Crystal Display)/LED (Light Emitting Diode)
- OLED (Organic LED)
- AMOLED (Active Matrix OLED)

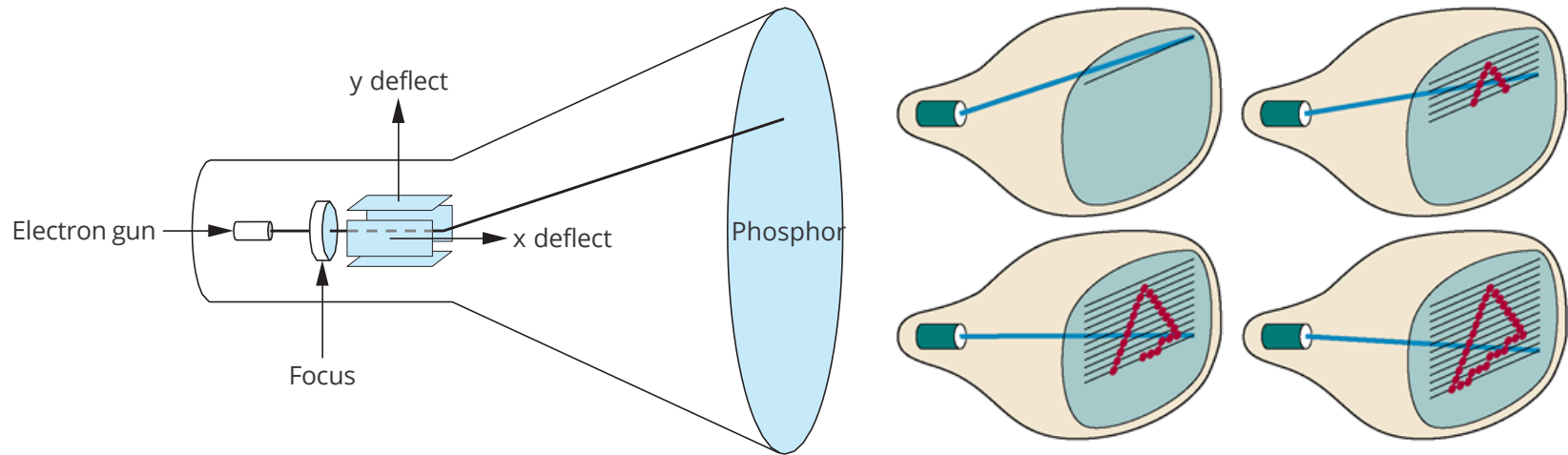
- **Printers**

- Laser printers
- Inkjet printers
- Dot printers (-1990s)
- not much of interests in this course

Cathode Ray Tube (CRT)

- **Raster scan display**

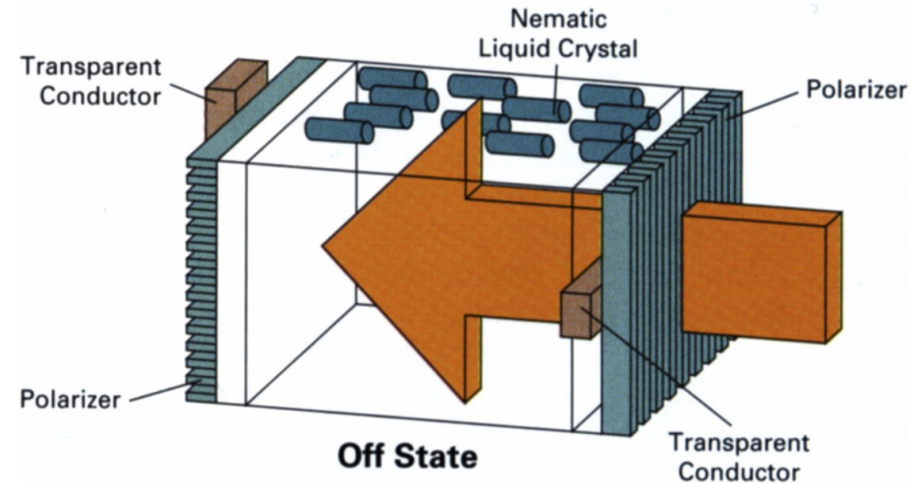
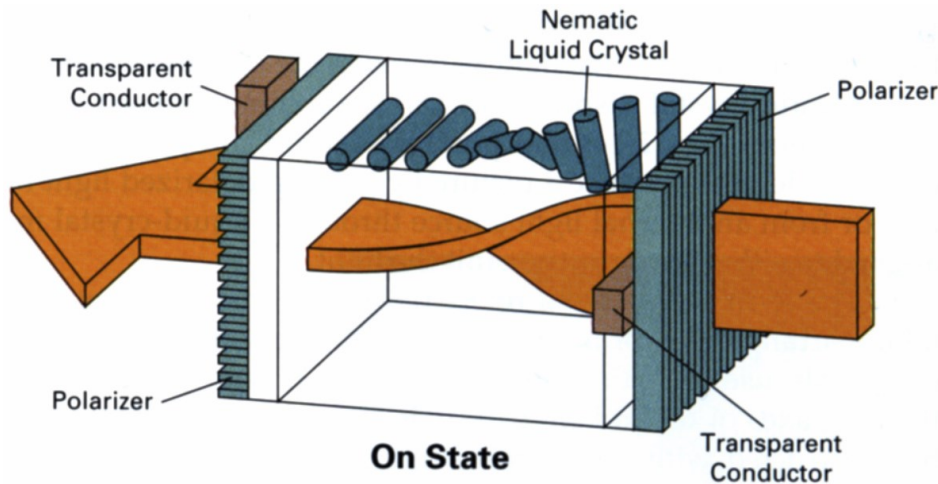
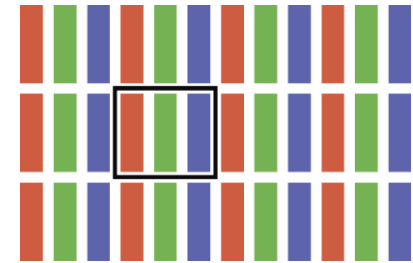
- Can be used either as vector (calligraphic or random-scan) display device or raster display system (from frame buffer)
- TV-standards: PAL, NTSC
- Direct view storage tube (DVST):
 - an early alternative for persistent display without constant refresh



LCD Flat Panel (TN: Twisted Nematic)

- **Principle:**

- Block or transmit light by twisting its polarization
- Intermediate intensity levels possible by partial twist
- Fundamentally raster technology
- Always need backlight (often using LED)

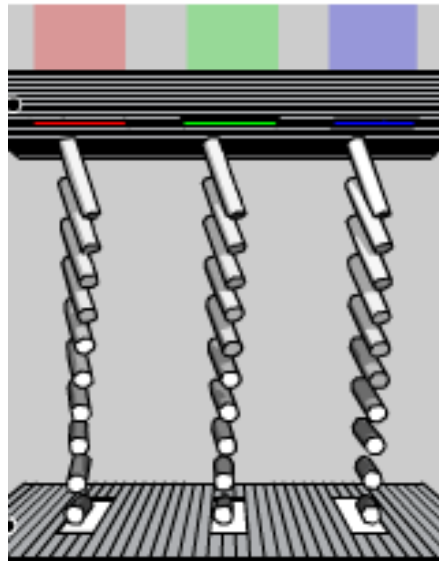
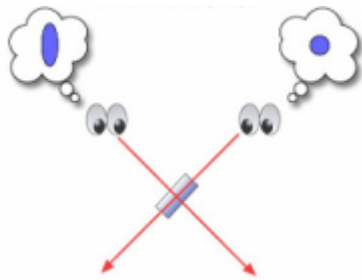


LCD Flat Panel (IPS: In-plane Switching)

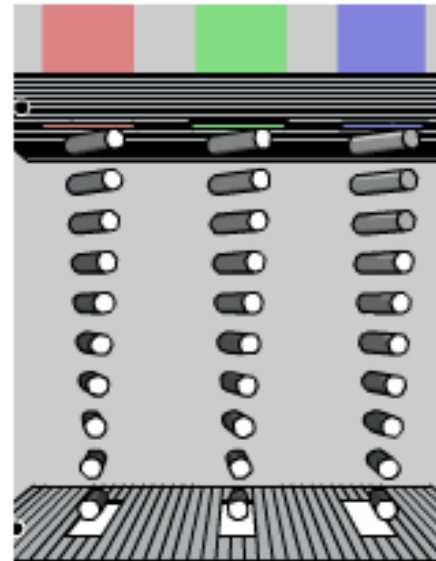
- **Principle:**

- While TN panel twists LC vertically, IPS panel twists LC horizontally in its plane.
- Better for wide-angle viewing.

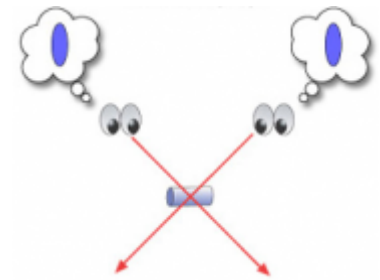
From Computer Desktop Encyclopedia
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TN



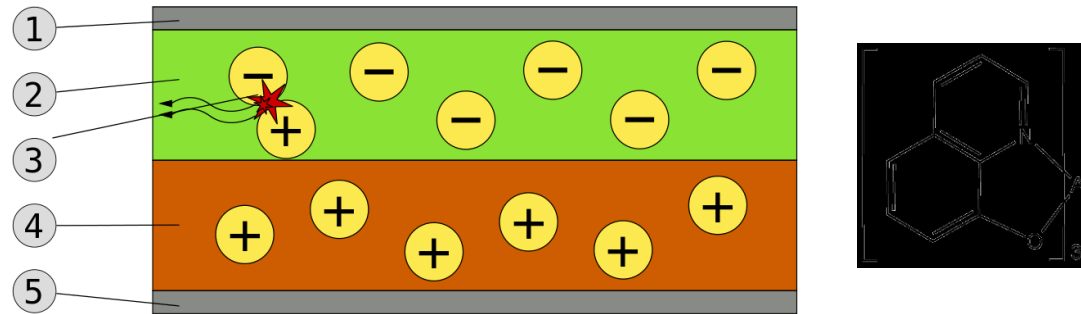
IPS



OLED (Organic Light Emitting Diode)

- **Principle:**

- Self-emit or not light by organic materials
- Works without backlit: better in contrast ratio than LCD
- Fundamentally raster technology

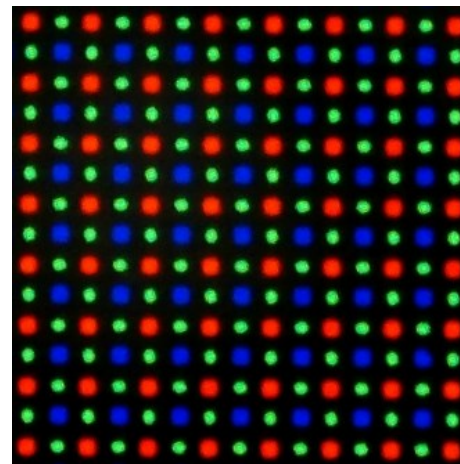
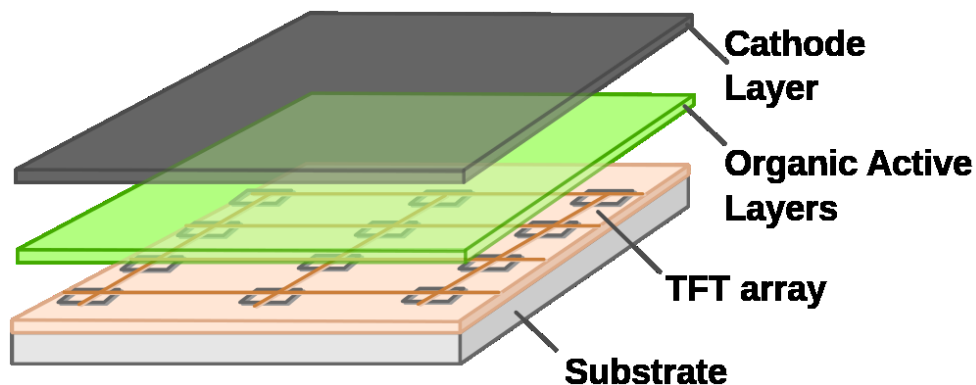


1. Cathode (-), 2. Emissive Layer, 3. Emission of radiation, 4. Conductive Layer, 5. Anode (+)

AMOLED (Active-Matrix OLED)

- **Principle:**

- Active matrix addressing:
 - Each element's state is maintained by individual circuits.
 - Faster than passive matrix addressing in refresh rates



Pentile matrix pattern on Galaxy S6/S7

※ Super AMOLED (Samsung Elec. Co. Ltd.) = AMOLED + touch digitizer