PH 301

ENGINEERING OPTICS

Lecture_Display Devices-2_31

Organic LED Display

- An OLED is an LED, in which emissive electroluminescent layer is a film of organic compound that emits light in response to an electric current.
- Organic layer is situated between two electrodes; at least one of these electrodes is transparent.
- Uses: TV screens, computer monitors, smartphones, handheld game consoles, etc.
- A major area of research is the development of white OLED devices for use in solid state lighting applications.
- There are two main families of OLED: those based on small molecules & those employing polymers.
- Adding mobile ions to an OLED creates a light emitting electrochemical cell (LEC) which has a slightly different mode of operation.

- **OLED display - driven with a passive-matrix (PMOLED) or active-matrix (AMOLED) control scheme.**
- **PMOLED scheme: each row (& line) in display is controlled sequentially, one by one.**
- **AMOLED scheme: uses a thin-film transistor backplane to directly access & switch each individual pixel on or off higher resolution & larger display).**
- **It works without a backlight because it emits visible light.**
- **In low ambient light conditions (such as a dark room), an OLED screen can achieve a higher contrast ratio than an LCD, regardless of whether the LCD uses cold cathode fluorescent lamps or an LED backlight.**

OLED lighting panels

TV Goes 8K

Better imaging: Medicine & Entertainment

- 1950s: TV signal transmission with vacuum-tube technology
- 2000s: First full high-definition television (HDTV) format with resolutions of 1920 × 1080 pixels.
- Doubling resolution: 3840 × 2160 pixels (4K) & adding high dynamic range (HDR)
- New generation: 7680 × 4320 pixels (8K)

How much of that enhanced resolution can the human eye see?

Measure optical acuity!

[Jeff Hecht, Opt. Phot. News 31 (May 2020) 40-47]

From CRT to Flat Panels

- TV became a mass medium after World War II (Black & White – until mid 1960s).
- Color TV: US was leader with Federal Communications Commission adopting National Television System Committee (NTSC) color standards in 1953.
- NTSC (6 MHz) broadcast thirty 525-line frames every second, although CRT showed only 486 lines.
- Countries with 50 Hz power grids adopted PAL (Phase Alternating Line) & SECAM standards, which transmitted 625-line frames 25 times a second.

From CRT to Flat Panels

- Color broadcast equipment & sets were expensive, & color quality was almost an oxymoron. Colors drifted so much that sets came with color tuning knobs – not that they stopped mud-covered football fields from appearing a cartoonish bright green on screen.

  Critics dubbed NTSC “Never The Same Color” or “Not True Skin Colors”.

Color quality improved after introduction of solid-state electronics in 1970s, but CRT technology remained a bottleneck.

Cost, bulk, & weight of CRT TVs scaled steeply with screen size, making direct-view CRT screens larger than 35 to 40 inches impractical even in 1990s.

Larger size required projecting bright image from a small screen CRT or other display onto a large translucent or reflective screen. Rear-projection sets became popular in early 2000s, & eventually reached sizes upto 100 inches (2.5 m), but their screen brightness remained limited.

Digital Transition

- 1996: Screen formats: 1280 × 720 pixels (HD)
  1920 × 1080 pixels (Full HD)

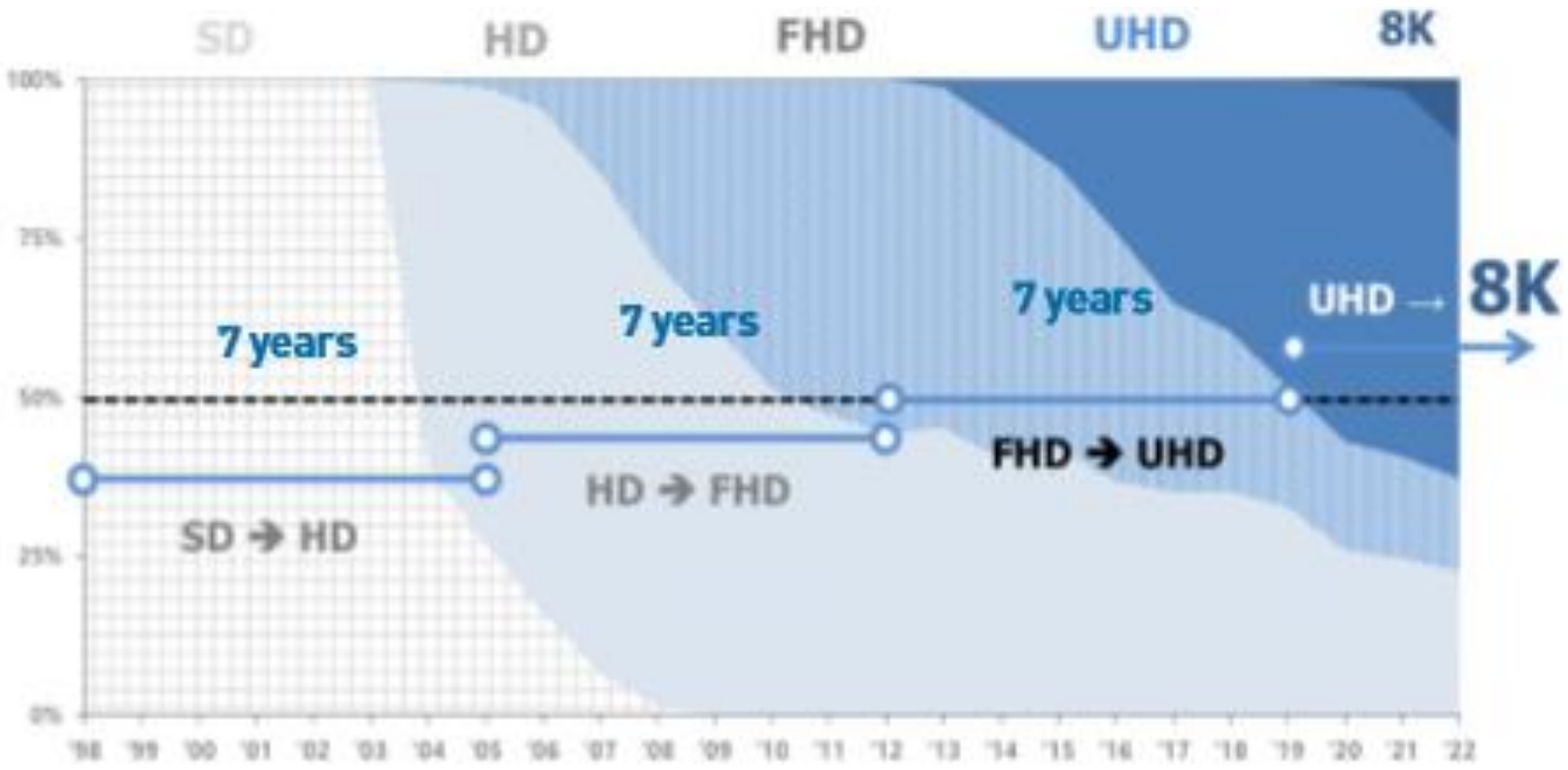
  Both formats used 16:9 screen shape

  Digital TV went on sale in August 1998 in US.
  Price: US$ 5,000 (55 inch screen) to US$ 12,000 (72 inch screen)

- Doubled resolution: 3840 × 2160 pixels (Ultra HD) – 4K
  4K + HDR (High Dynamic Range)

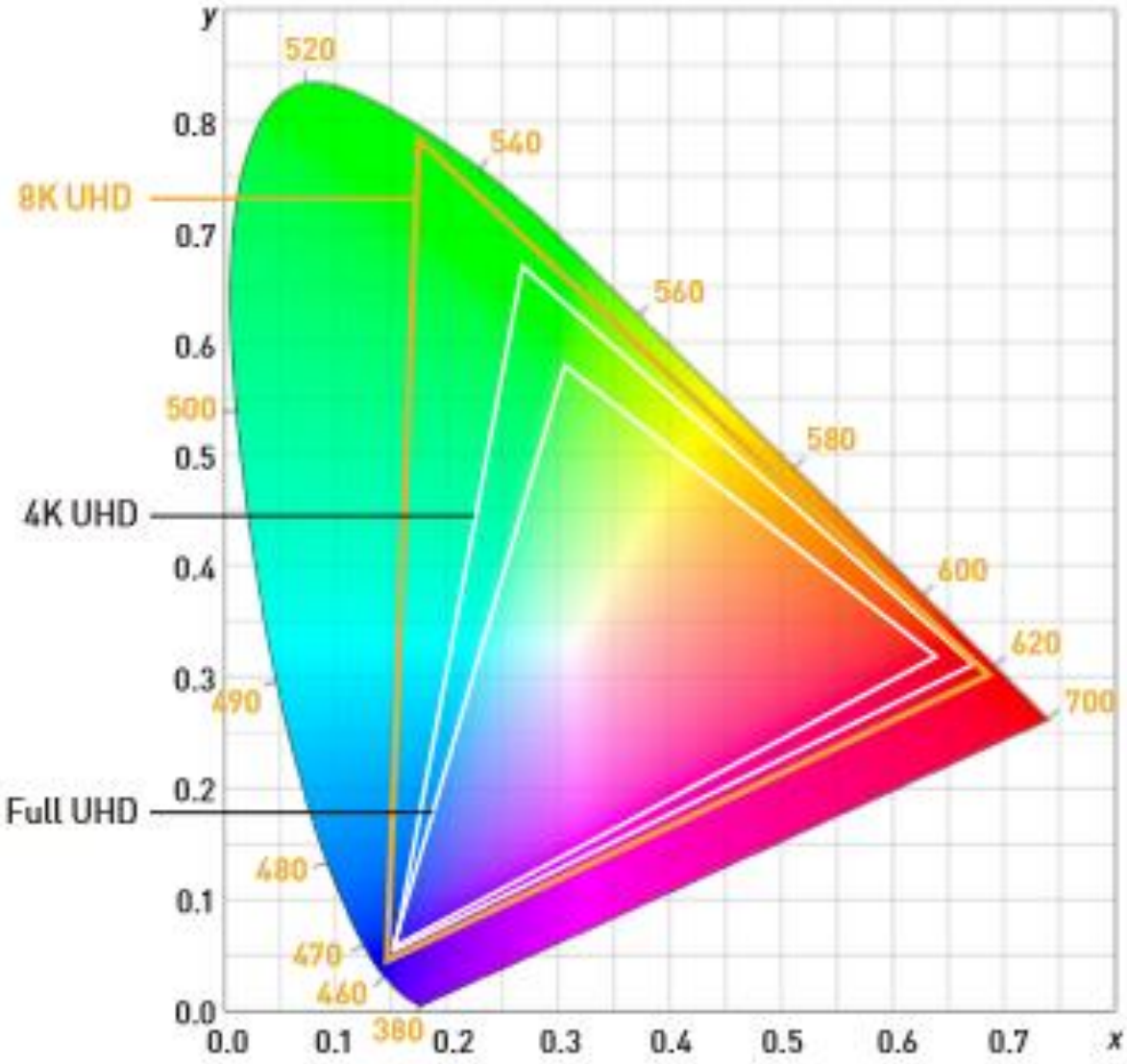
HDR increases the range of color brightness, from blacker blacks to higher-intensity colors, so images seem much more vivid, especially those chosen to highlight the effect in showroom.

- Next Gen: 7680 × 4320 pixels (8K) + HDR



Seven-year cycle of TV resolution upgrades: from 525-line standard definition (SD) to High-definition (HD), Full HD, Ultra-high definition (UHD) & 8K.

- Screen improvement: enhancing range of colors
- For LCD displays, this is done by changing backlight that illuminates the arrays of tiny liquid crystal light modulators that create image.
- Early LCD displays were illuminated uniformly by lamps.
- White-light LEDs offered an improvement in backlight quality because they can be driven individually to change the distribution of light across screen, giving darker blacks & brighter colors.
- Next upgrade came from switching to arrays of red, green, & blue LEDs, which produce purer colors that are closer to edges of chromaticity diagram, increasing range of color gamut.
- Manufacturers describe LCDs with LED backlighting as "LED" displays, although it's the LCDs that are modulating light.
- Next Gen is coating blue LEDs with films containing quantum dots, which produce very narrow slices of red & green spectrum.



Chromaticity diagram showing the difference between full HD, 4K, & 8K color gamuts, with 8K (yellow triangle) offering broadest color range.

8K Generation

8K screens display a resolution of 7680 × 4320 pixels for a total of 33.18 million pixels, resulting in images that are 16 times more detailed than full HD.

8K Generation

- 8K displays: latest generation, combines HDR & expanded color gamut with screens displaying 7680 × 4320 pixels, four times no. on a 4K screen & 16 times no. on a full HDTV. Pixels are so close together that we see smooth & lose pixelated effect.

- 8K electronics use artificial intelligence to classify parts of image as hair, sky, faces or other things, & then apply appropriate upscaling algorithms.

- HDR – natural documentary

- Conventional metric for human visual acuity would suggest no difference should be visible between 4K & 8K.

- In 1862, Dutch ophthalmologist Herman Snellen designed the now-standard eye chart so that, when viewed at proper distance, letters would subtend an angle of five arcminutes, & lines in letters would be one arcminute wide.

One arcminute remains standard definition of optical acuity.

8K Generation

- To compare eye's resolution on chart to the display of pixels on a screen, assume viewer sits at a distance where screen subtends a 45° angle in horizontal field.

- For a modern 16:9 display, that's about 2.5 times the screen height, or 6.6 feet from a 65-inch screen. The 45° field of view equals 2700 arcminutes, so if the eye's resolution is one arcminute, it could resolve 2700 pixels on that screen, between 1920 pixel width of full HDTV & 3840 pixel width of 4K.

- So if visual acuity was that simple, our eyes could not tell the difference between 4K & 8K screens.

- It is based on "a line of assumptions". Eye-chart resolution "is all based on seeing letters that are black & white targets, with sharp edges & no gray scale". TV shows continually changing color images of various brightness.

TV screen is very different from an eye chart.

- **Ocular acuity varies across field of view.**
- **Acuity has a sharp peak in central fovea, where photosensors are packed most closely, & drops off on all sides.**
- **Vision in central fovea is limited by optics of eye because each neuron carries input from one photosensor.**
- **However, each neuron on periphery of eye receives input from many photosensors, so peripheral vision is limited by neural processing, which throws away spatial information needed for high-resolution vision by mixing multiple inputs.**
- **Hyperacuity: Sometimes our eyes can see anomalies in shape that are beyond our normal visual acuity.**

Examples of hyperacuity

- **Vernier effect: we can spot a slight offset in straight lines that is only a fraction of their width. This is how Vernier scale, which lets us measure distances that subtend angles smaller than usual one arcminute.**
- **Stair-step or "jaggie effect": we can see pixels along diagonal lines.**
- **Moire patterns: wave-like patterns appear when two window screens or very fine meshes appear to cross at a slight angle.**
- **Our eyes see at least four pixels per arcminute – as in smartphone "retina" screens – to avoid pixelation.**

(Left) Tennis court image shows examples of hyperacuity: anomalies inlcude jagged white lines & wavelike moire patterns in net. (Right) a higher resolution image showing smoother lines.

LG’s 88-inch 8K OLED set