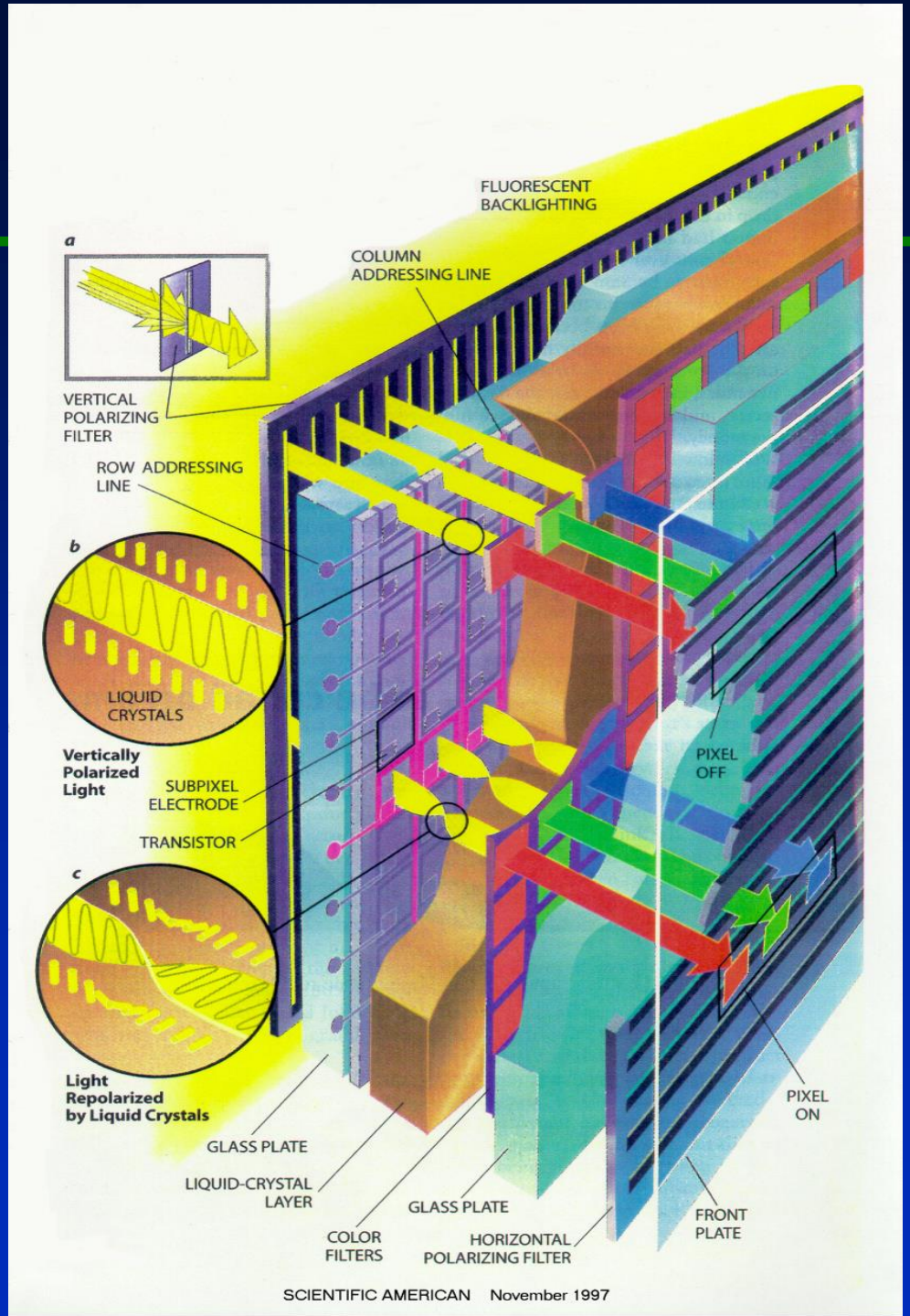
Advanced Display Technology

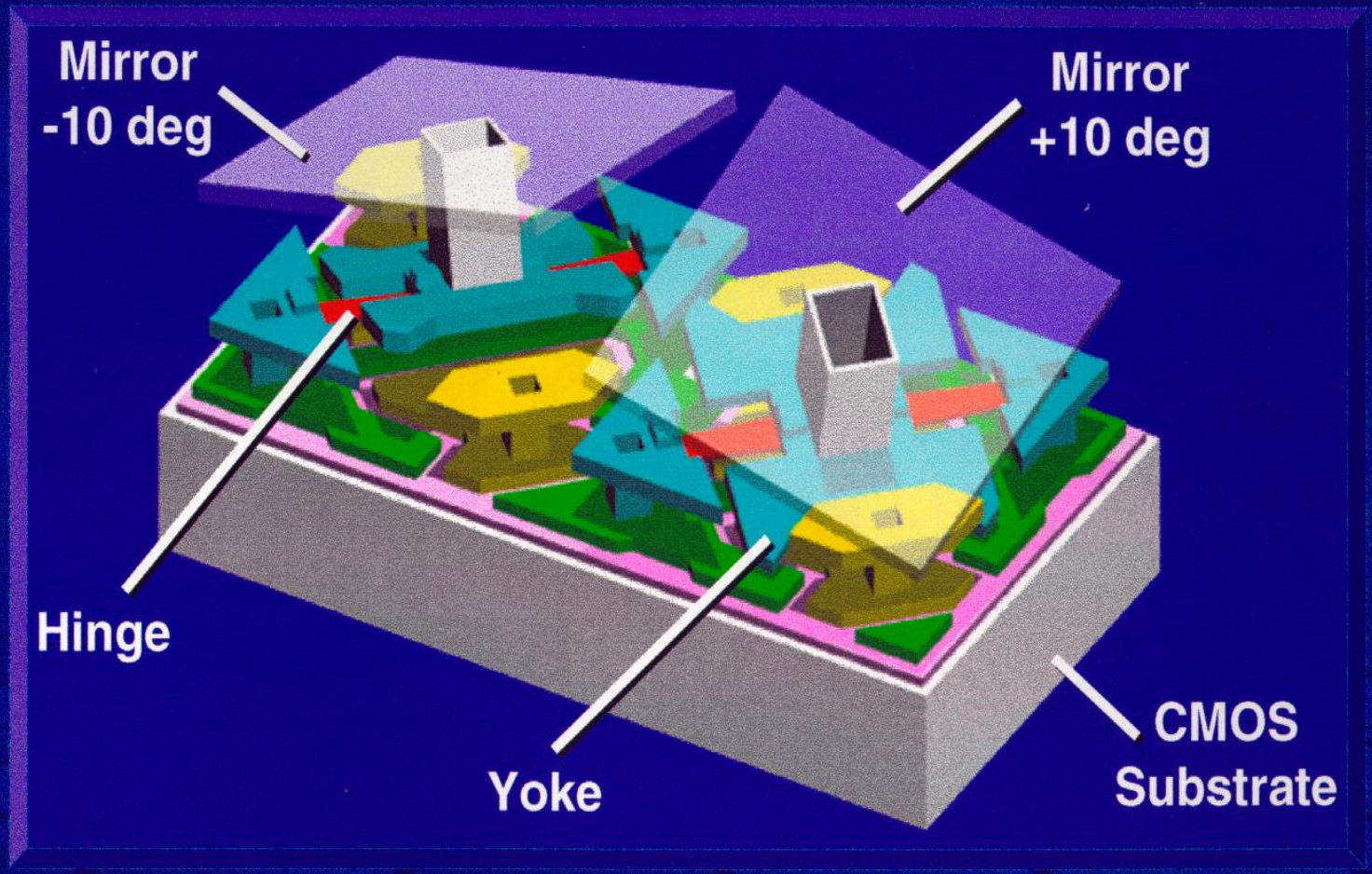
Lecture 13
October 15, 2020
Imaging in the Electronic Age
Donald P. Greenberg

Liquid Crystal Color Display



Scientific American, November 1997

DMD Structure



Digital Micromirror Device (DMD™)

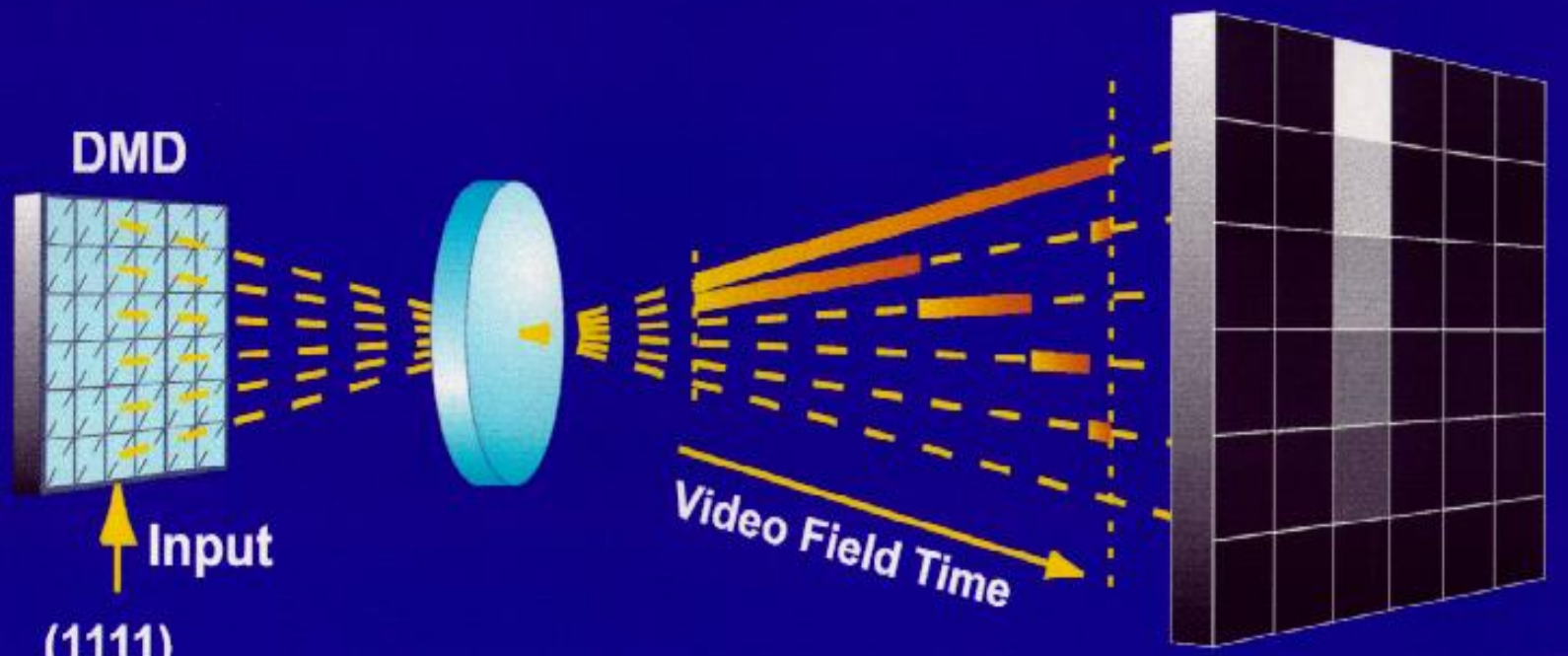
A True Microelectromechanical System

DLP™

A TEXAS INSTRUMENTS TECHNO

How Grayscale is Created

DMD™ Binary Pulsewidth Modulation



(1111)
(1001)
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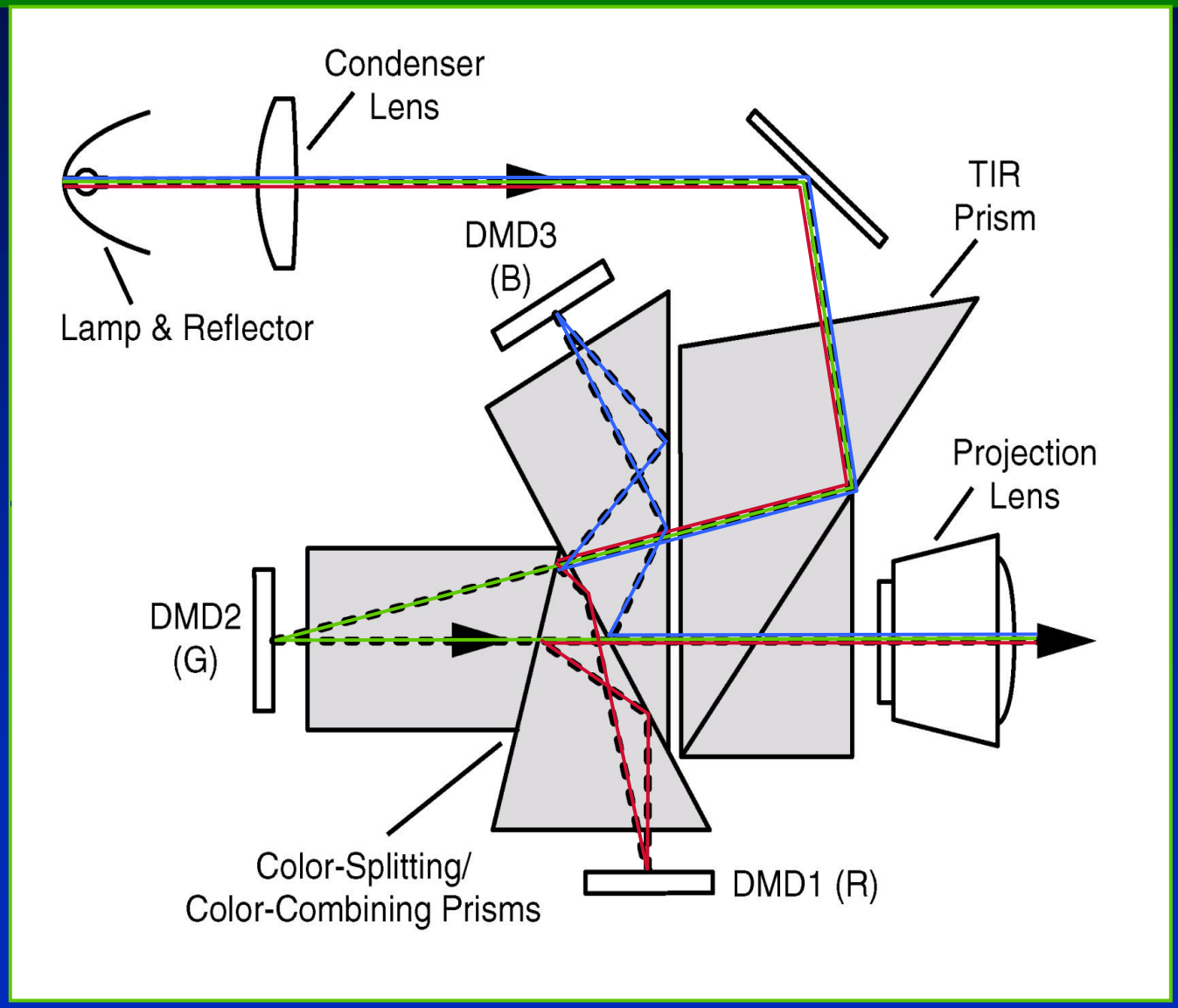
(Sensations of Gray Shade By Viewer's Eye)

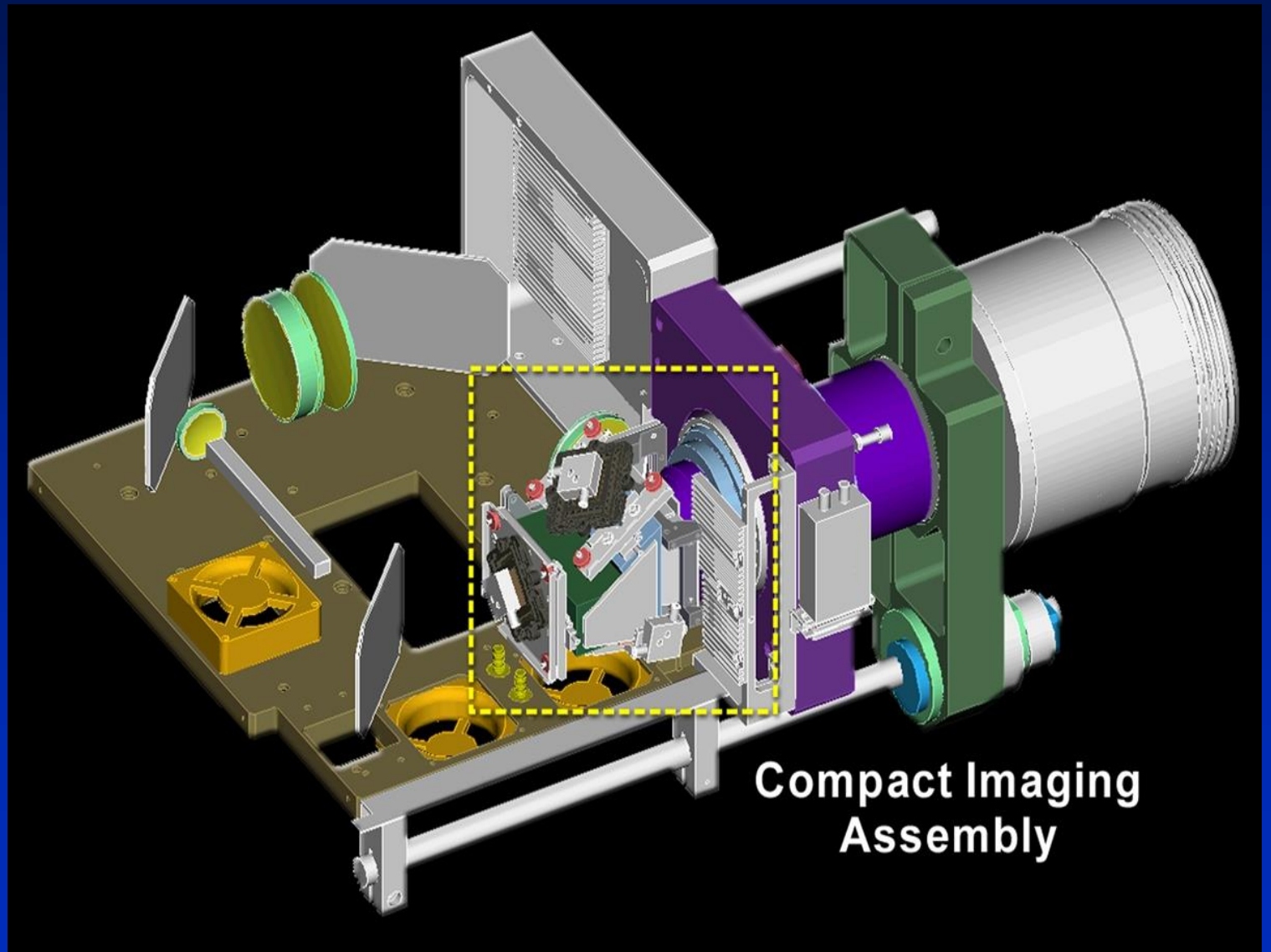
4-Bit, 16 Gray-Level Example

How can we extend this technology to color?

3-Chip DLP Color Optical System



DLP Projection System



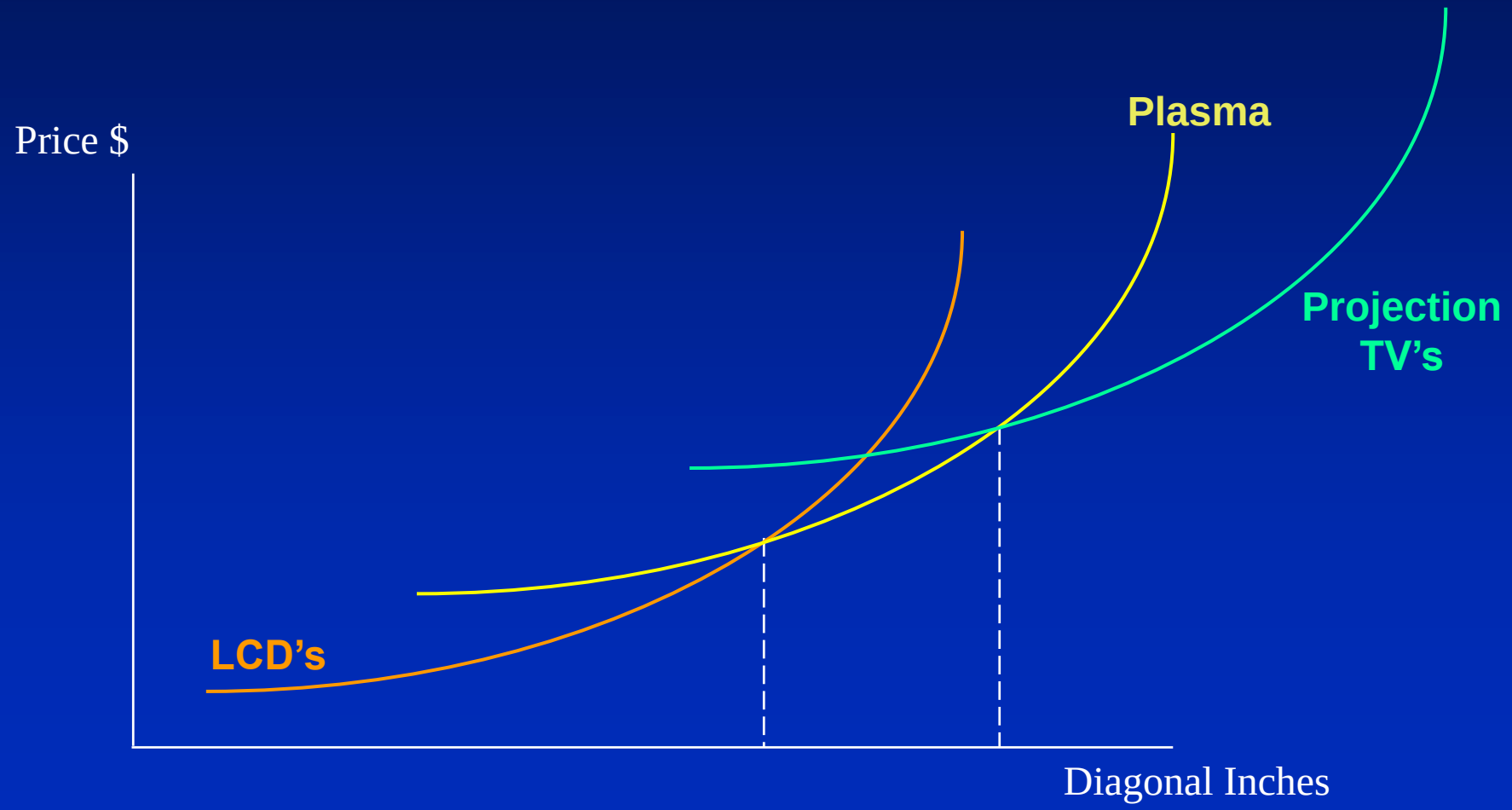
Digital Micromirror Devices (DMD)

- 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)

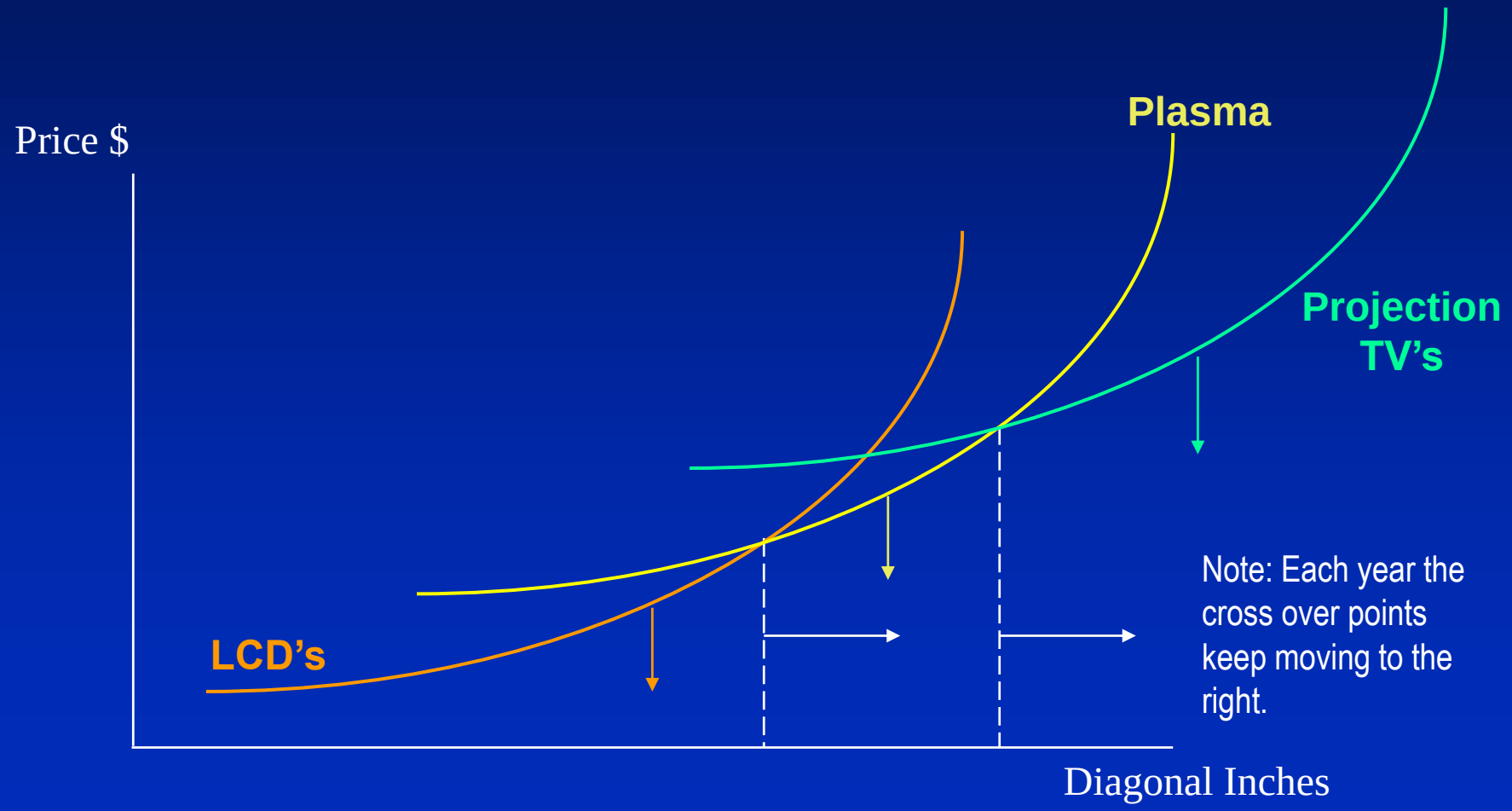
Christie CP4230 Digital Cinema Projector

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

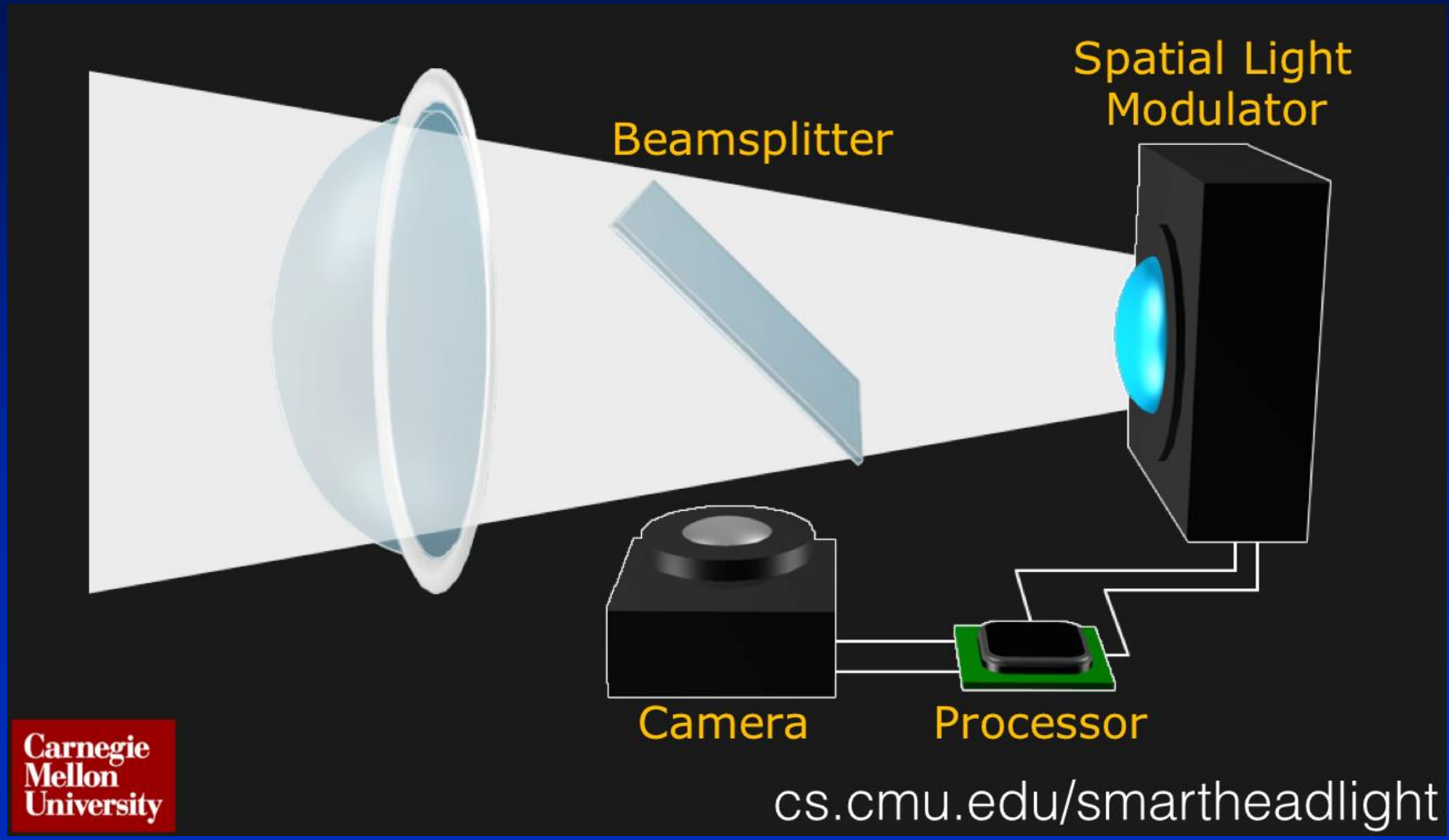
Cost of HDTV Displays



Cost of HDTV Displays



Smart Headlight

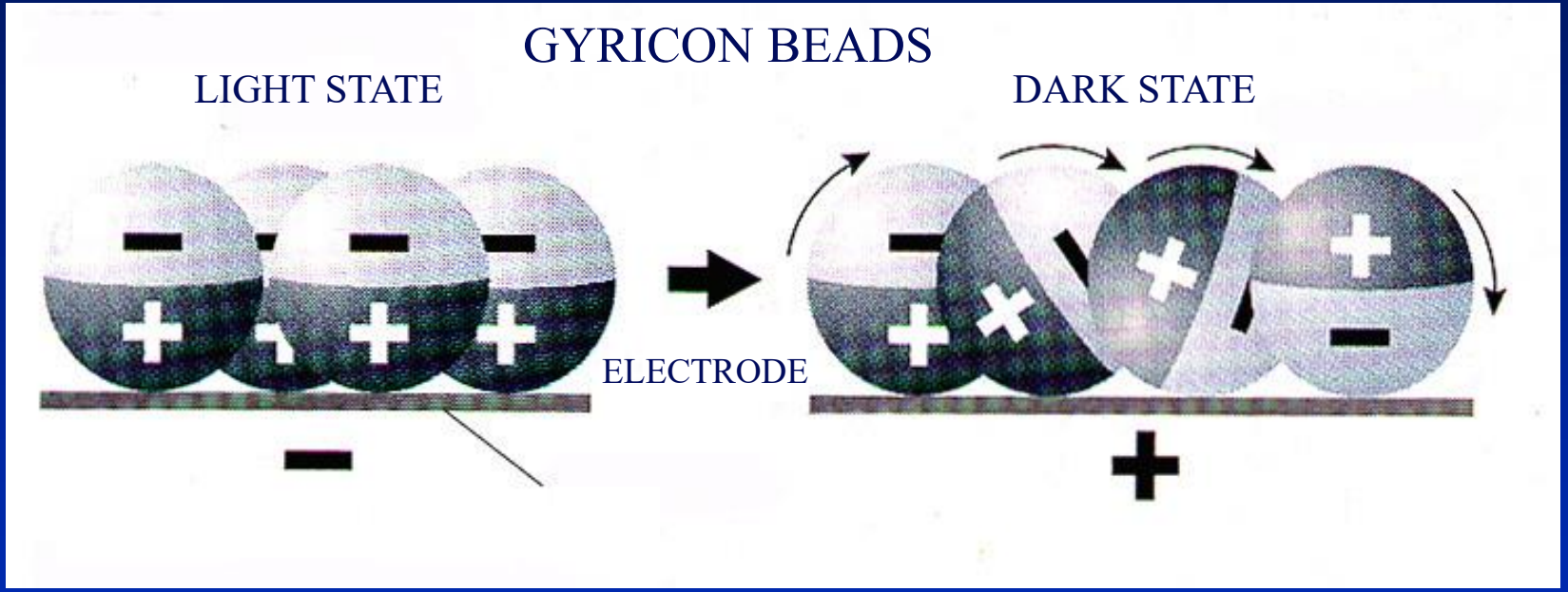


Headlights- Carnegie Mellon

Modifications to Existing Technology

- The quest for energy reduction

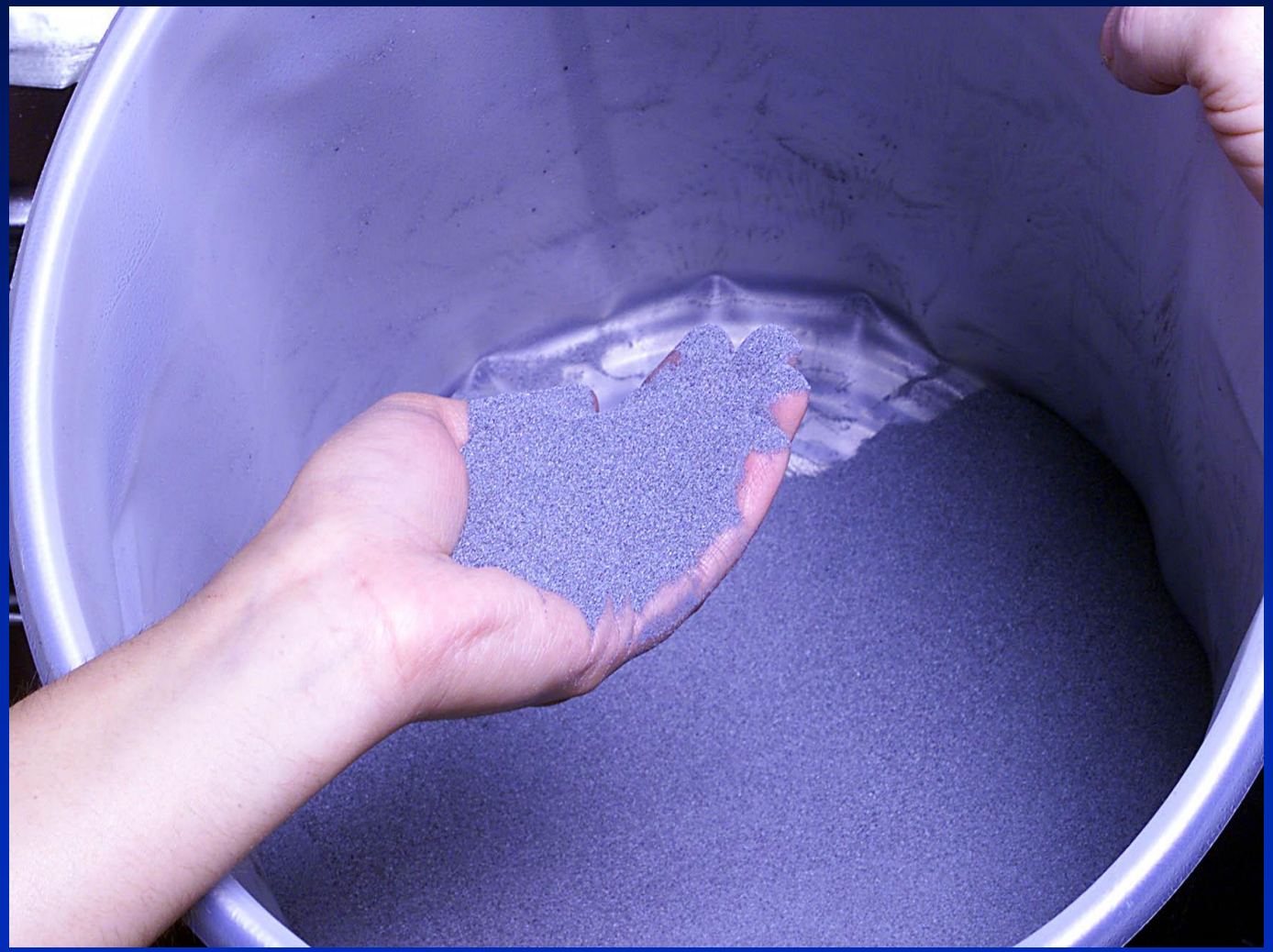
How E-Paper Works



Scientific American, 11/2001, p. 54.

Electronic Reusable Paper

The paper pulp of the future.

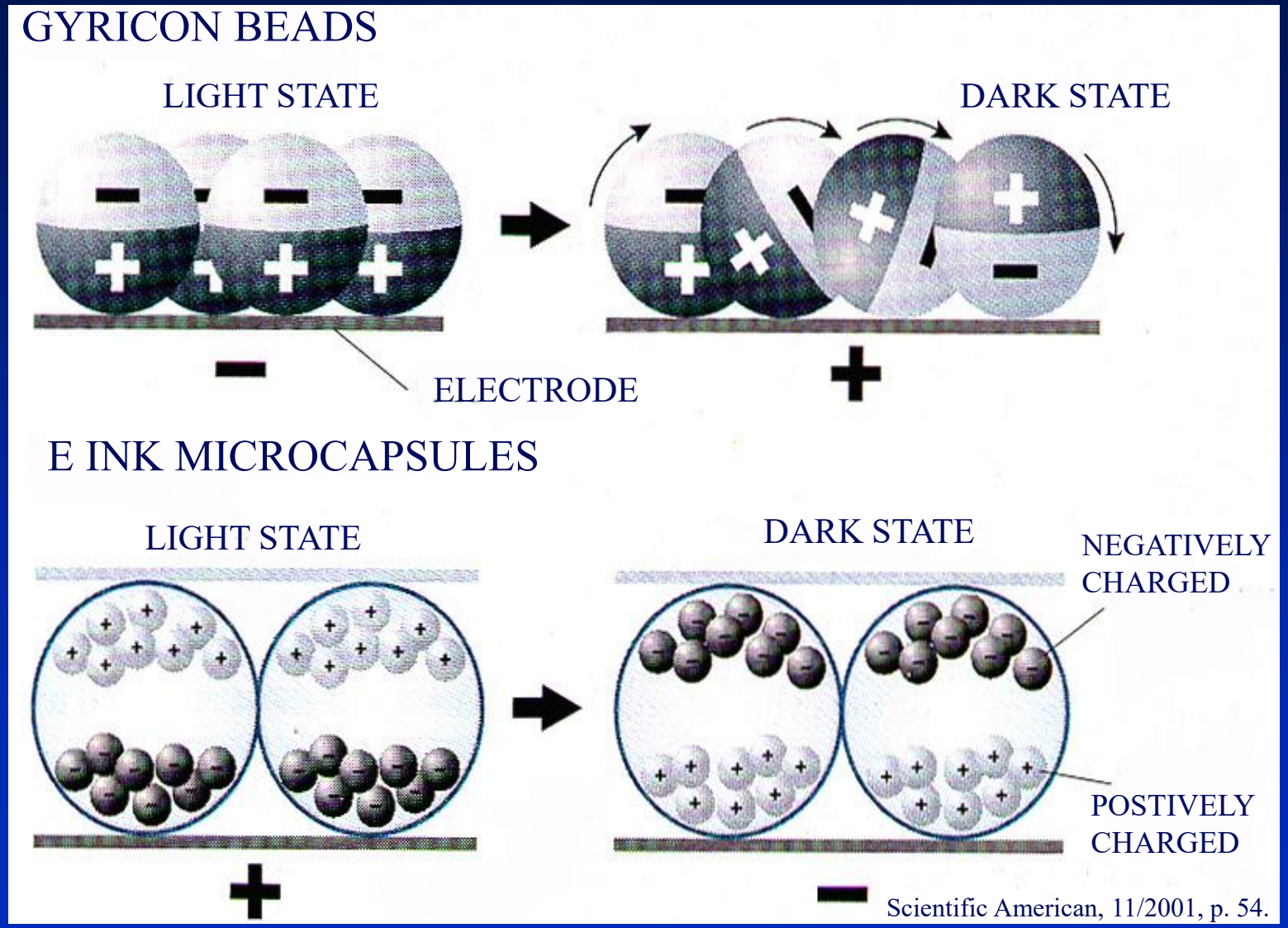


http://www2.parc.com/hsl/projects/gyricon/

Nick Sheridon, Xerox PARC inventor of electronic reusable paper, and Fereshteh Lesani show off the first roll produced by 3M partners.

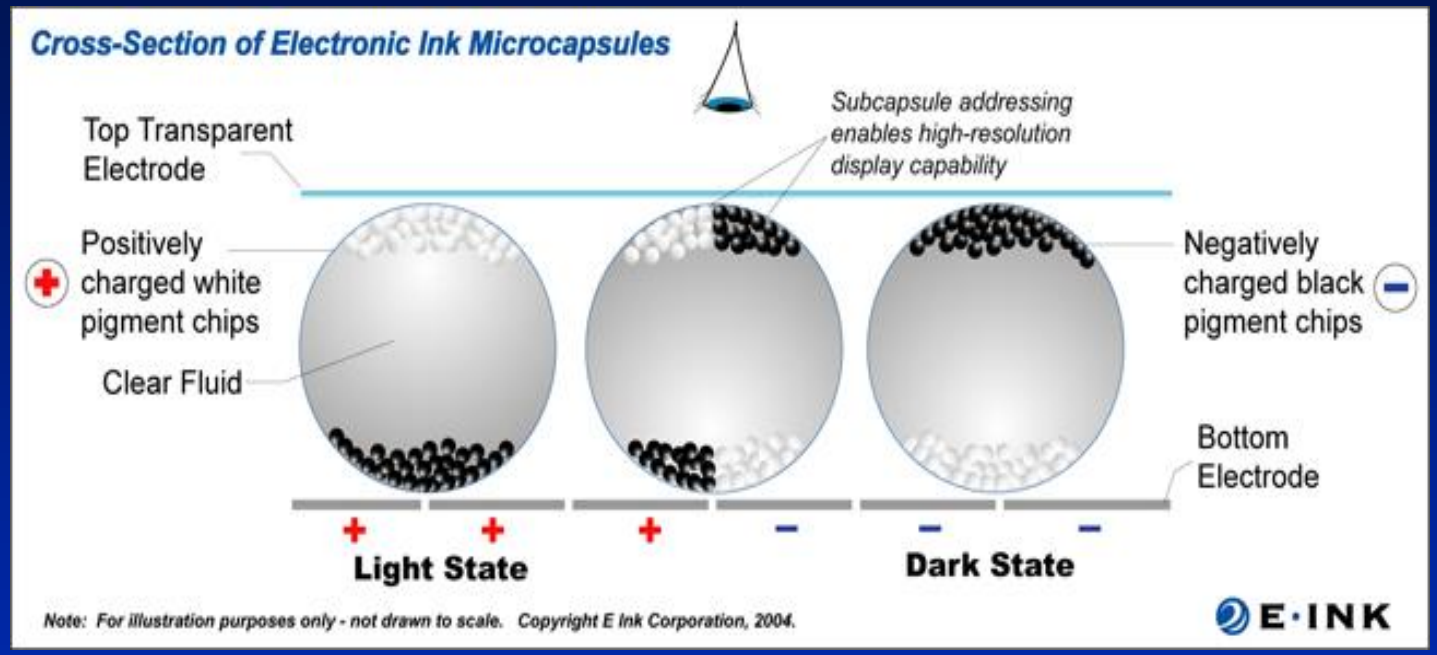
http://www2.parc.com/hsl/projects/gyricon/

How E-Paper Works



Scientific American, 11/2001, p. 54.

Flexible Electronic Paper Display

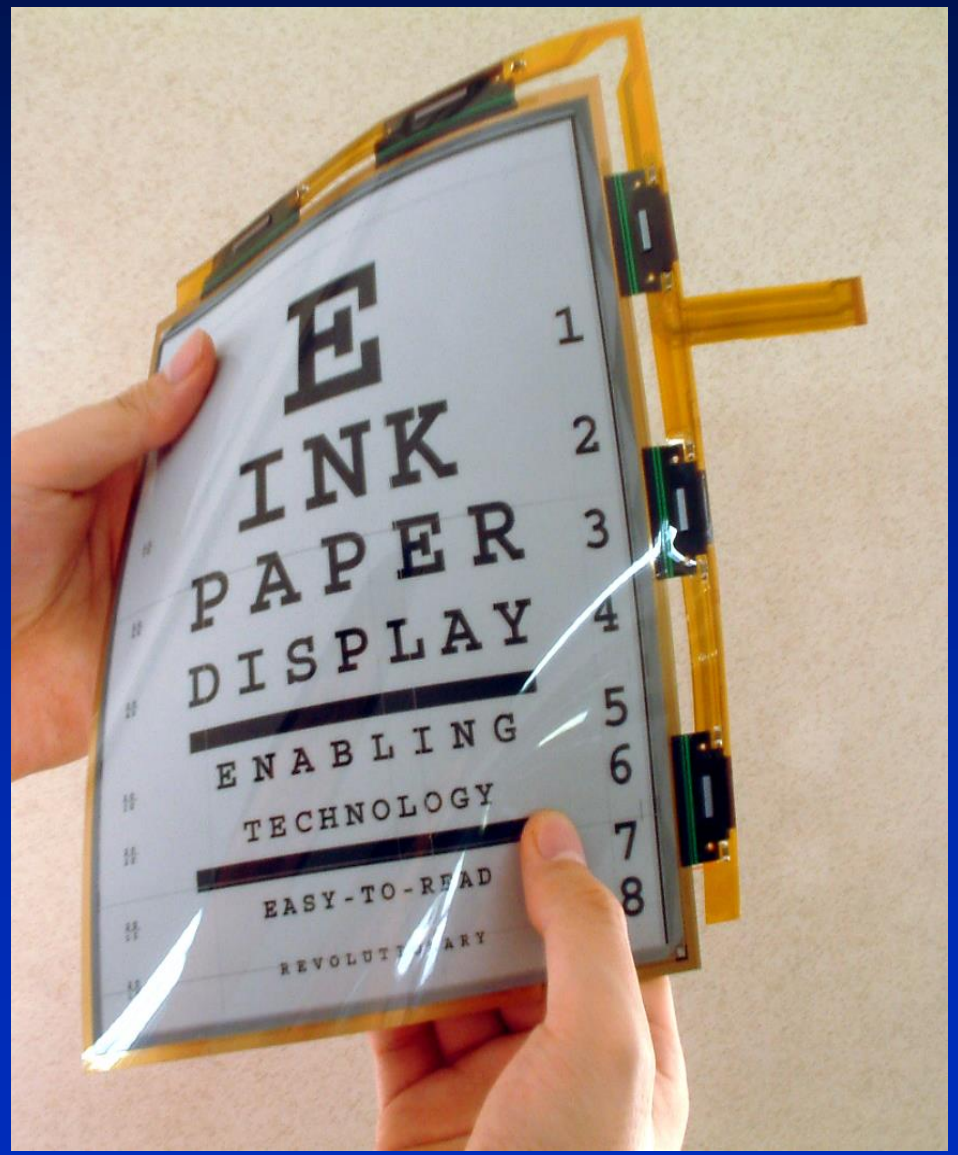


Electronic ink is a straightforward fusion of chemistry, physics and electronics to create this new material.

http://www.eink.com/technology/howitworks.html

E-Ink

MIT, Late 1990's

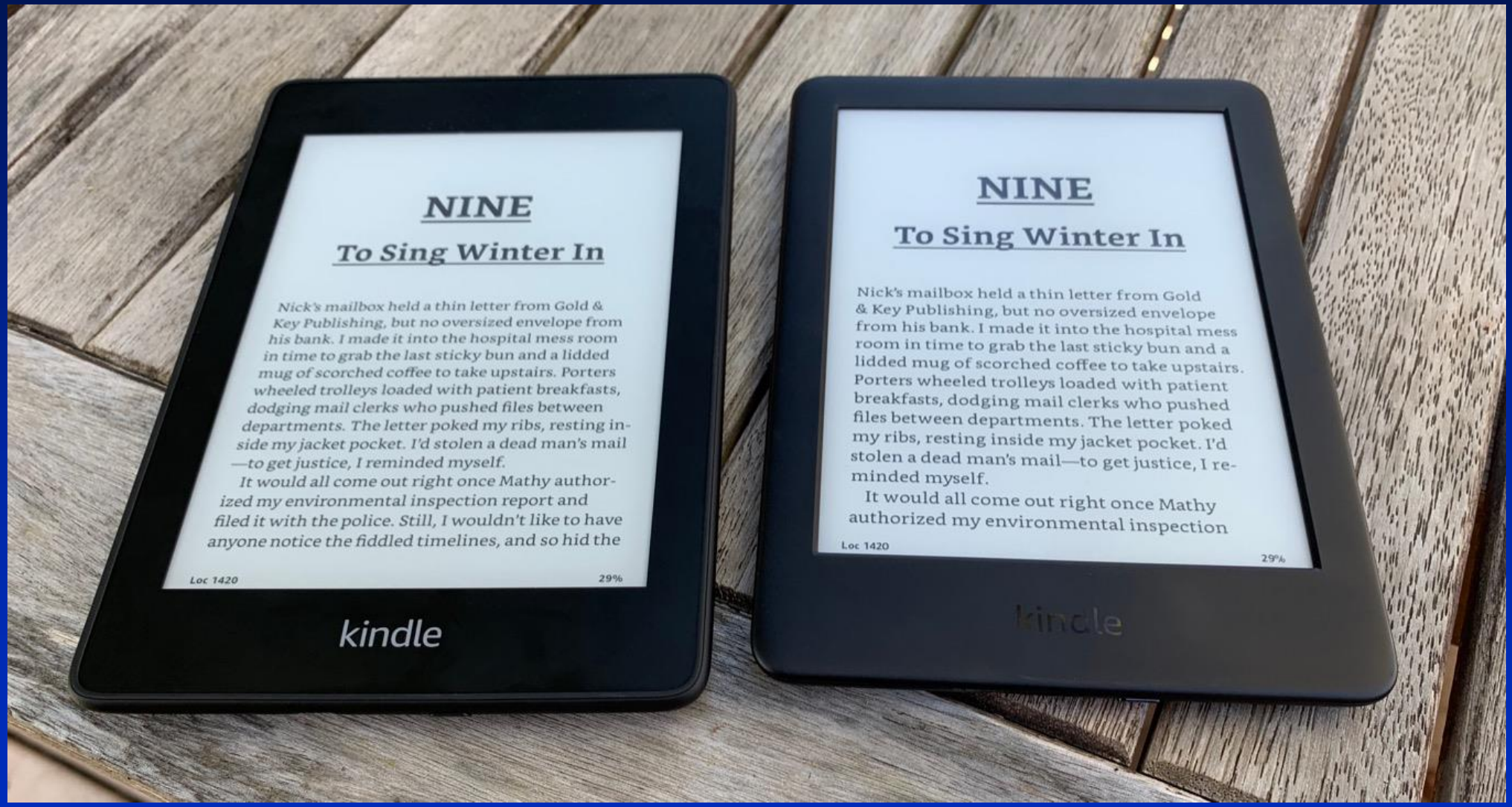


Flexible Tablet-Sized Display From
L.G. Philips
LCD and E Ink Corporation

http://www.eink.com/

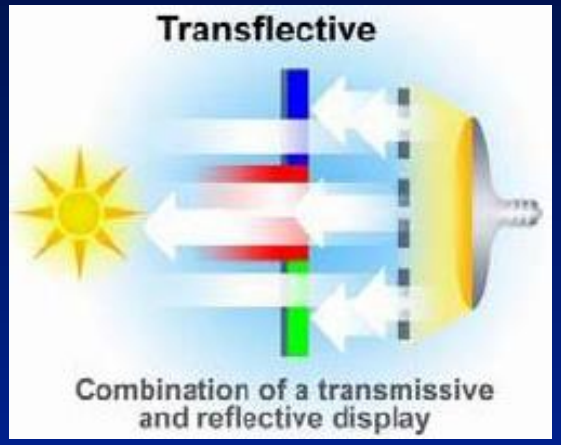
Plastic Logic 2000

Kindle 9 2019



https://sixcolors.com/post/2019/04/review-kindle-paperwhite-2019-and-kindle-2019/

The XO and One Laptop Per Child 2005

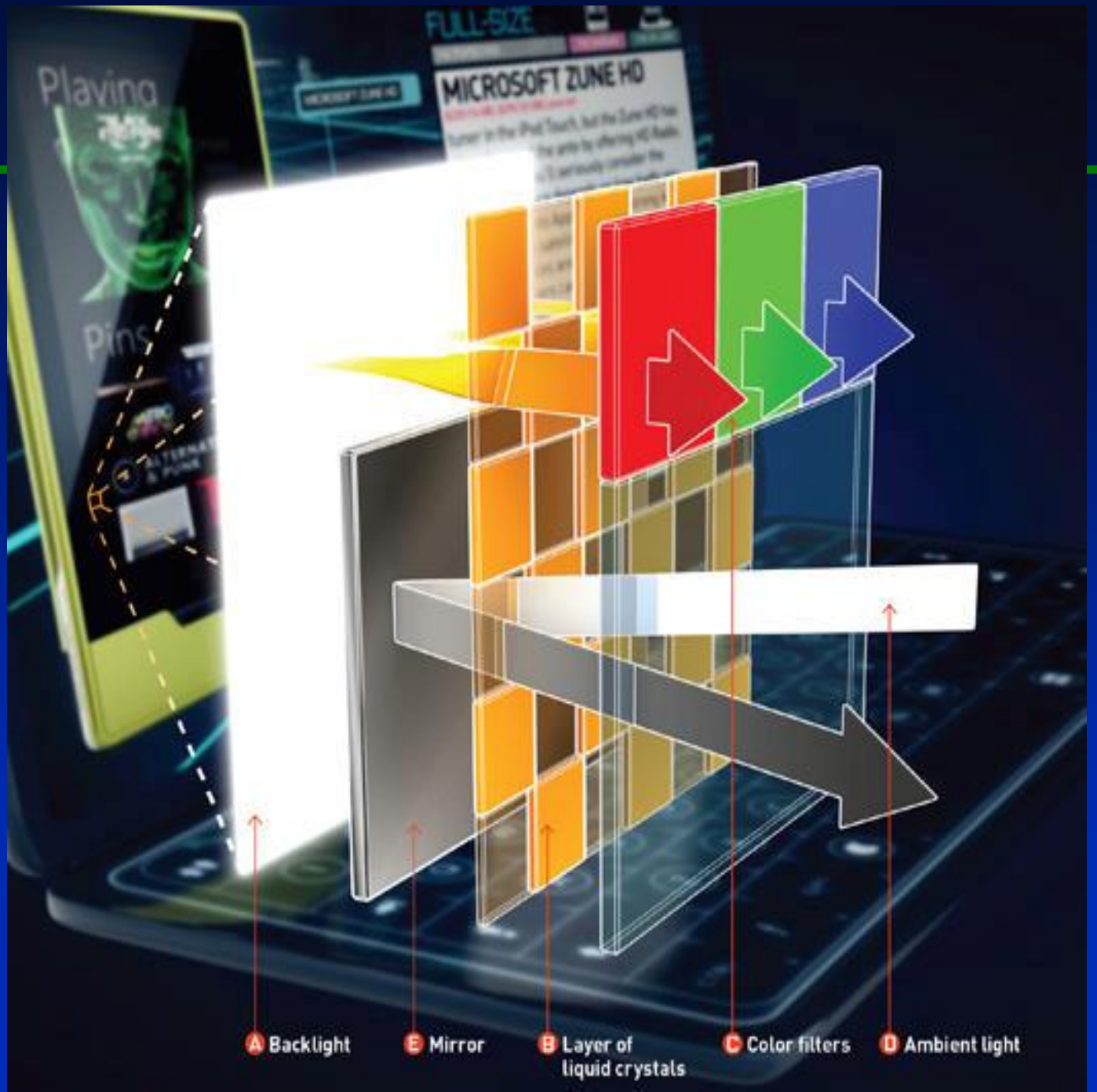


The custom XO display contains a reflective layer between it's backlight and the specially formatted LCD layer, allowing it to turn high ambient lighting conditions to it's advantage.

The display is not only inexpensive ($30/unit), but is also much easier on the eyes.

Images Through Screen Doors

Pixel Qi

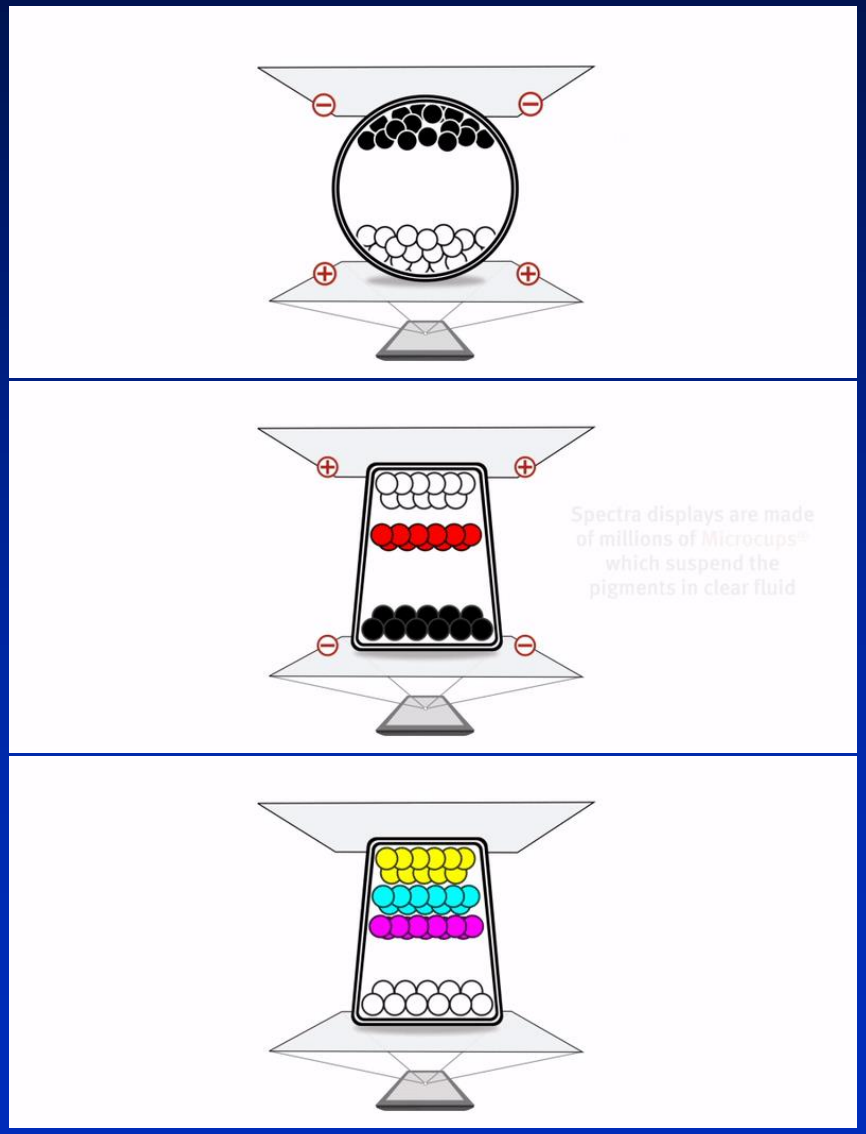

FULL-SIZE
MICROSOFT ZUNE HD
Playing
Pins
A Backlight
E Mirror
B Layer of liquid crystals
C Color filters
D Ambient light

Pixel Qi

2008

E-Paper The Quest for Color

E-paper Technology 2019



Spectral displays are made of millions of Microcapsules which suspend the pigments in clear fluid.

E-paper Technology 2019

E-paper Technology 2019

Organic LEDs (OLEDs) 2007

SOFT LIGHT: Junji Kido of Yamagata University shows off his bright and smooth prototype OLED system.

John Boyd. "Let There Be (a New Kind of) Light," IEEE Spectrum, July 2007.

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

John Boyd. “Let There Be (a New Kind of) Light,” IEEE Spectrum, July 2007.

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)

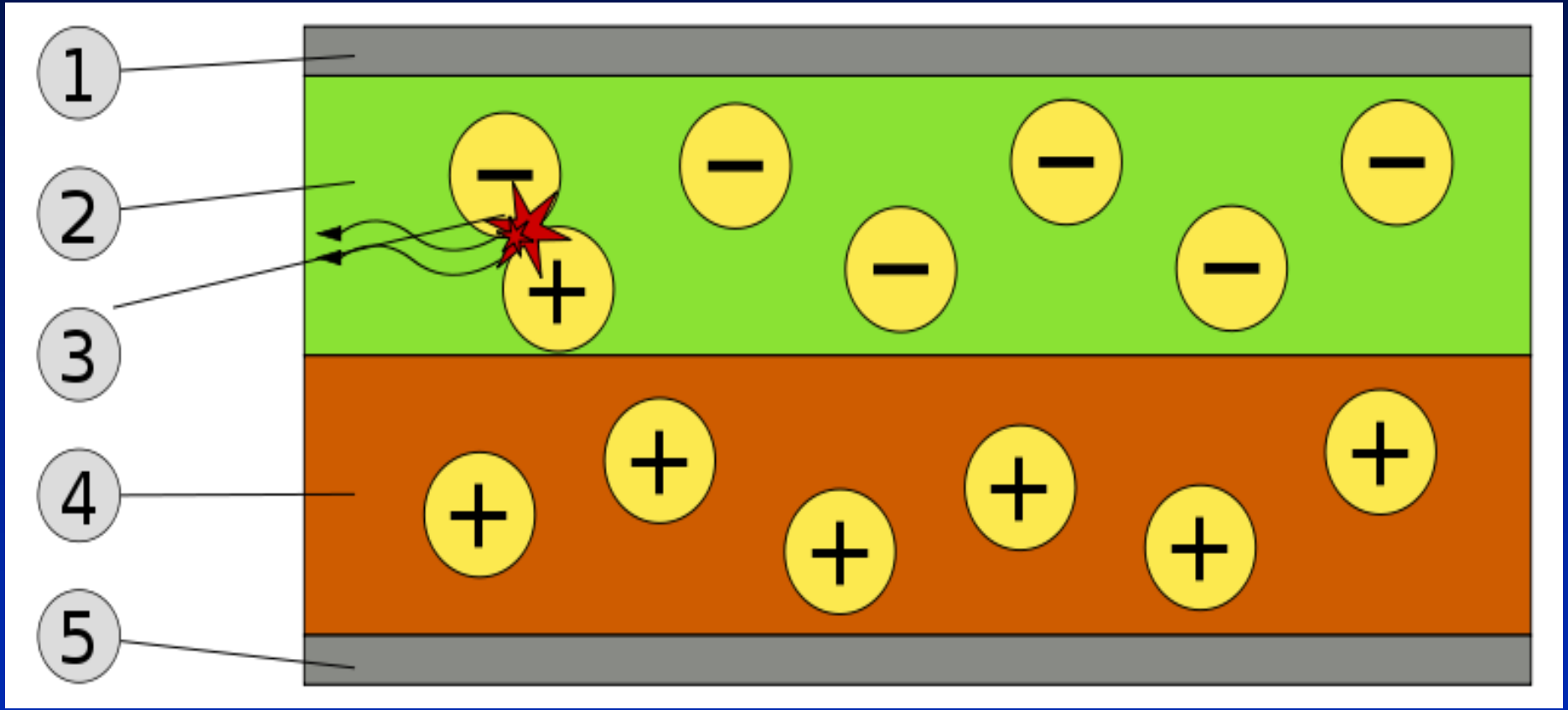
John Boyd. “Let There Be (a New Kind of) Light,” IEEE Spectrum, July 2007.

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

John Boyd. “Let There Be (a New Kind of) Light,” IEEE Spectrum, July 2007.

OLED schematic



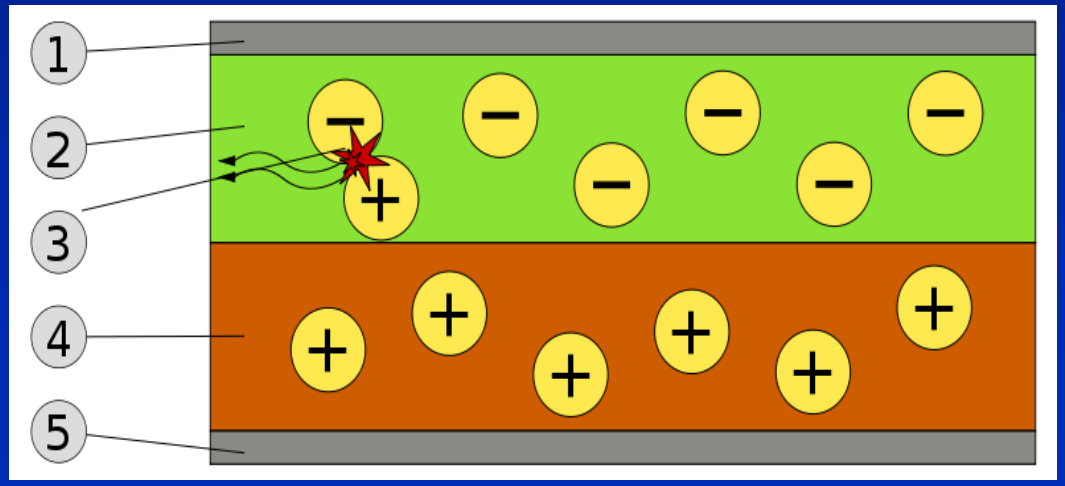
1. Cathode (-), 2. Emissive Layer, 3. Emission of radiation, 4 . Conductive Layer, 5. Anode (+)

http://en.wikipedia.org/wiki/Organic_light-emitting_diode#Working_principle

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).

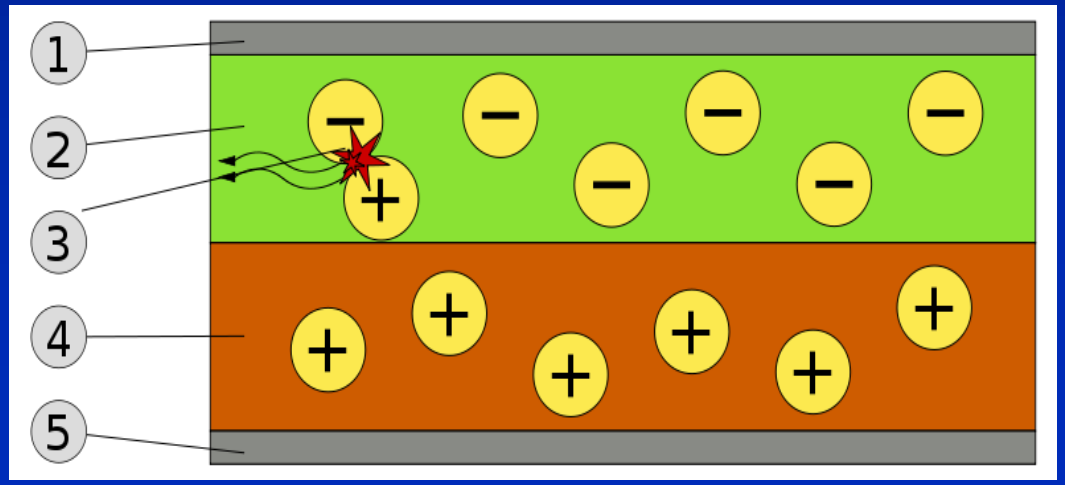


OLED Explanation

C. Electrostatic forces bring the electrons and holes together and they recombine.

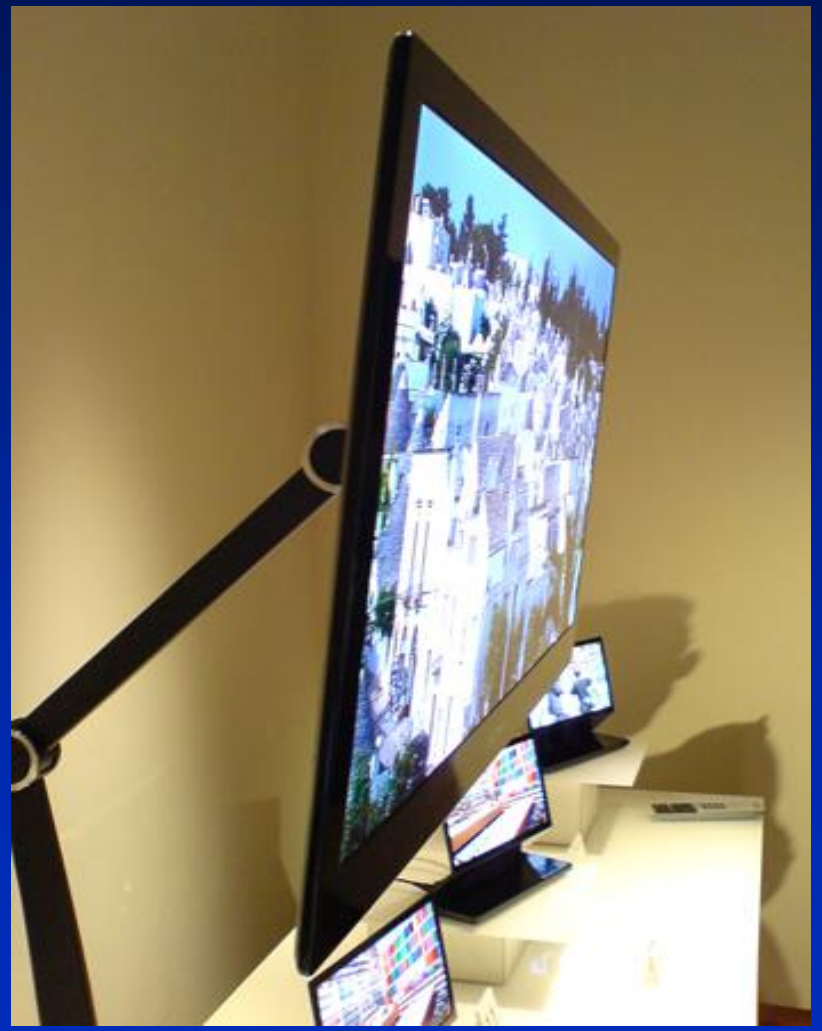
D. In organic semiconductors, holes are more mobile than electrons. This happens closer to the emissive layer.

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

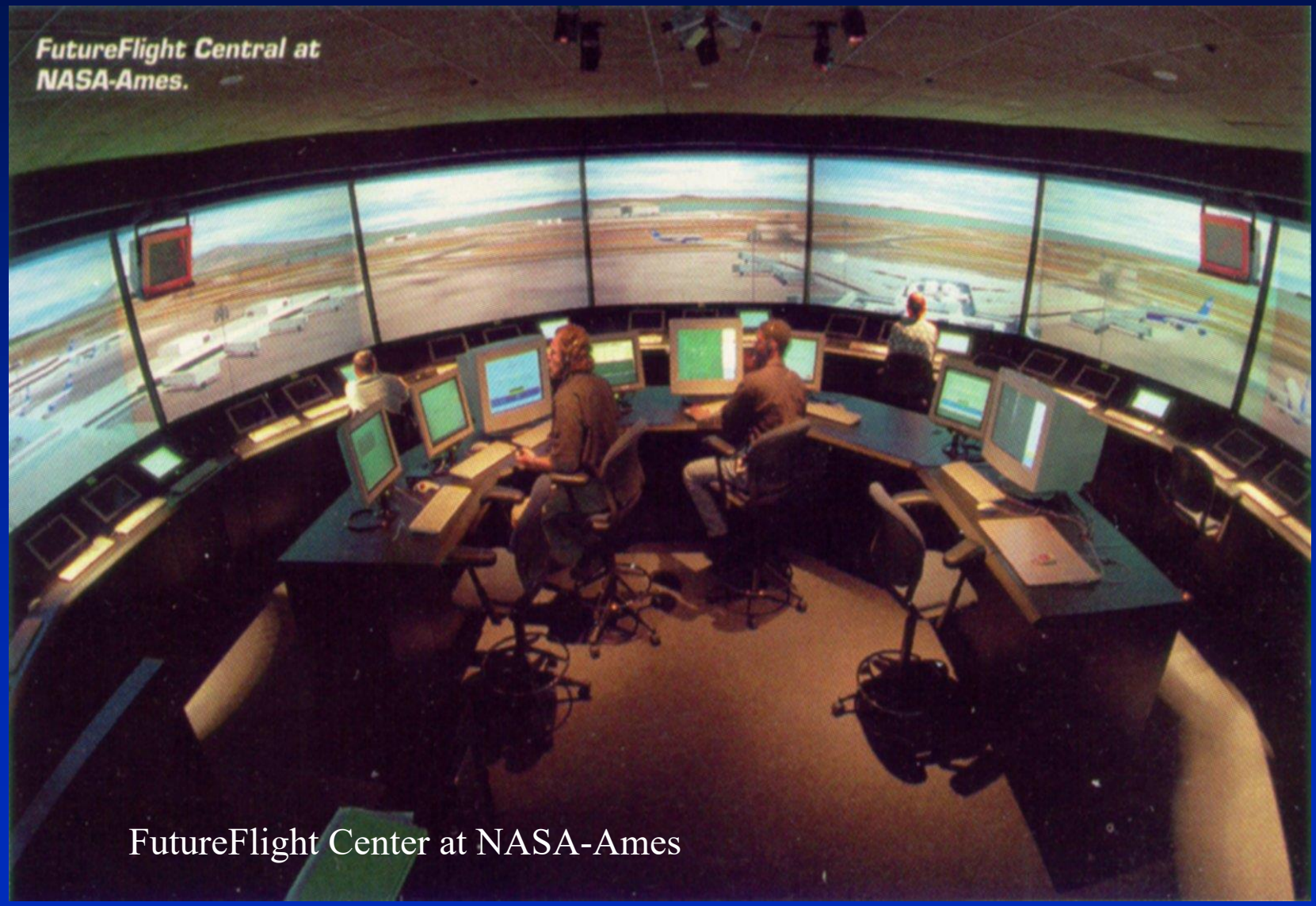


Modifications to Existing Technology

- The quest for energy reduction
- The quest for size

Cornell Panoramic Projection System

NASA Ames Control Room



FutureFlight Center at NASA-Ames

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 2019

88’

Crystal LED

SONY 2020

16 ft, 8K

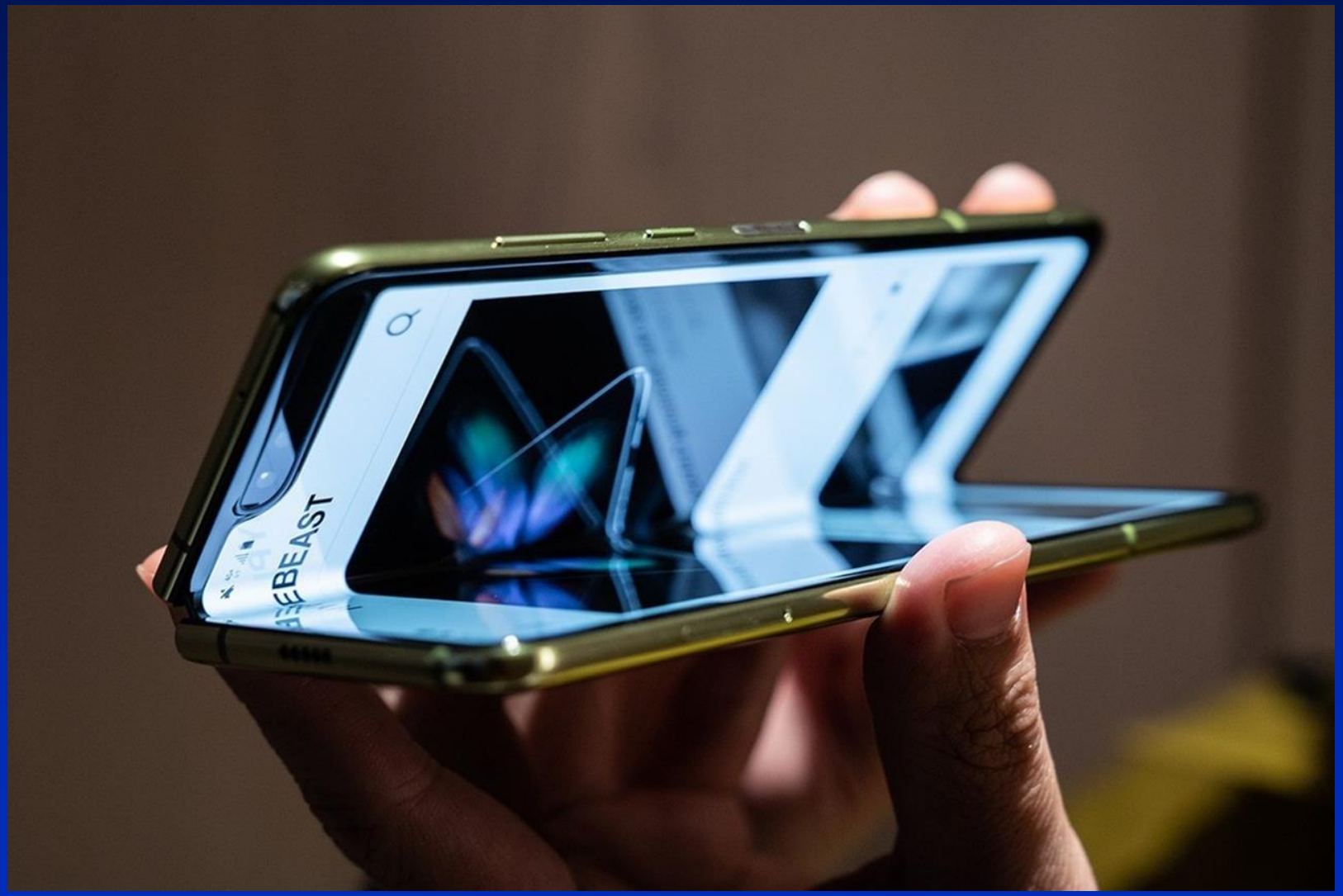
9 ft.

https://www.digitaltrends.com/[illegible]sony-[illegible]assive-new-microled-display-stands-[illegible]-tall-and-packs-16k-resolution/

4K

$877,000

Foldable Phones 2019



Foldable Laptops 2019

OLED TV RX

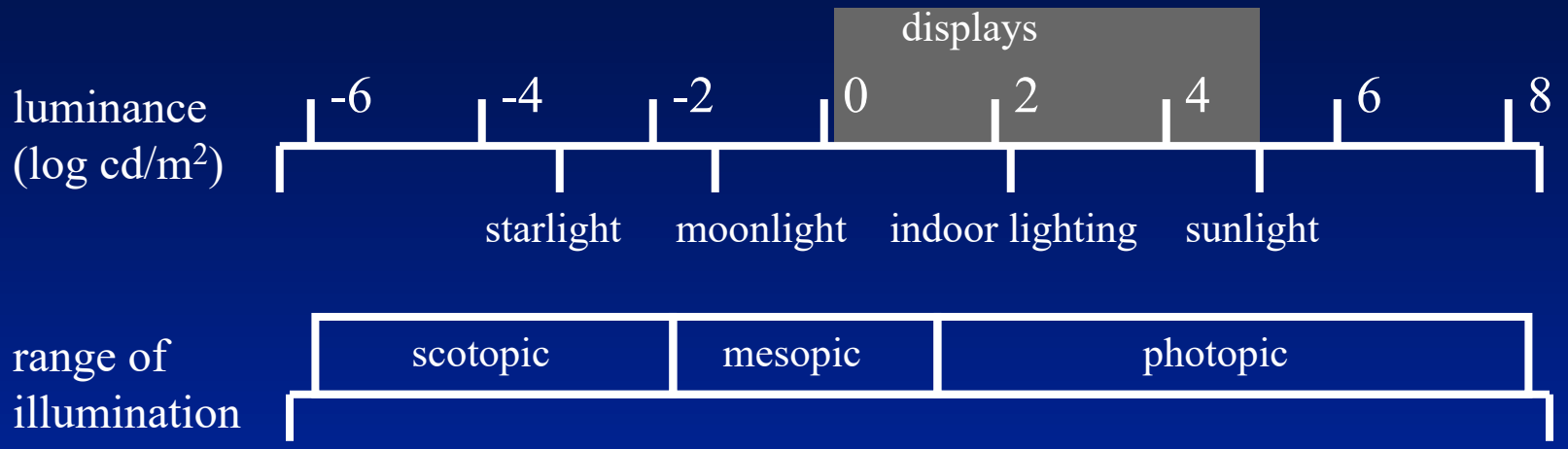
Flexible Displays

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



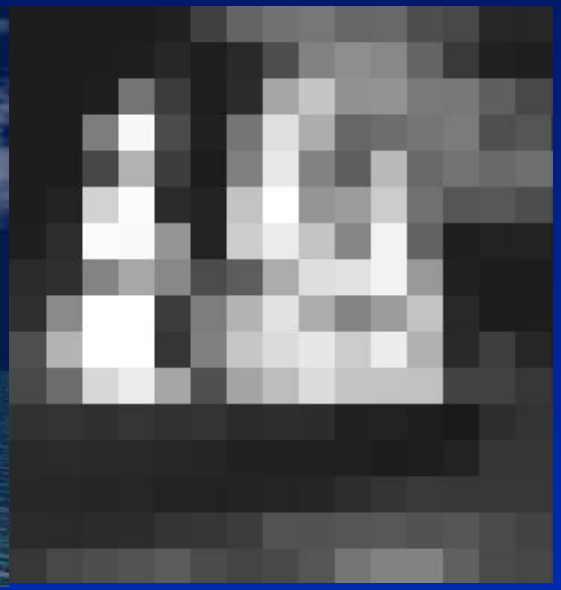
- poor contrast
- no color
- low acuity

- good contrast
- good color
- high acuity

Sunnybrook Display Technology

High resolution
colour LCD

High Dynamic Range
Display



Low resolution
Individually Modulated
LED array

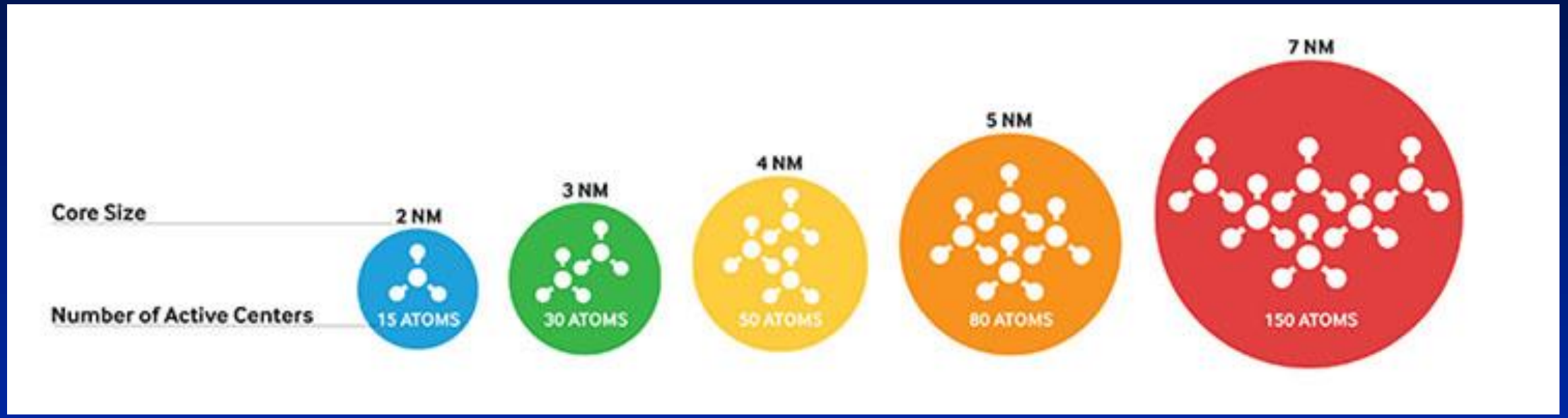
4K Ultra HD

LG 2020

3840 x 2160 Pixels

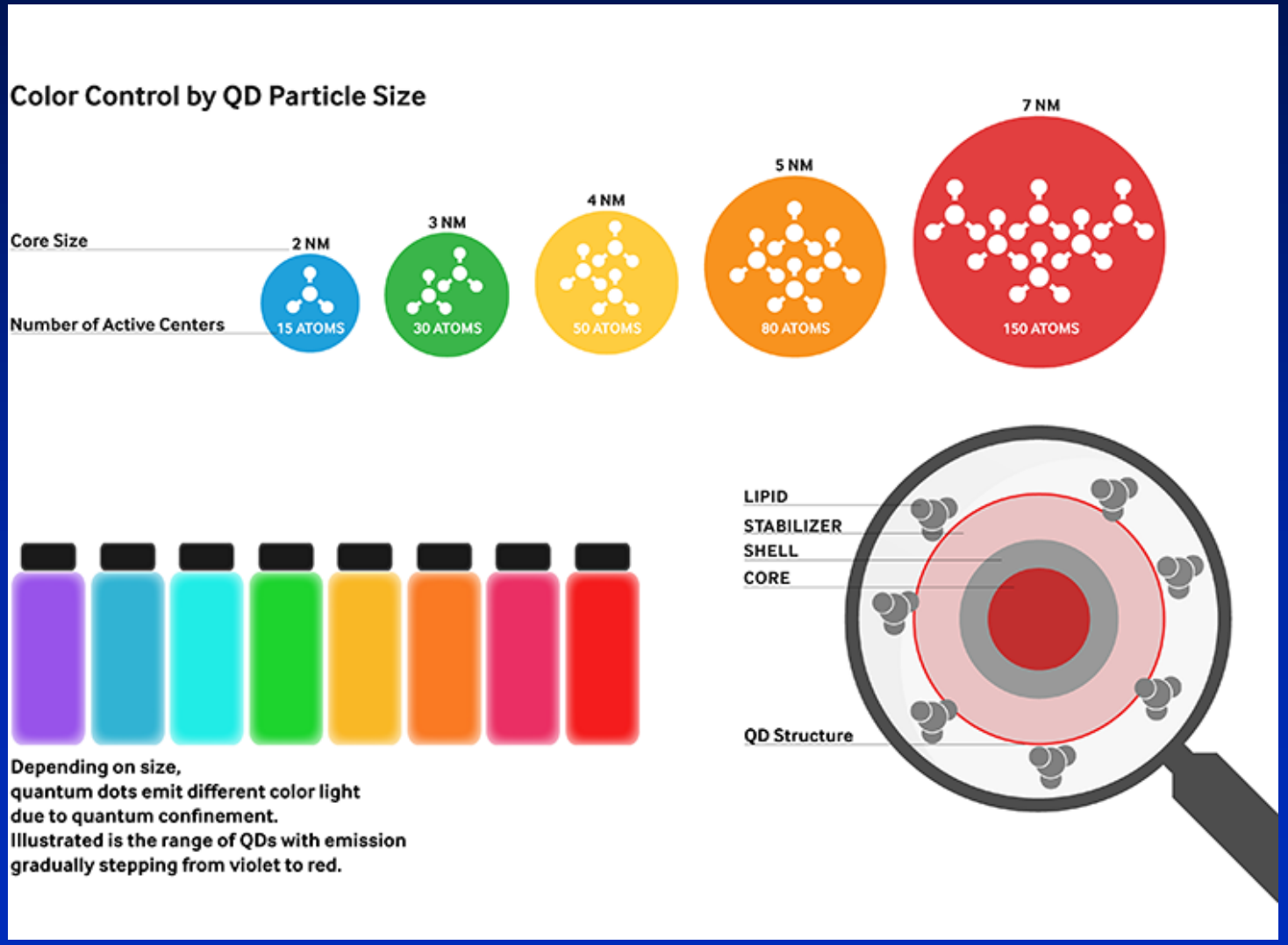
Quantum Dots

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



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

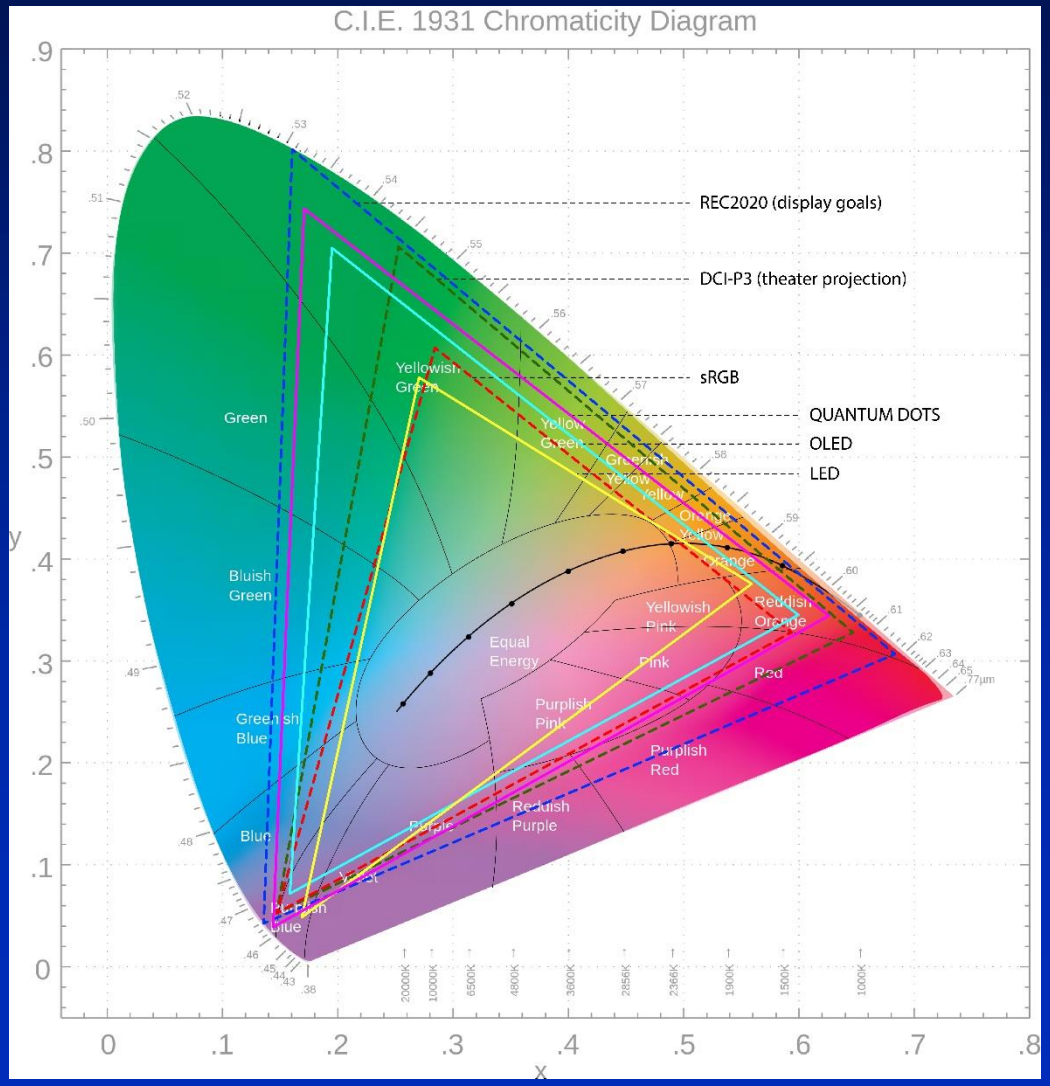
Light from the Blue quantum dots pass directly through the black sub-pixels to illuminate the display.

Samsung Quantum Dot Display 2017

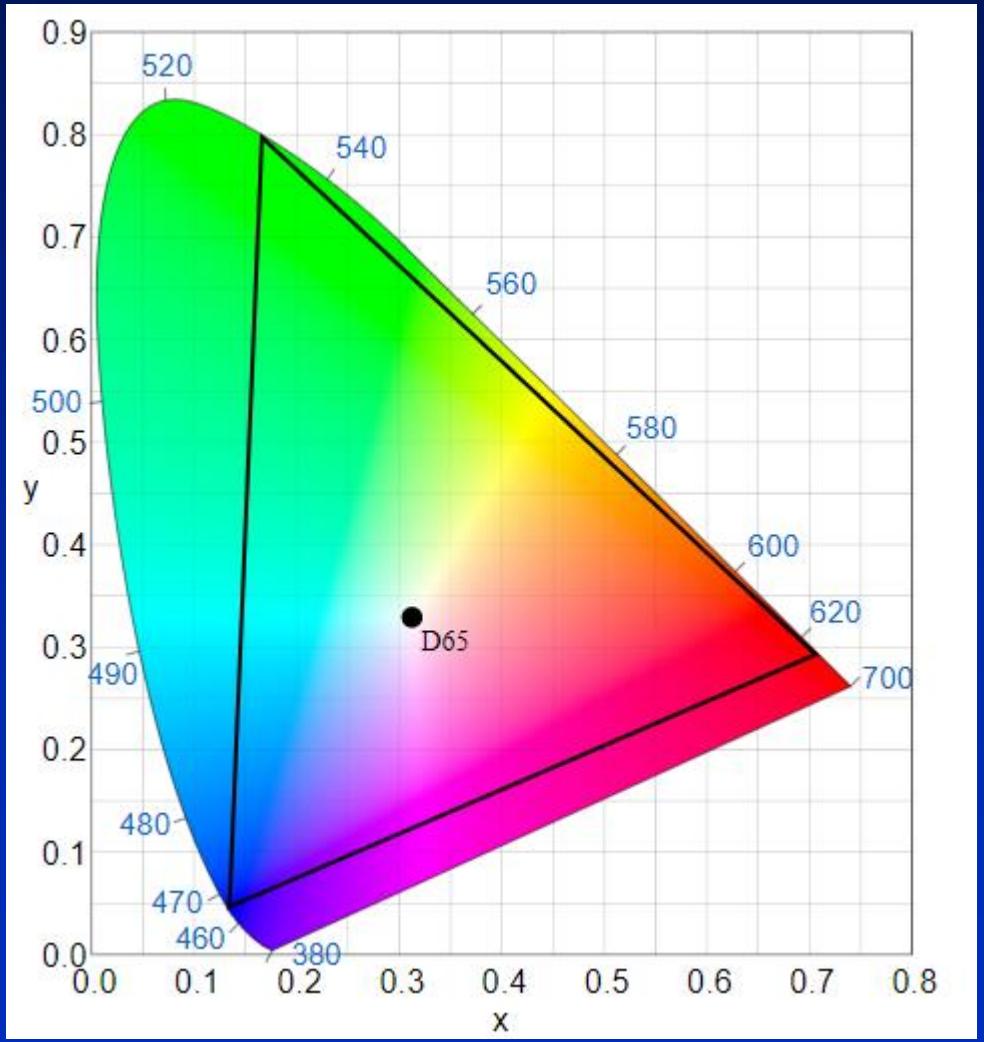
Modifications to Existing Technology

- The quest for energy reduction
- The quest for size
- The quest for brightness
- The quest for larger gamut

Color Gamut Comparison 2019



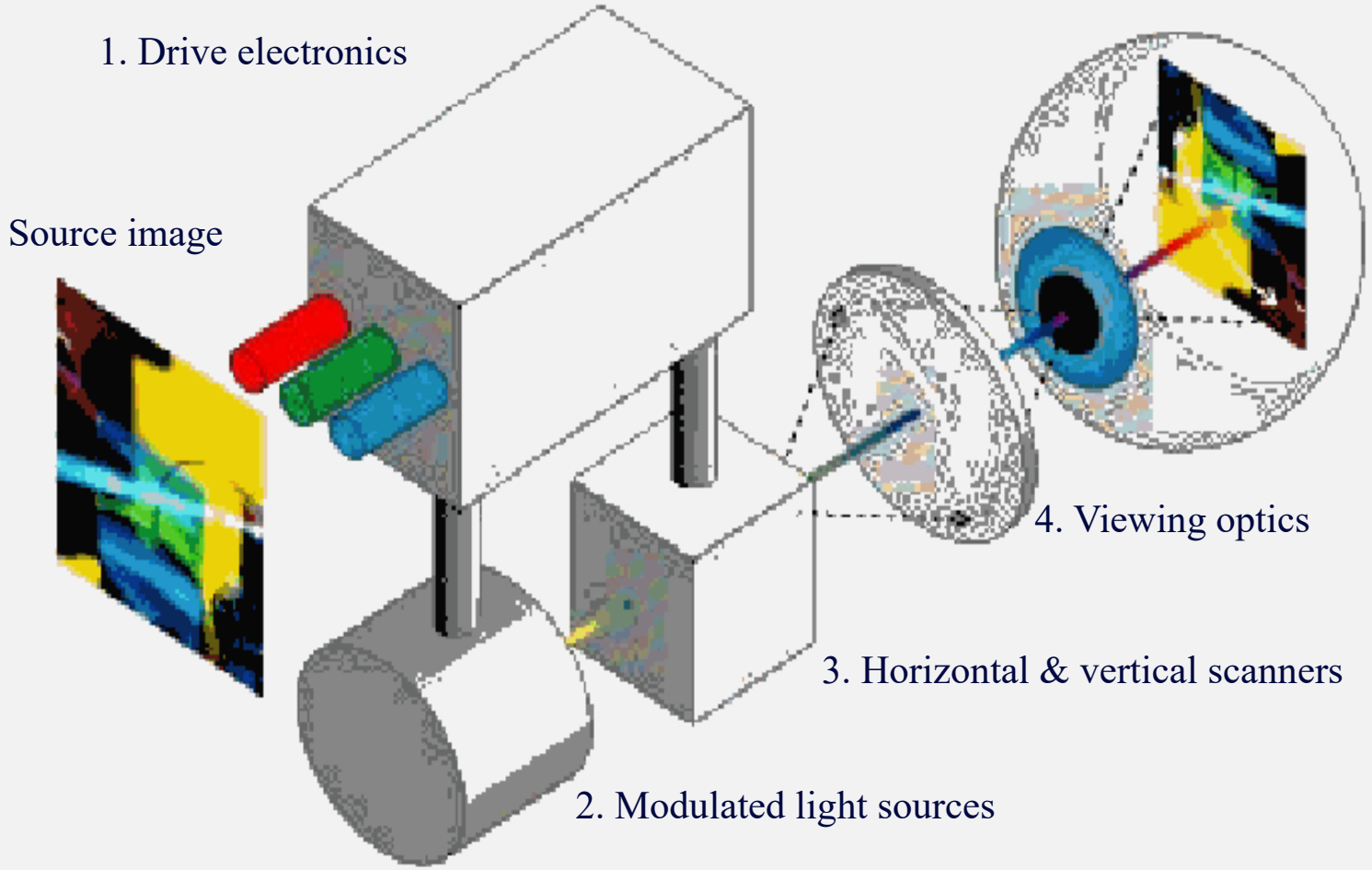
Color Gamut 2020



Modifications to Existing Technology

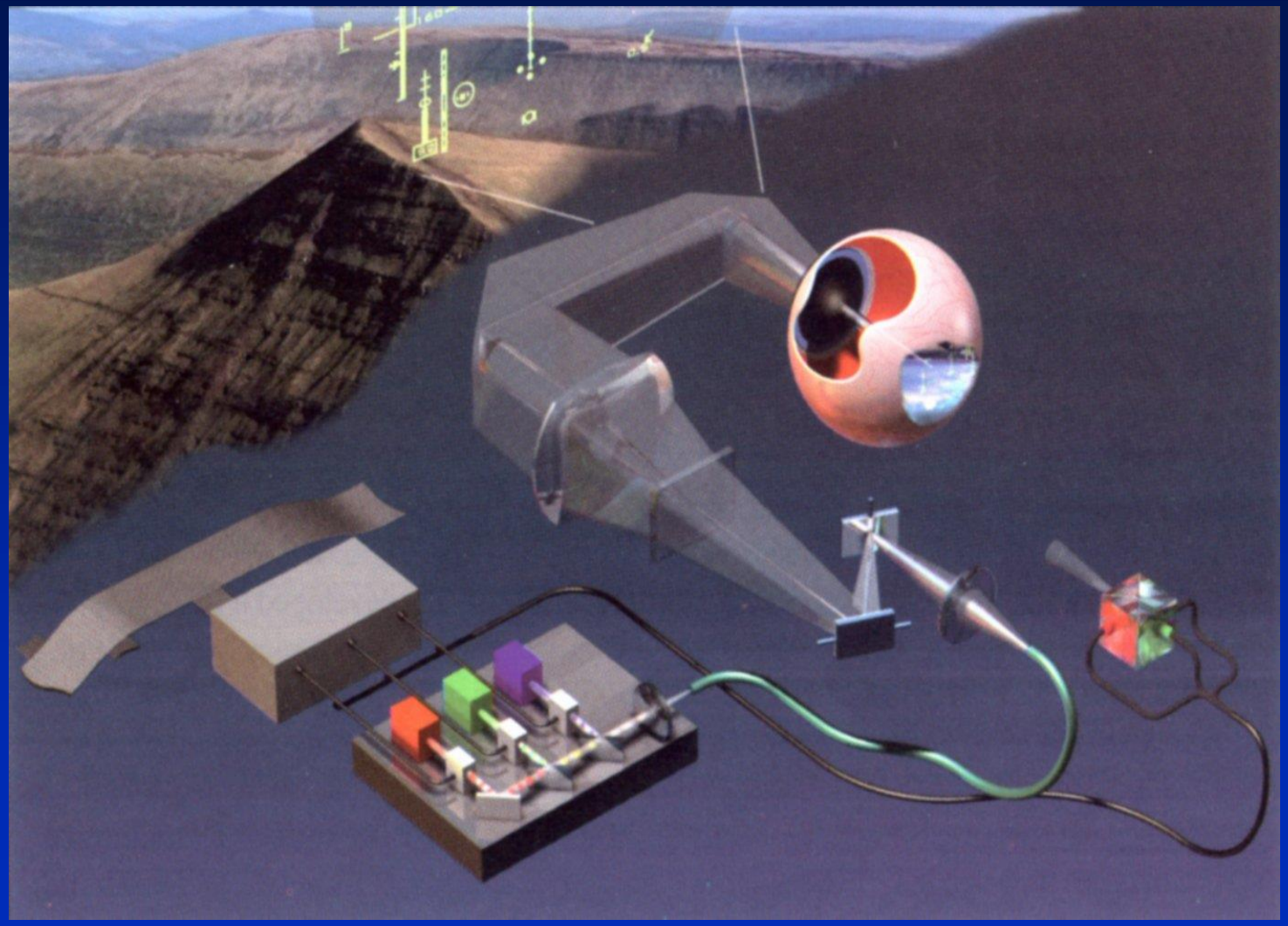
- The quest for energy reduction
- The quest for size
- The quest for brightness
- The quest for larger gamut
- The quest for resolution

Retinal Displays



Virtual Retinal Display primary components.

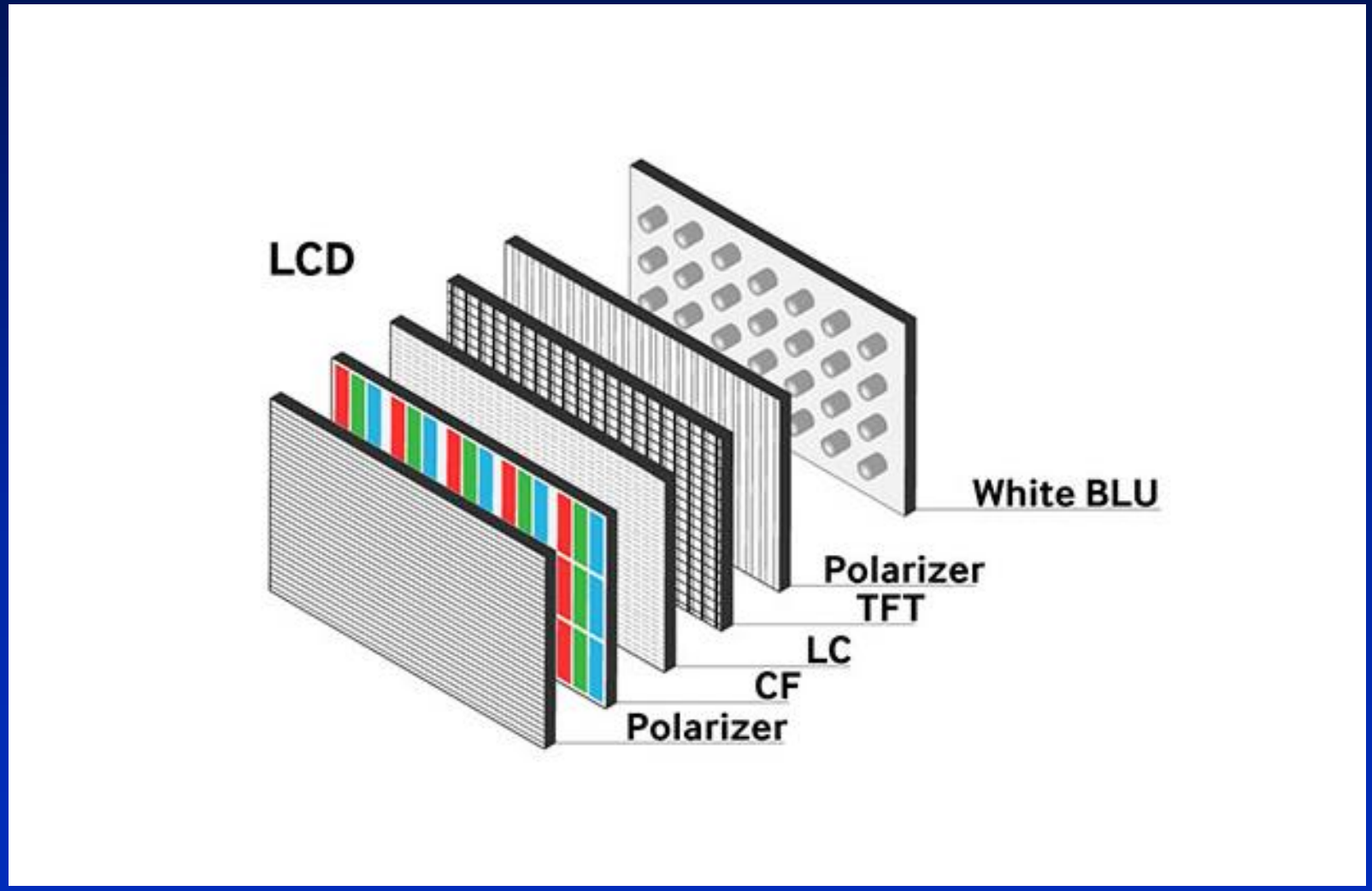
This schematic diagram illustrates the functional components of a laser-scanned display system.



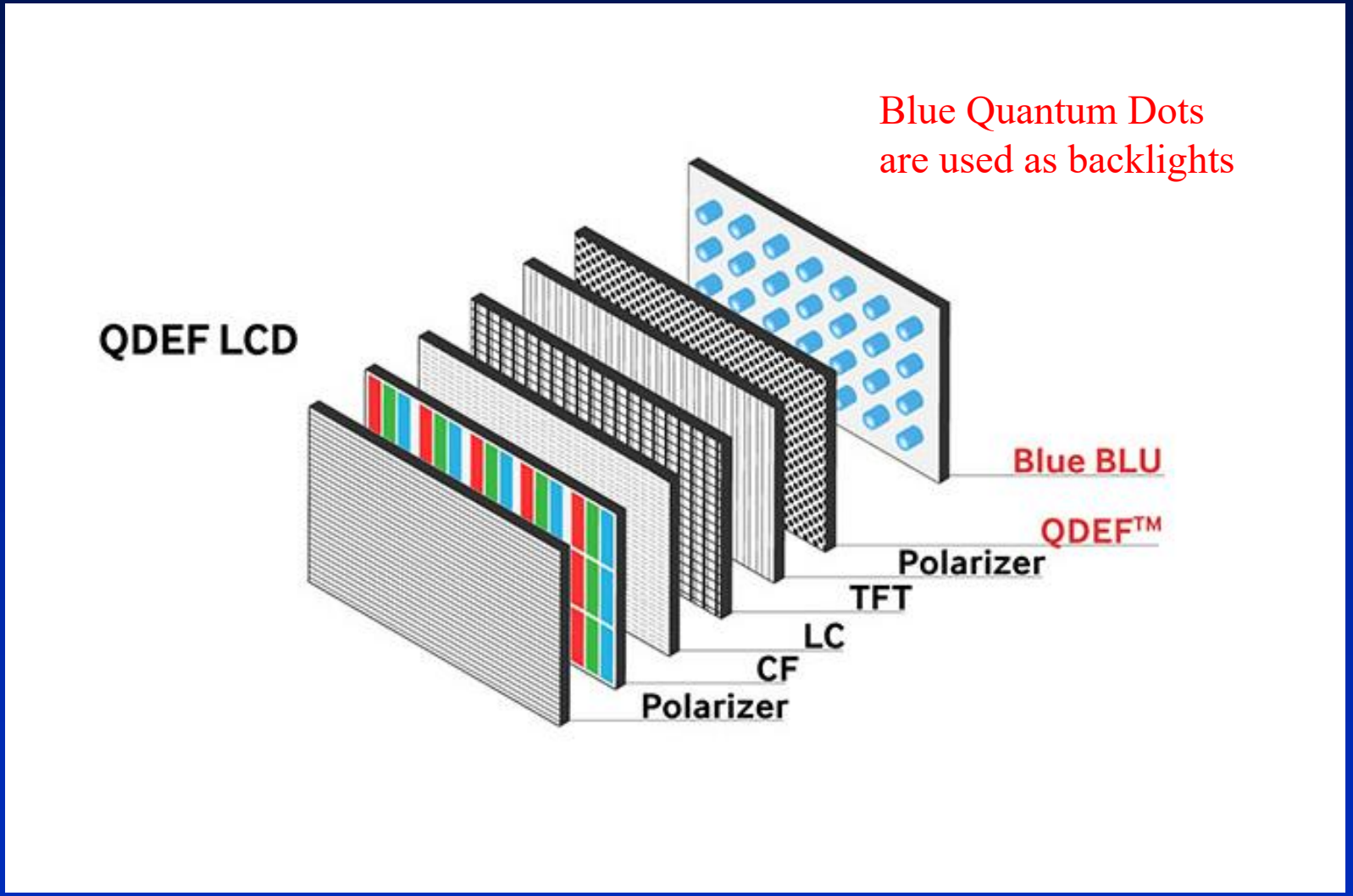
Information Display, “A Helmet-Mounted Laser Display,” January 2000, vol. 16, no. 1, p. 13.

End

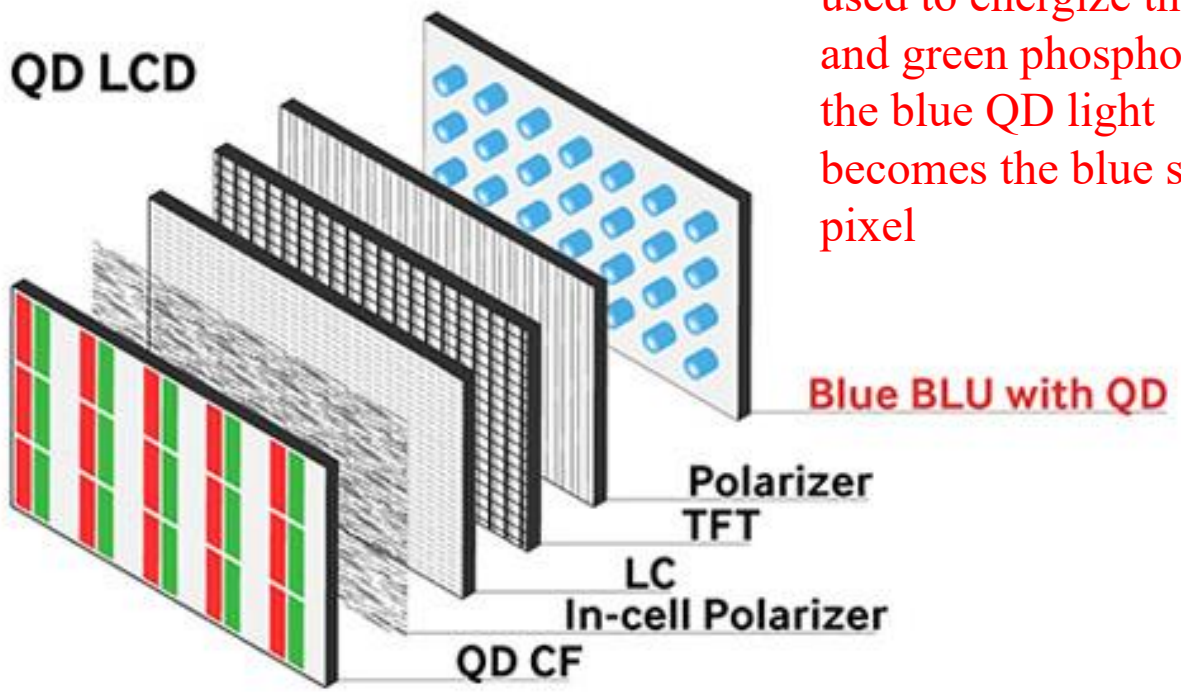
Liquid Crystal Display (LCD)



QDEF LCD


Blue Quantum Dots
are used as backlights
QDEF LCD
Blue BLU
QDEF™
Polarizer
TFT
LC
CF
Polarizer

QD LCD



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