Liquid Crystal Color Display
Digital Micromirror Device (DMD™)
A True Microelectromechanical System
How Grayscale is Created

DMD™ Binary Pulsewidth Modulation

Input

(1111)
(1001)
(0100)
(0010)
(0001)
(0000)

Video Field Time

(Sensations of Gray Shade® By Viewer’s Eye)

4-Bit, 16 Gray-Level Example
How can we extend this technology to color?
3-Chip DLP Color Optical System
DLP Projection System
Digital Micromirror Devices (DMD)

• Pioneered by Texas Instruments. The research on these micromechanical (MEMs) devices started in 1977.

• The first digital light valve projection systems (DLPs) had mirrors measuring 17 microns per side. At 1280 x 1028 resolution (HDTV) this resulted in a rather large chip in 1996.

• Today this technology is used in almost all digital theaters and some home televisions.

• Most theaters now use DLP with 4K resolution (4096 x 2160)
Christie CP4230 Digital Cinema Projector

- 4K DLP
- Screen size up to 105ft (32m)
- 4096 x 2160 resolution
- 2100:1 contrast
Cost of HDTV Displays

- LCD's
- Plasma
- Projection TV's
Cost of HDTV Displays

Note: Each year the cross over points keep moving to the right.
Smart Headlight

cs.cmu.edu/smartheadlight
Headlights - Carnegie Mellon

Seeing Through Snow

Standard Headlight

Our Headlight

*Video captured at 30 Hz
Modifications to Existing Technology

- The quest for energy reduction
How E-Paper Works

[Diagram of GYRICON BEADS showing light state and dark state with an electrode]
Electronic Reusable Paper

The paper pulp of the future.

http://www2.parc.com/hal/projects/gyricon/
Nick Sheridon, Xerox PARC inventor of electronic reusable paper, and Fereshteh Lesani show off the first roll produced by 3M partners.
How E-Paper Works

GYRICON BEADS

LIGHT STATE

E INK MICROCAPSULES

LIGHT STATE

DARK STATE

ELECTRODE

NEGATIVELY CHARGED

POSTIVELY CHARGED

Electronic ink is a straightforward fusion of chemistry, physics and electronics to create this new material.
E-Ink

MIT, Late 1990’s

Flexible Tablet-Sized Display From L.G. Philips LCD and E Ink Corporation

http://www.ink.com/
Nick’s mailbox held a thin letter from Gold & Key Publishing, but no oversized envelope from his bank. I made it into the hospital mess room in time to grab the last sticky bun and a lidded mug of scorching coffee to take upstairs. Porters wheeled trolleys loaded with patient breakfasts, dodging mail clerks who pushed files between departments. The letter poked my ribs, resting inside my jacket pocket. I’d stolen a dead man’s mail—to get justice, I reminded myself.

It would all come out right once Mathy authorized my environmental inspection report and filed it with the police. Still, I wouldn’t like to have anyone notice the fiddled timelines, and so hid the
The custom XO display contains a reflective layer between it’s backlight and the specially formatted LCD layer, allowing it to turn high ambient lighting conditions to it’s advantage.

The display is not only inexpensive ($30/unit), but is also much easier on the eyes.
Images Through Screen Doors
Pixel Qi
E-Paper

The Quest for Color
Spectral displays are made of millions of Microcapsules which suspend the pigments in clear fluid.
E-paper Technology 2019
E-paper Technology
SOFT LIGHT: Junji Kido of Yamagata University shows off his bright and smooth prototype OLED system.

Organic LEDs (OLEDs)

• Composed of a thin film of organic compounds and conductive layers sandwiched between two electrodes

• When the charges recombine in the organic layer, energy is released in the form of photons

• Can be made with fluorescent-based or phosphorescent material

Organic LEDs (OLEDs) Advantages

• In theory, the energy of this conversion could reach 100%

• Thickness can be measured in nanometers (extremely thin and lightweight) excluding the substrate

• Can be manufactured in sheet form

• Can be put on a variety of substrates including flexible plastic

• Material is environmentally friendly (no harmful elements)

Potential Uses

• Could be applied as wallpaper for illumination purposes

• Very bright and can replace light bulbs – already 4x more efficient than light bulbs in terms of lumens/watt

• With ability to produce red, green, and blue (new), can be used for displays

OLED Explanation

A. A voltage is applied across the OLED such that the anode is positive with respect to the cathode. Electrons flow from cathode to anode.

B. Thus the cathode gives electrons to the emissive layer and the anode withdraws electrons from the conductive layer (causing electron holes).
C. Electrostatic forces bring the electrons and holes together and they recombine.

D. In organic semiconductors, holes are more mobile than electrons. This happens closer to the emissive layer.

E. The recombination causes an emission of radiation whose frequency is in the visible region.
Sony 11-inch OLED Panel 2007
Sony 27-inch OLED Panel

2007
Modifications to Existing Technology

• The quest for energy reduction
• The quest for size
Cornell Panoramic Projection System
Stonybrook’s Reality Deck
Stony Brook’s Reality Deck
Samsung model S9 4K OLED TV, 98” behemoth  2013
Samsung 110-inch 4K UHD TV

2014
Samsung Curved OLED TV

55 inches
LG UHD Display

88’
Crystal LED Display System


16 ft, 8K

9 ft.

4K

$877,000
Foldable Laptops 2019
OLED TV RX
Flexible Displays
LG press-on 'wallpaper' TV under 1mm thick
Modifications to Existing Technology

• The quest for energy reduction
• The quest for size
• The quest for brightness
Visual Adaptation

luminance (log cd/m²)
-6 -4 -2 0 2 4 6 8
starlight moonlight indoor lighting sunlight displays

range of illumination
scotopic mesopic photopic

- poor contrast - good contrast
- no color - good color
- low acuity - high acuity
Sunnybrook Display Technology

- High resolution colour LCD
- High Dynamic Range Display
- Low resolution Individually Modulated LED array
Quantum Dots
Quantum Dots

- QD’s can generate spectrally narrow primaries
- Color can be easily controlled by quantum dot size
- QD technology is more cost-effective than OLED’s
Color Control by QD Particle Size

Depending on size, quantum dots emit different color light due to quantum confinement. Illustrated is the range of QDs with emission gradually stepping from violet to red.
Quantum Dot Manufacture

Nanosys/3M
Quantum Dot Advantages

• Saves watts as almost all energy is converted into light
• QD’s are very small (1.5nm (violet) → 5.0nm (red)) allowing
• Very high resolution (ppi)
• QD’s can support large flexible displays
• QD’s offer high brightness (50-100x) LED’s
Quantum Dot Backlighting

**LCD**
Quantum Dots used to create even white Backlighting Light passes through RGB filters.

**QDEF LCD**
Quantum Dots use a Blue LED and the Blue quantum dots to energize the red and green phosphors.

**QD LED**
Light from the Blue quantum dots pass directly through the black sub-pixels to illuminate the display.
Samsung Quantum Dot Display 2017
Modifications to Existing Technology

- The quest for energy reduction
- The quest for size
- The quest for brightness
- The quest for larger gamut
Color Gamut 2020
Modifications to Existing Technology

• The quest for energy reduction
• The quest for size
• The quest for brightness
• The quest for larger gamut
• The quest for resolution
Retinal Displays

Virtual Retinal Display primary components.

1. Drive electronics
2. Modulated light sources
3. Horizontal & vertical scanners
4. Viewing optics

Source image
This schematic diagram illustrates the functional components of a laser-scanned display system.
End
Liquid Crystal Display (LCD)
QDEF LCD

Blue Quantum Dots are used as backlights.
Blue Quantum Dots are used to energize the red and green phosphors and the blue QD light becomes the blue sub-pixel.