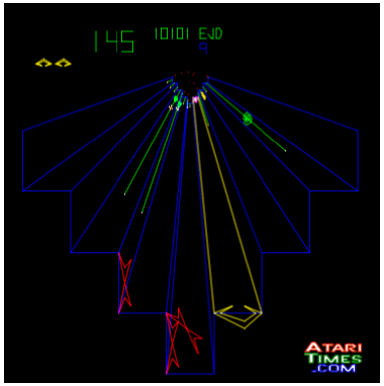
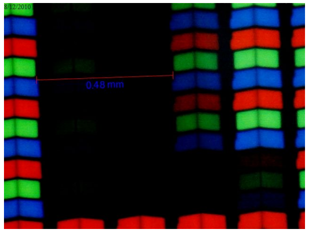
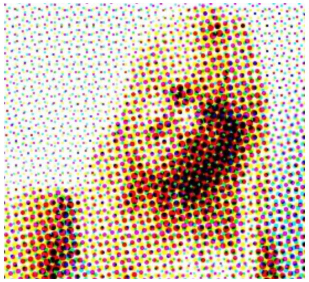
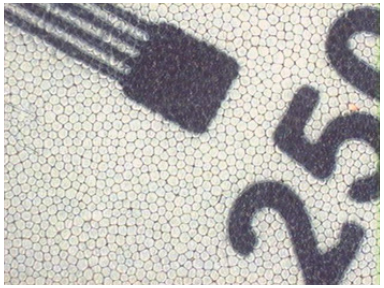
Displays - CSE160

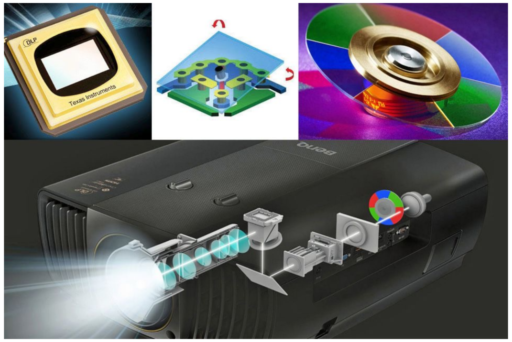
- The display matters
- CRT and Interlacing
- LCD
- DLP
- E-Ink
- Perception
- Gamma
- Dithering
- Administrative
- Q&A





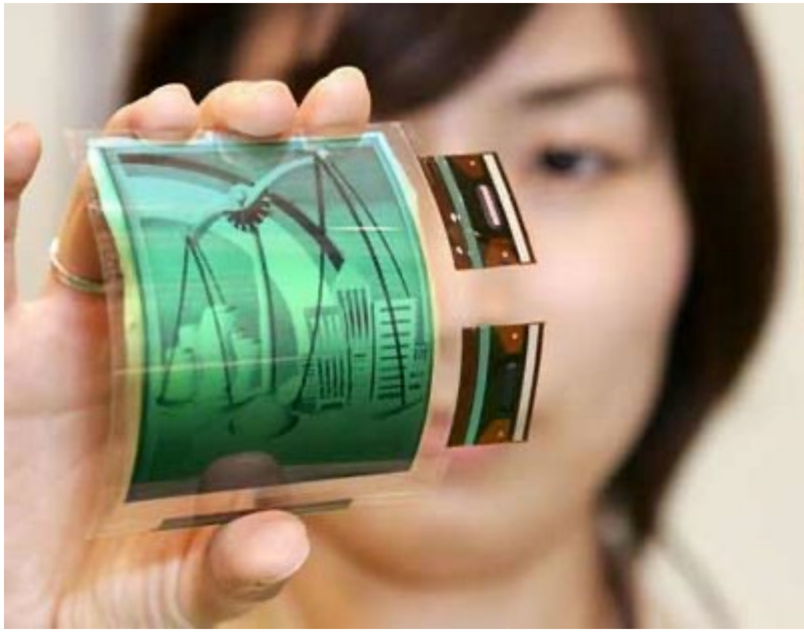






The display matters

Displays



Graphics = Framebuffer

(but that's not the end of the story)

Discrete Image Representation

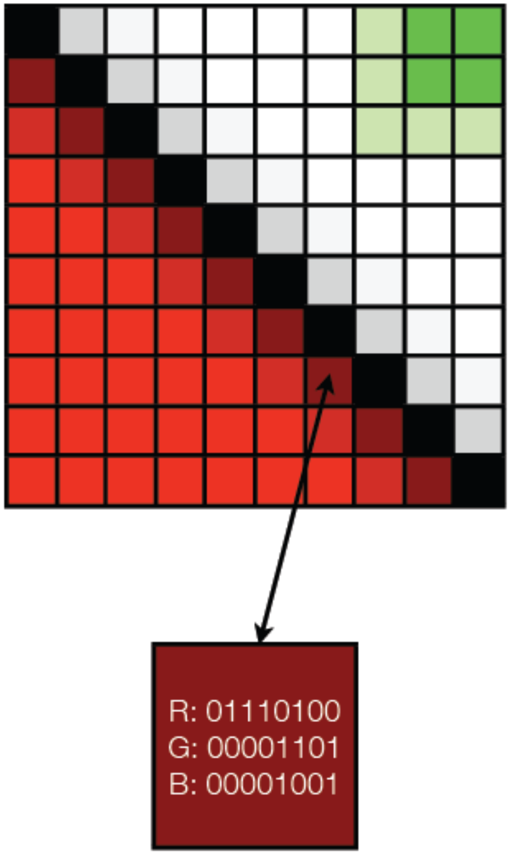
- Rectangular grid of **pixels**
- Each pixel encodes:
  - RGB triple for color images
  - Single value for grayscale images

Resolution

- Number of pixels
- 640x480, 1024x768, etc.

Color Depth

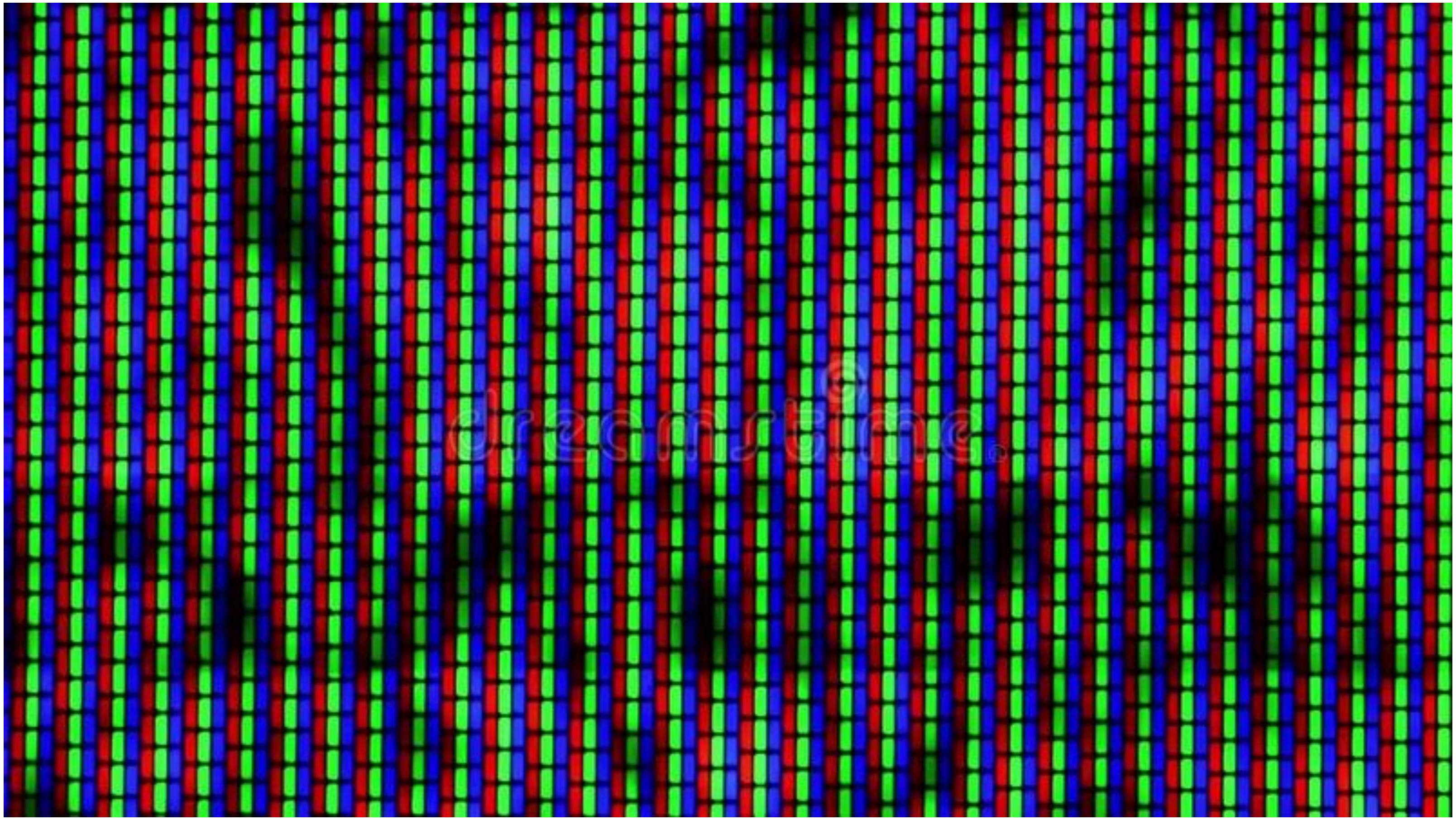
- Number of bits per pixel
- 24 bit color image uses 8 bits per channel



[From Talton]

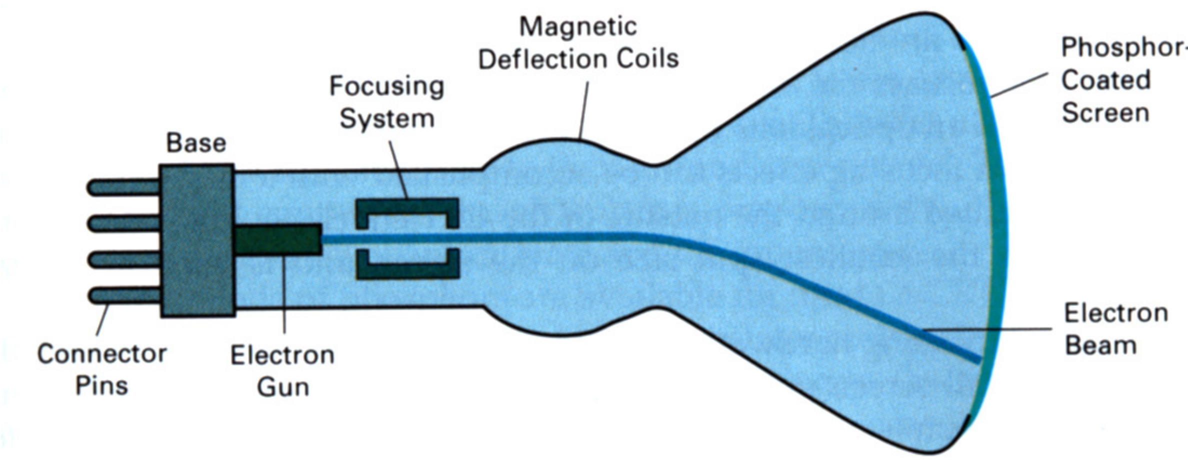
CRT and Interlacing


GAME OVER
XL-100
RCA
Nintendo
SUPER MARIO BROS./DUCK HUNT
MONSTER PARTY
GHOSTS 'N GOBLINS


dreamstime

Cathode ray tube (CRT)

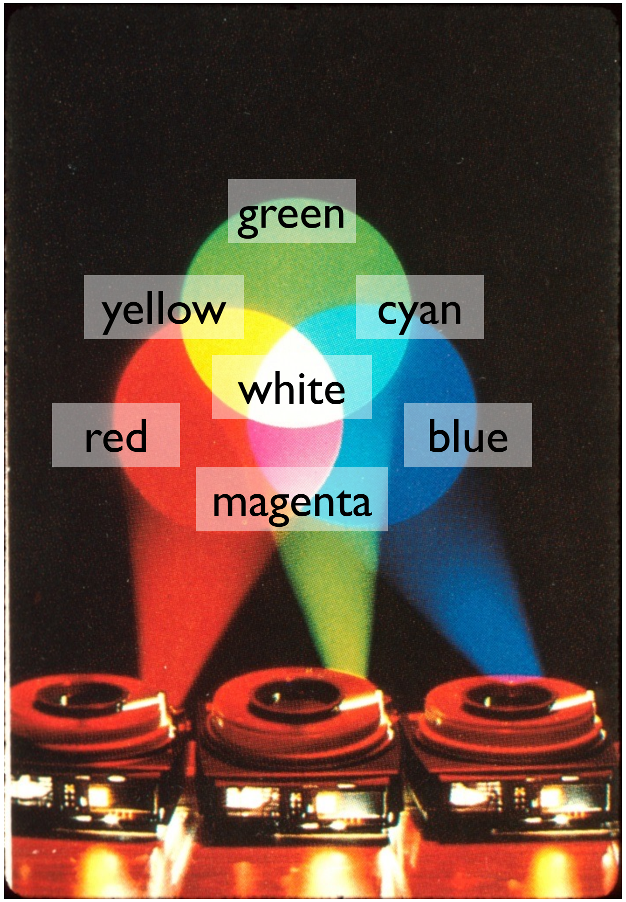
- First widely used electronic display
  - developed for TV in the 1920s–1930s



[H&B fig. 2-2]

Color displays

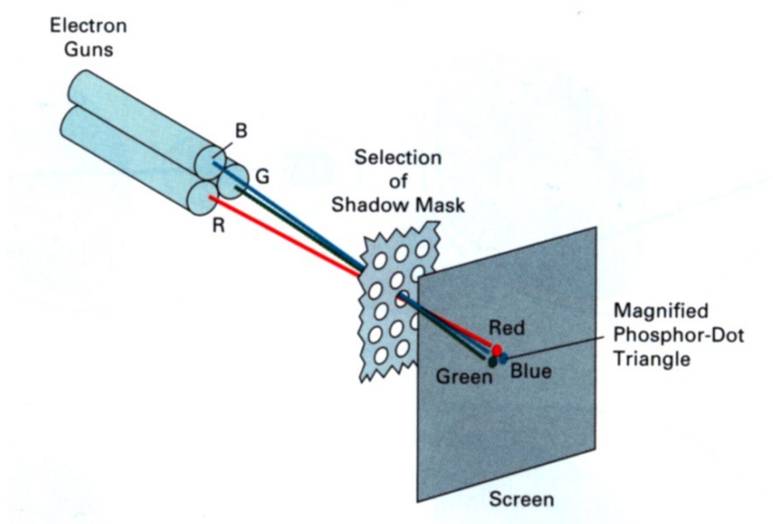
- Humans are trichromatic
  - match any color
    with blend of three
- Additive color
  - blend images by sum
  - R, G, B make good primaries



[cs417 S02 slides]

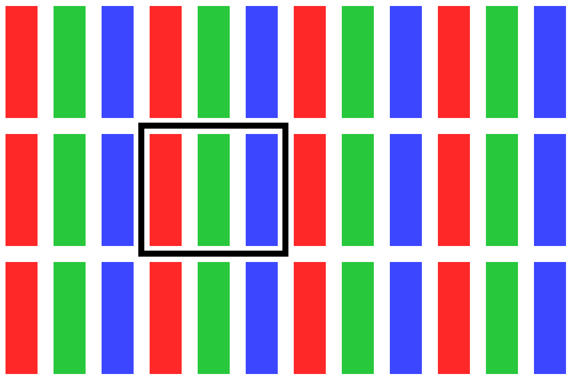
Color displays

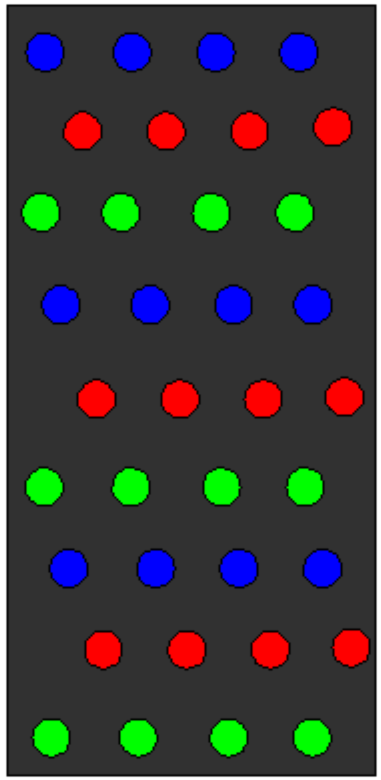
- CRT: phosphor dot pattern to produce finely interleaved color images



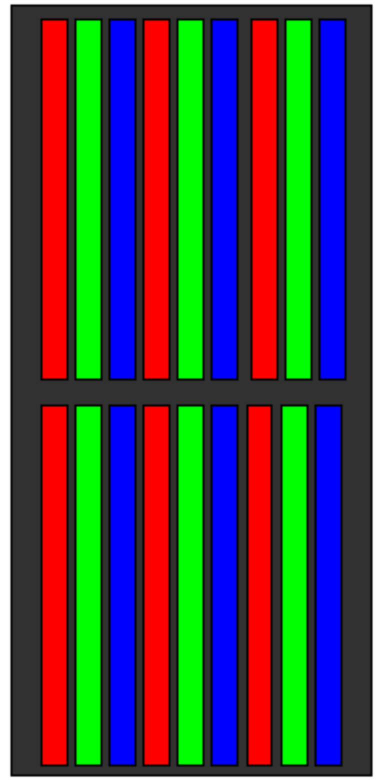
[H&B fig. 2-10]

- LCD: interleaved R,G,B pixels





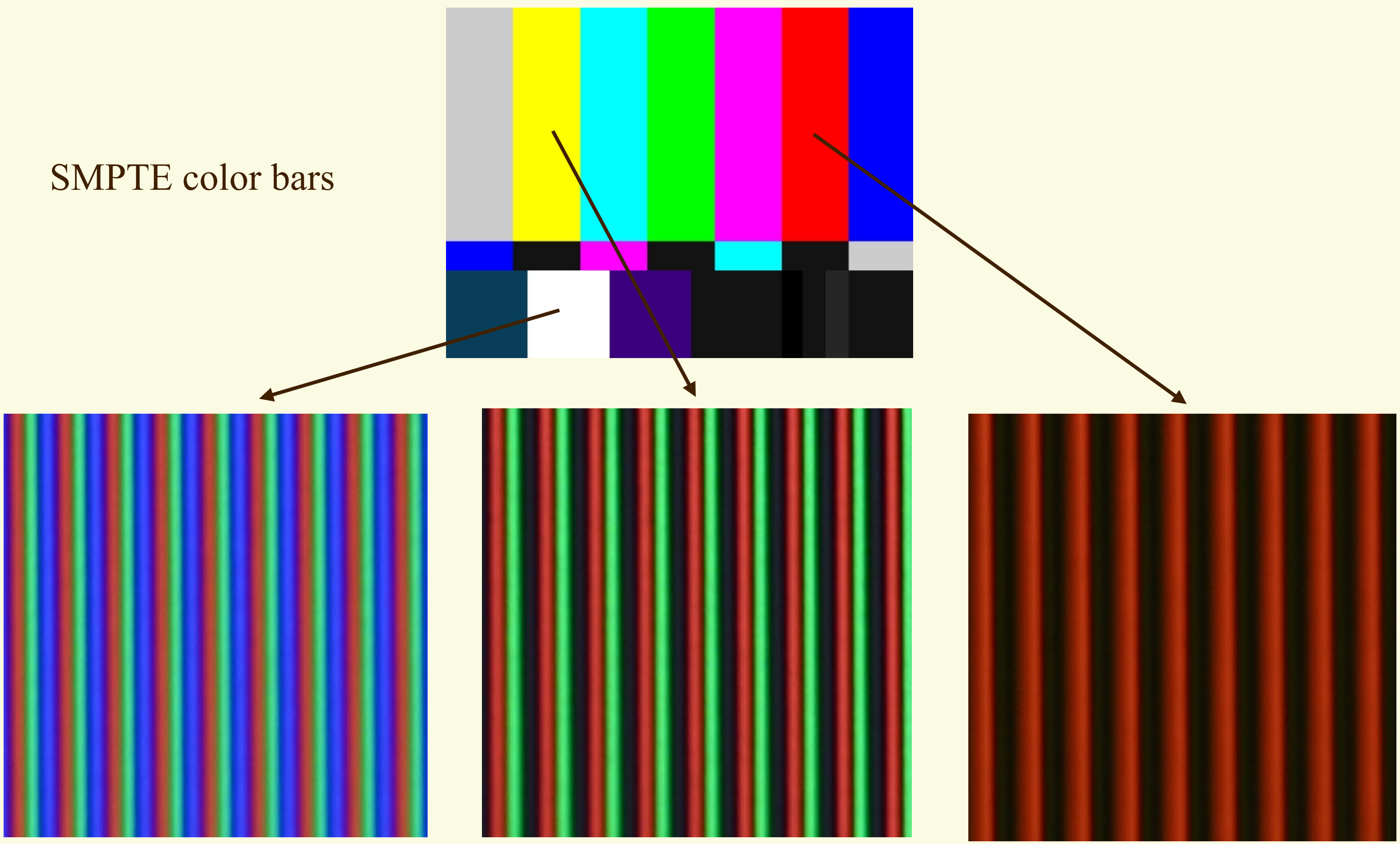
Traditional mask



Trinitron

Triads and color mixing

SMPTE color bars

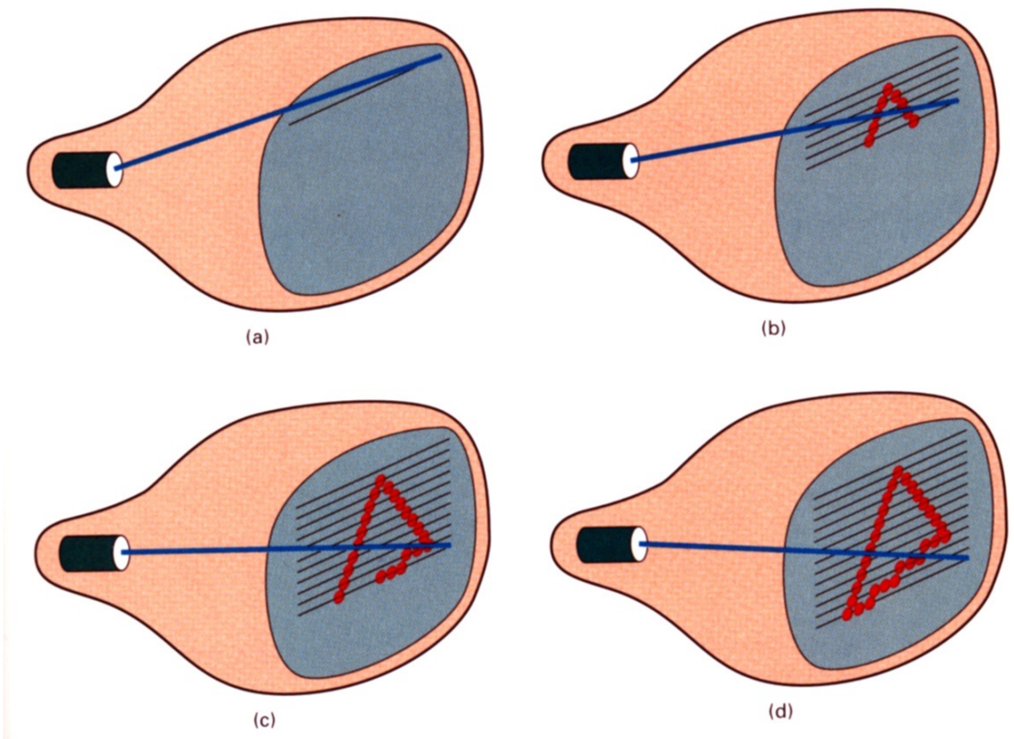


closeup on a Sony Trinitron monitor

Slide from Marc Levoy

Raster CRT display

- Intensity modulated to produce image
- Originally for TV
  - (continuous analog signal)



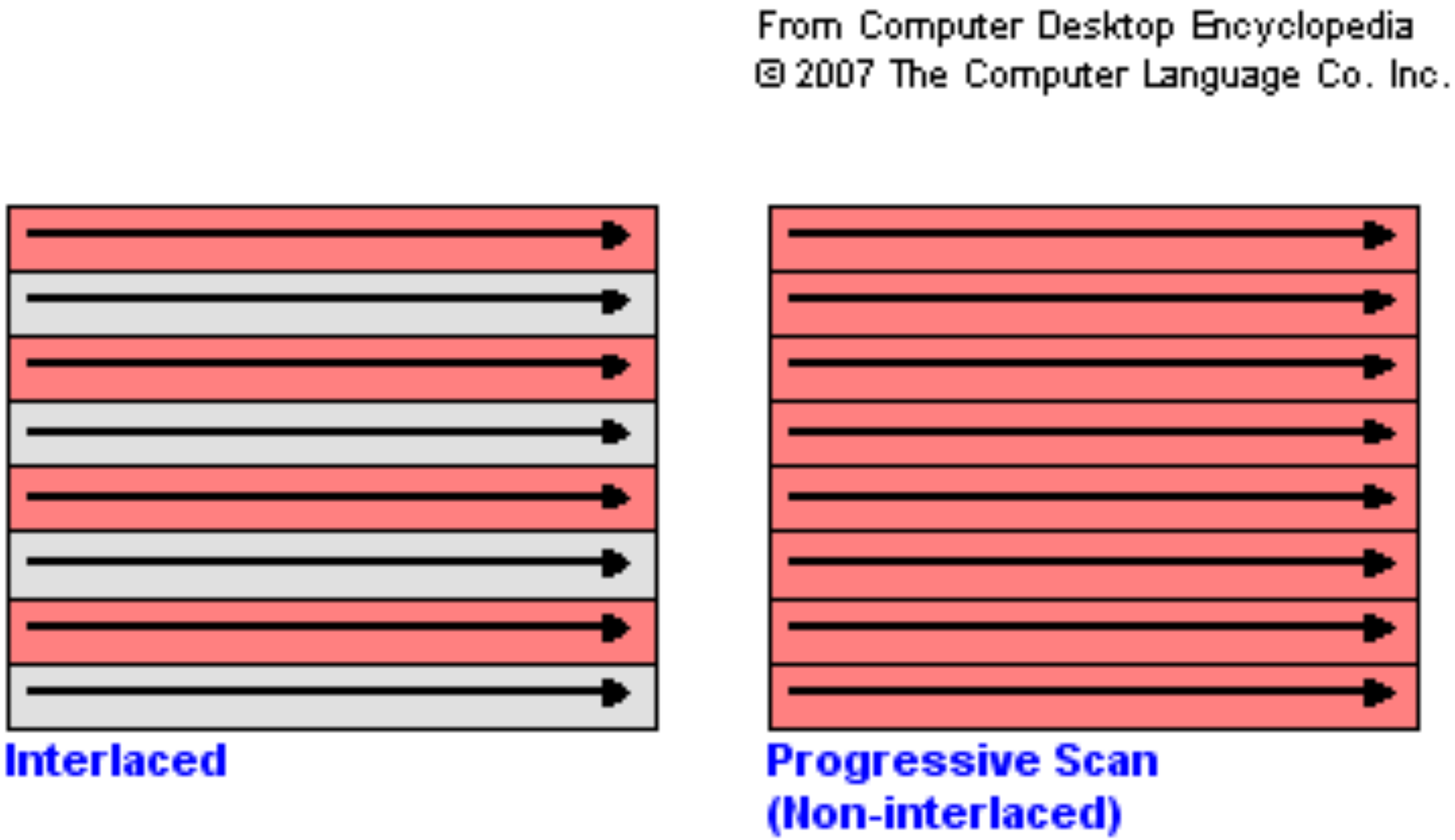
[H&B fig. 2-7]

CRT refresh images

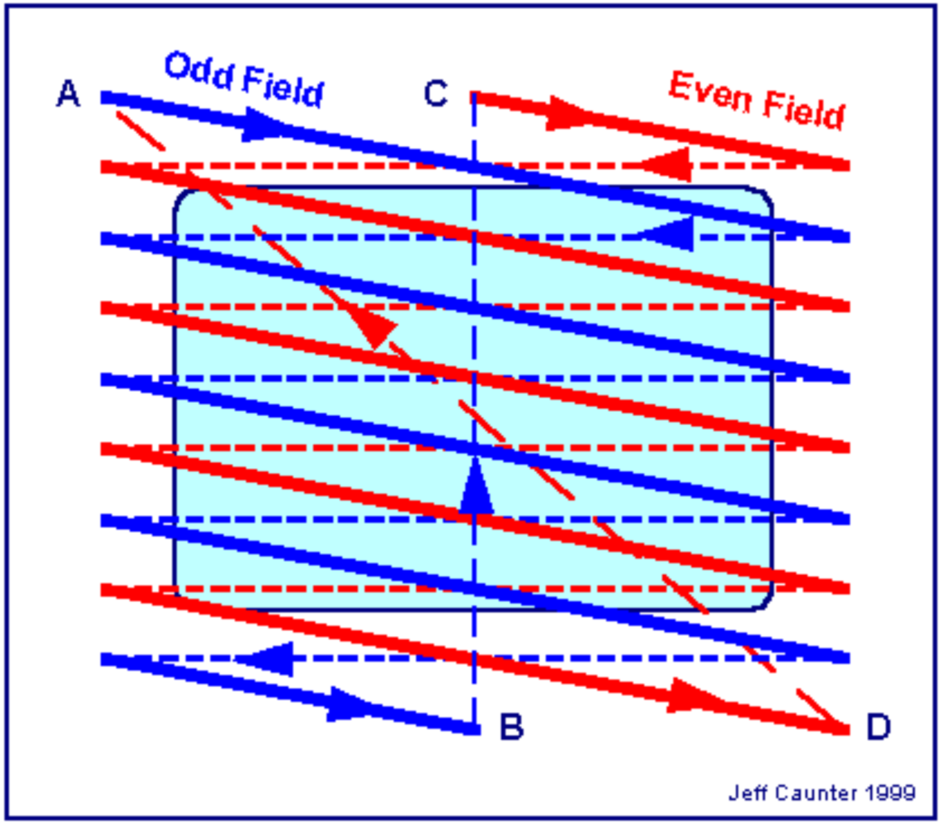
https://www.youtube.com/watch?v=3BJU2drrtCM&feature=youtu.be
How a TV Works in Slow Motion – The Slow Mo Guys

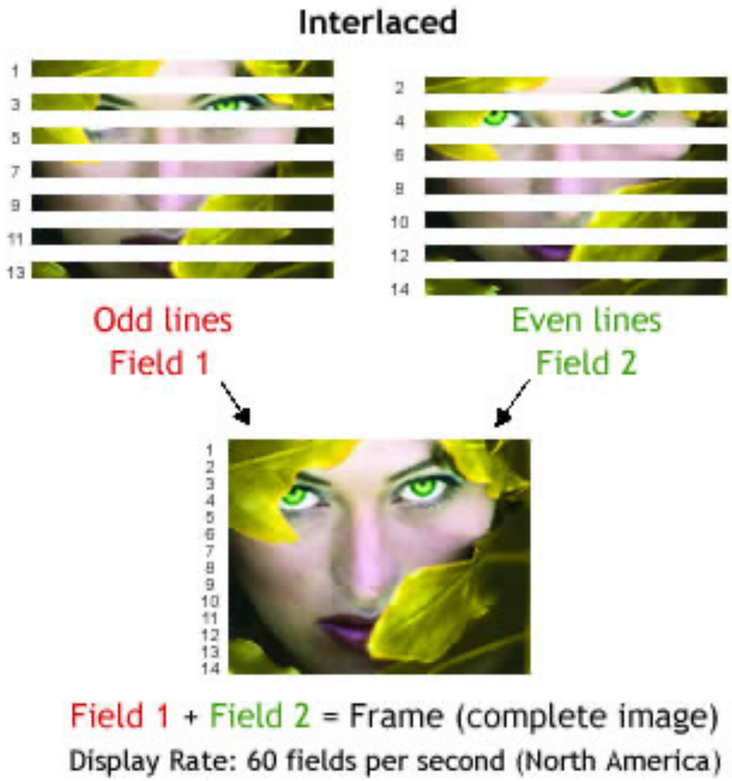

This is now 118,000 frames a second,

Interlacing vs progressive scan



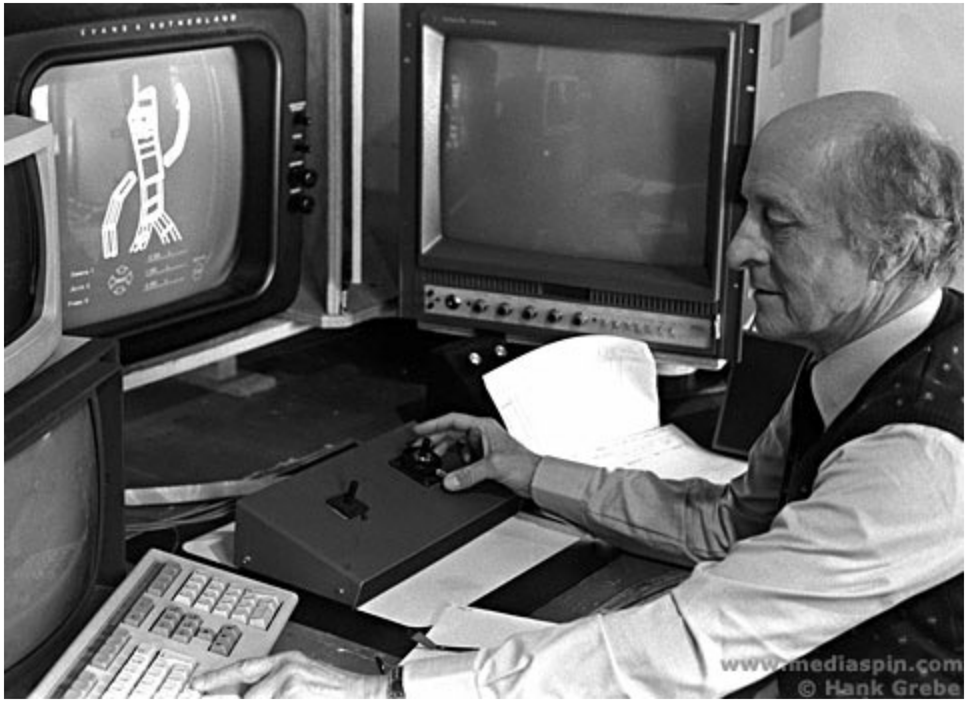
Interlacing vs progressive scan



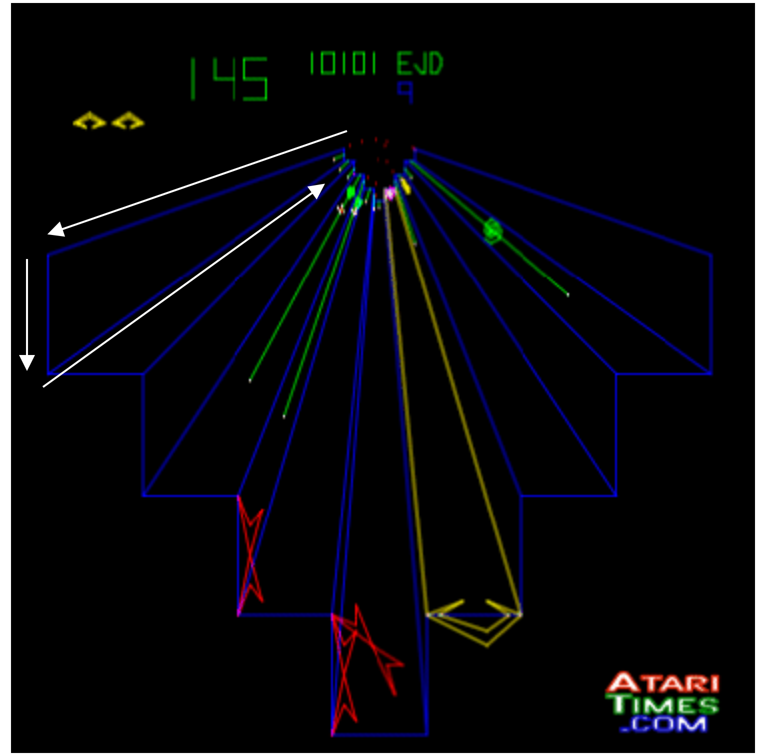


Interlacing vs progressive scan

Vector vs raster scan



Arthur Clokey, the creator of Gumby, trying out NYIT CGL's BBOP 3D keyframe animation system using an E & S vector display, 1984.



Tempest

8K memory!

This is why early graphics did not have a frame buffer.
1024x1024=1Megabit

Brain teaser

We have a CRT which can change the electron gun direction at a maximum rate of 1,000,000 pixels/second. Suppose we have a display which is nominally 1,000 x 1,000 pixel resolution.

a. If this is a raster scan display, how many times per second can we draw a single 10x10 square on the screen?

b. If this is a vector display, how many times per second can we draw a single 10x10 square on the screen?

Now suppose that we need to draw 1,000,000 squares.

c. If this is a raster scan display, how many times per second can we draw all the 10x10 square on the screen?

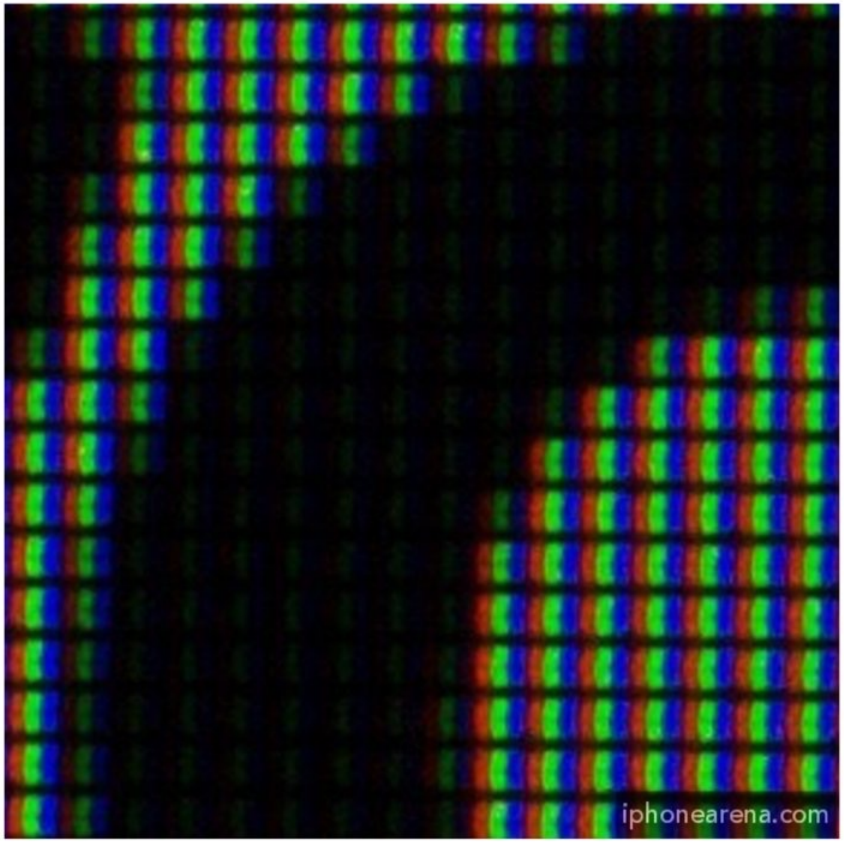
d. If this is a vector display, how many times per second can we draw all the 10x10 square on the screen?

Poll answers:

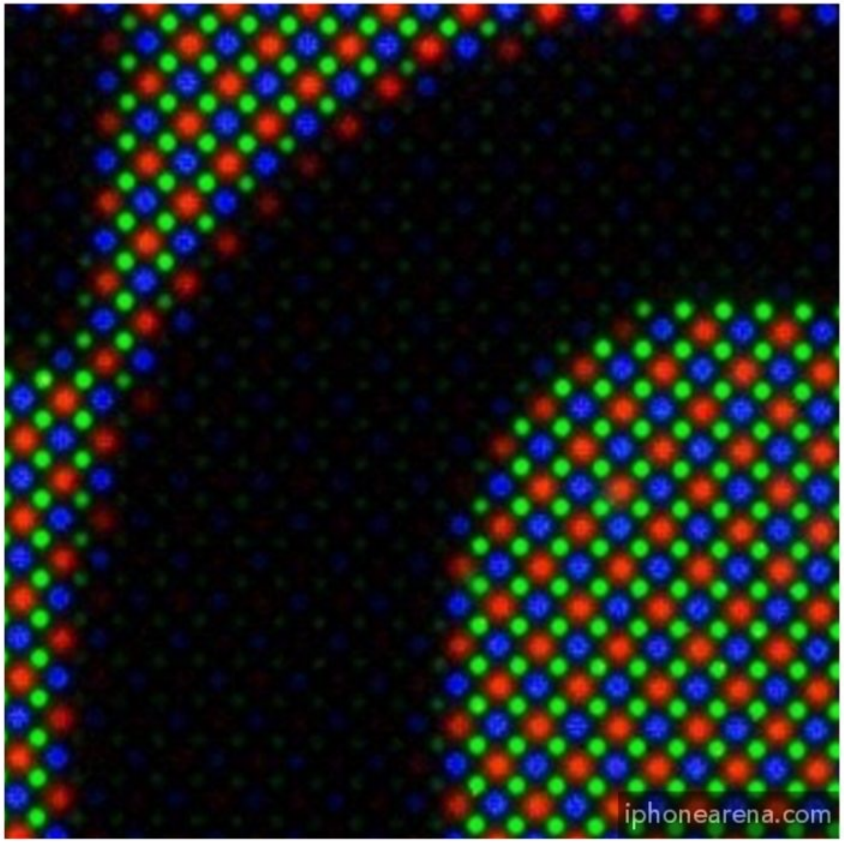
A <1 fps
B 1 fps
C 10 fps
D 100 fps
E >100 fps

LCD

real LCD screen pixels (closeup)



iPhone 6S

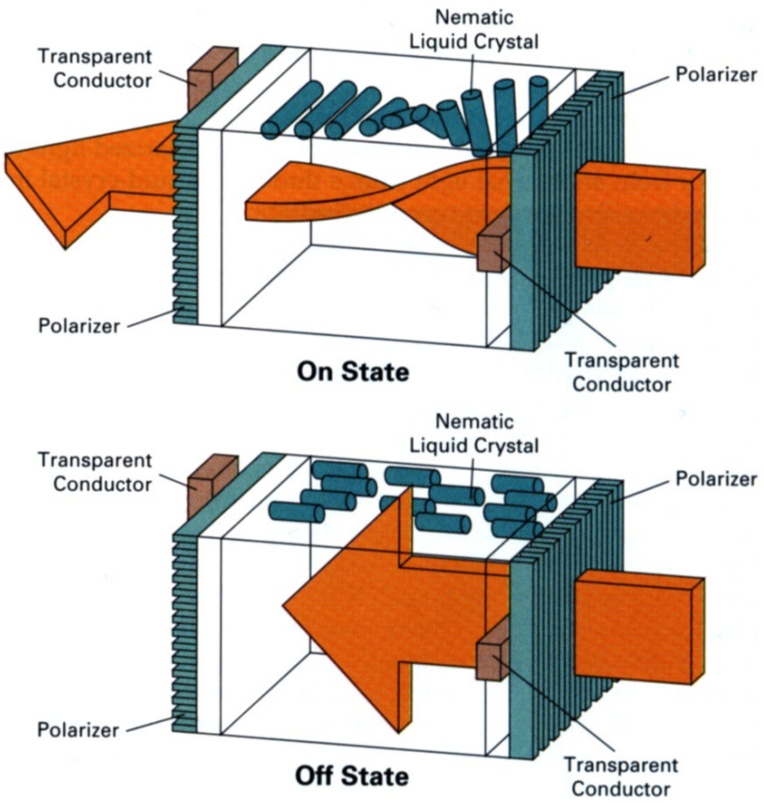


Galaxy S5

Notice R, G, B sub-pixel geometry.
Effectively three lights at each (x,y) location.

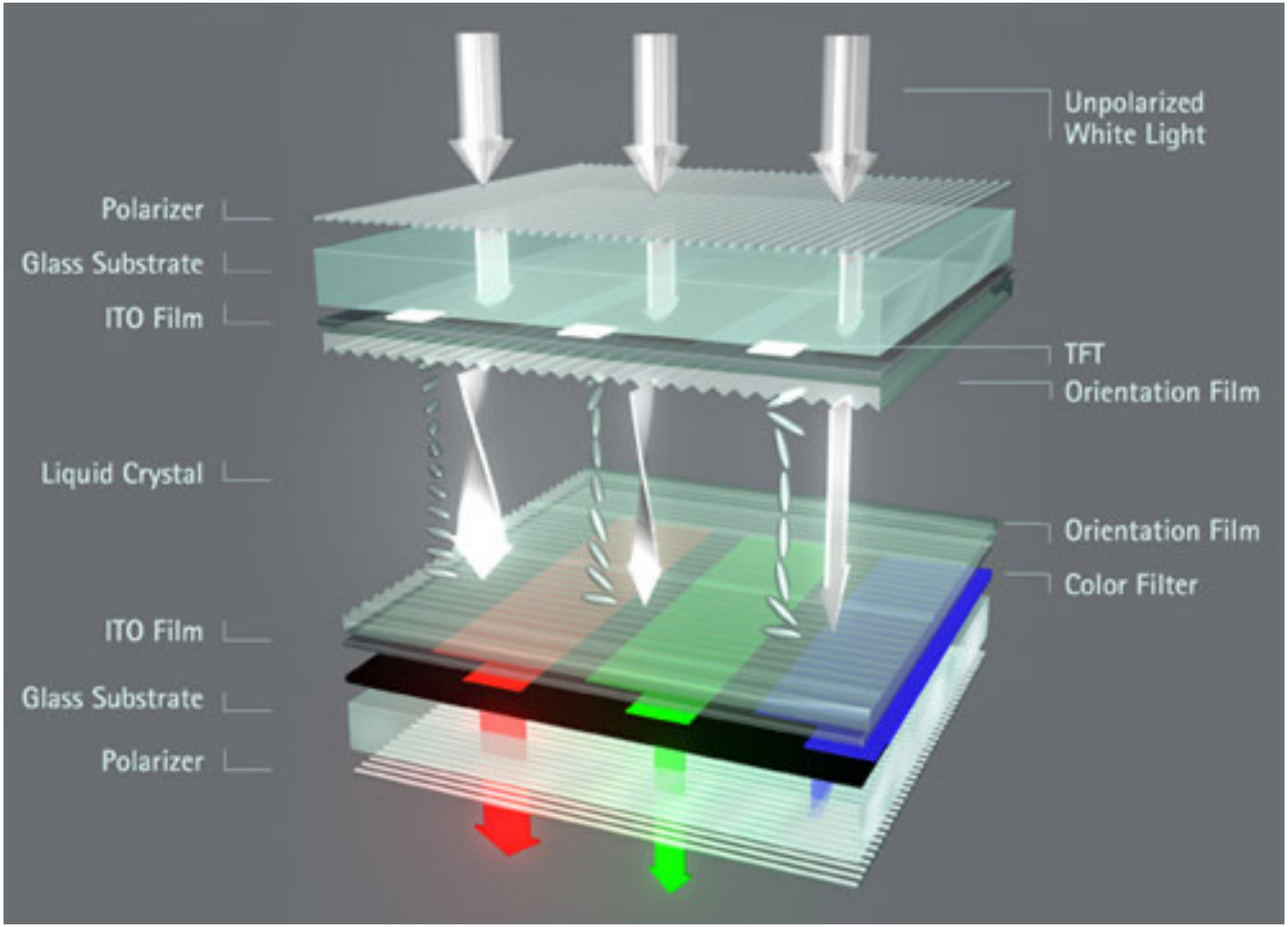
LCD flat panel or projection display

- Principle: block or transmit light by twisting its polarization
- Intermediate intensity levels possible by partial twist
- Fundamentally raster technology



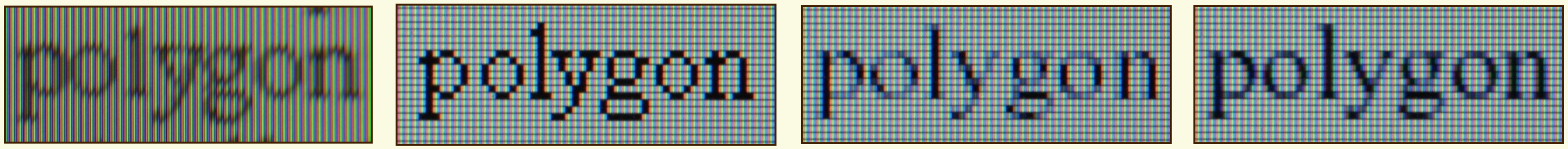
[H&B fig. 2-16]

LCD

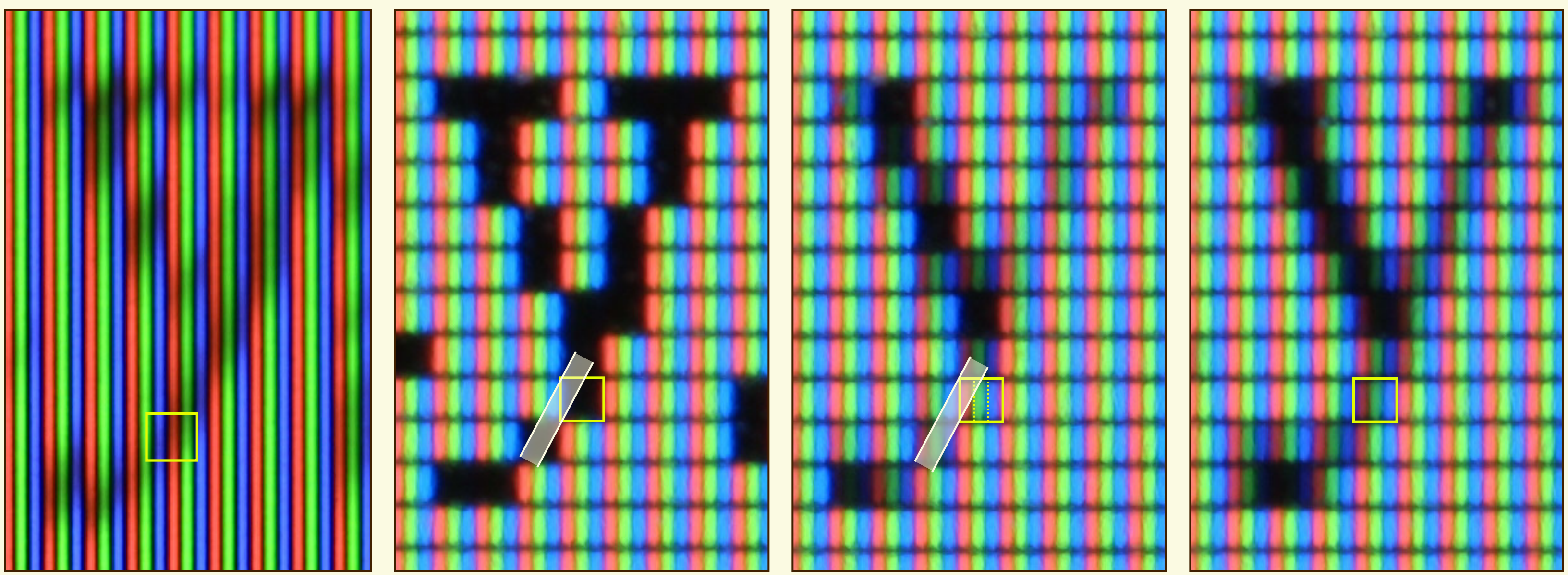


Unpolarized
White Light
Polarizer
Glass Substrate
ITO Film
TFT
Orientation Film
Liquid Crystal
Orientation Film
Color Filter
ITO Film
Glass Substrate
Polarizer

Triads versus pixels



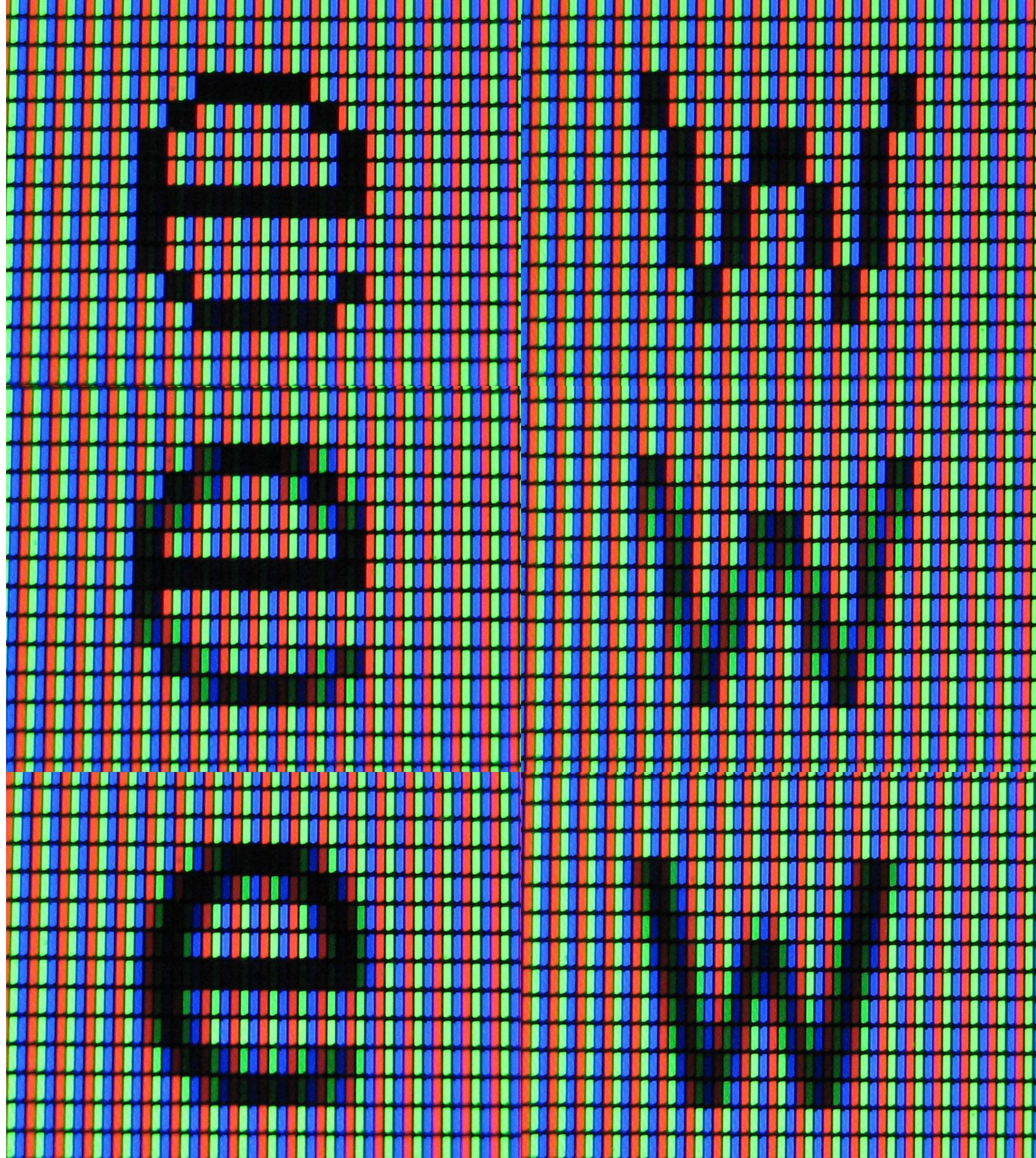
integral pixel font (Sony Trinitron)	integral pixel font (IBM LCD)	antialiased font (Adobe Acrobat)	subpixel font (Adobe Cooltype)

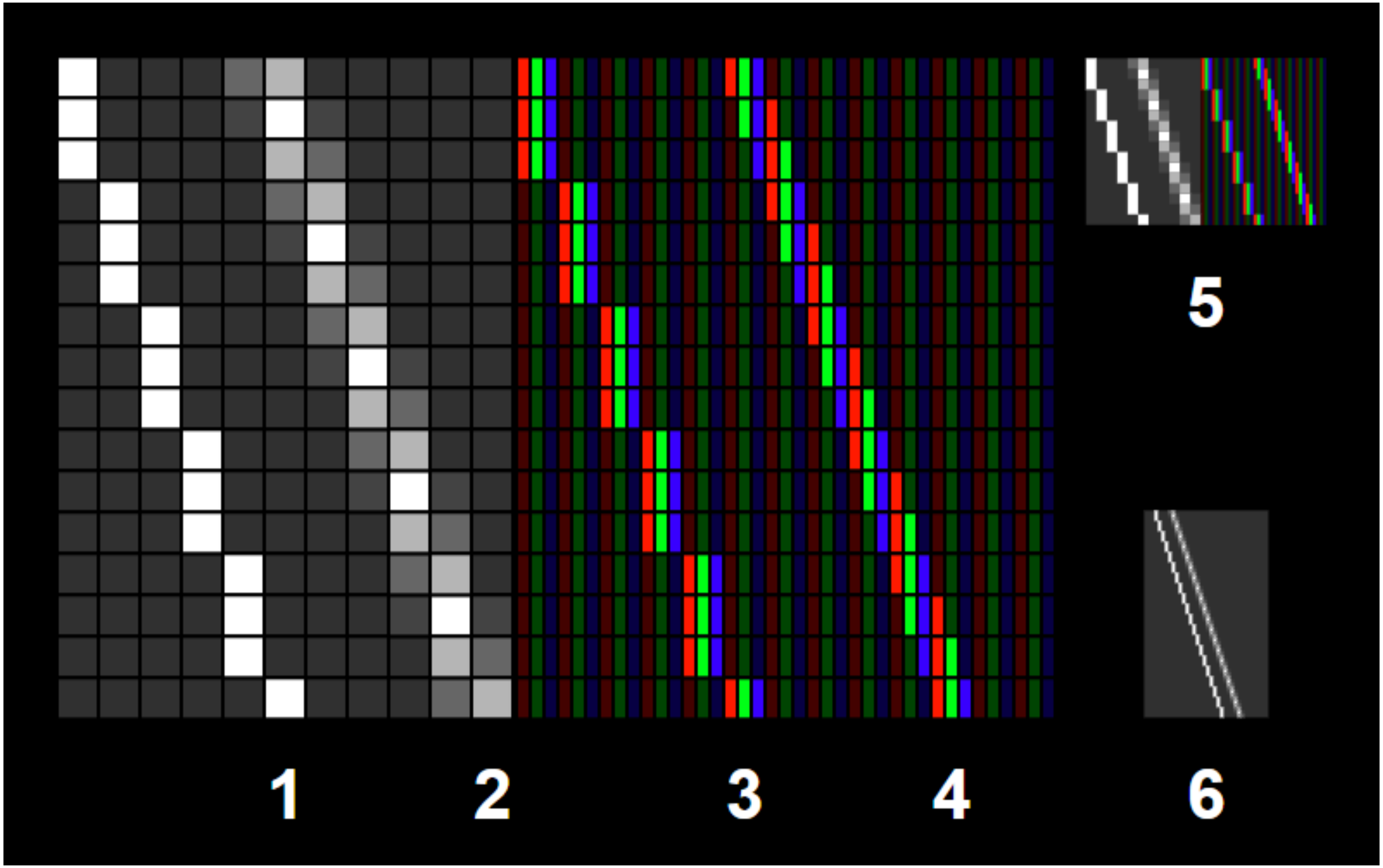


Monochrome

Antialiasing

Subpixel rendering



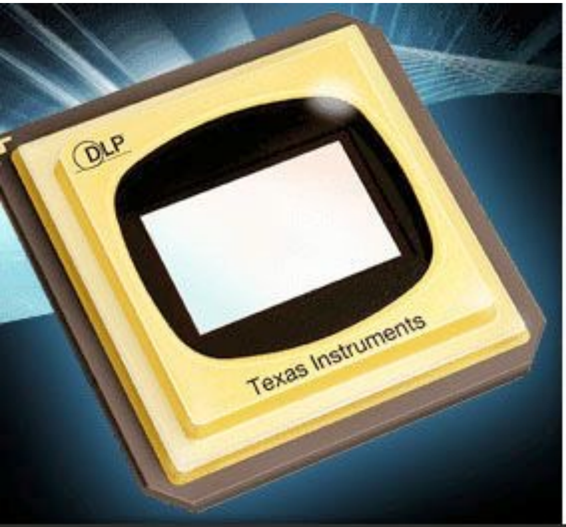


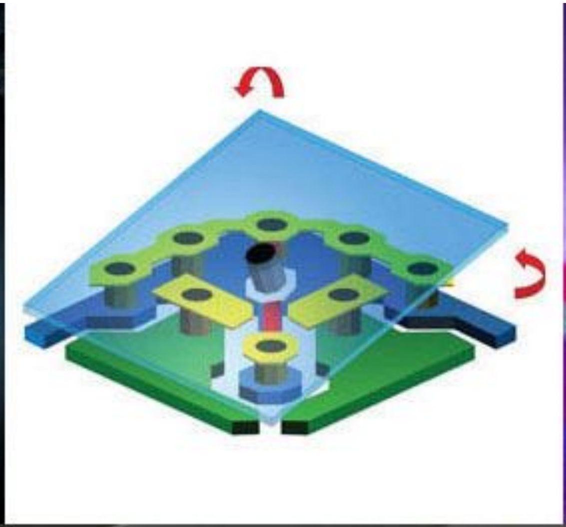
1
2
3
4
5
6

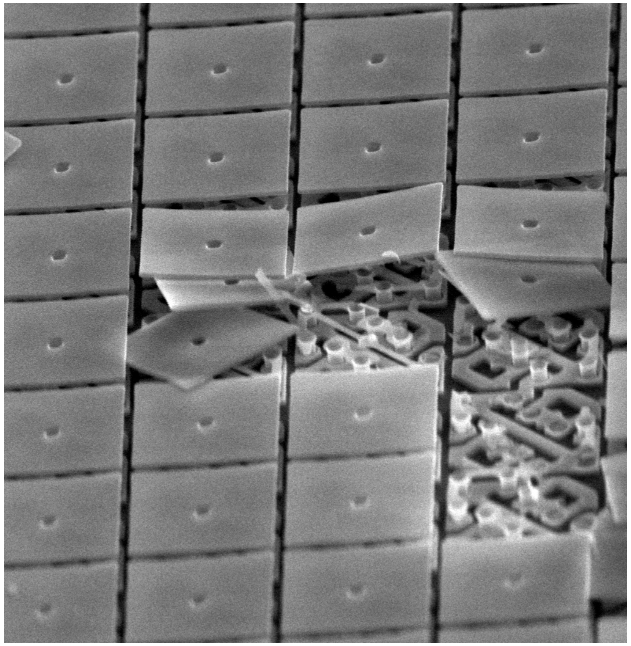
We stack two LCD on top of each other and place a backlight behind the whole assembly. We show yellow on the back LCD, and cyan on the front LCD. What color do we see in the front?

a) Red
b) Green
c) Blue
d) White
e) Black

DLP


DLP
Texas Instruments





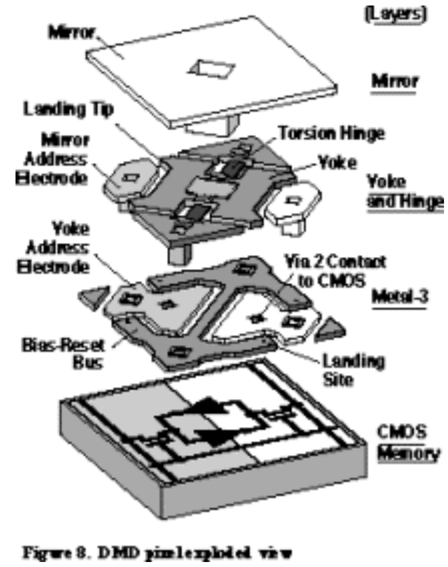
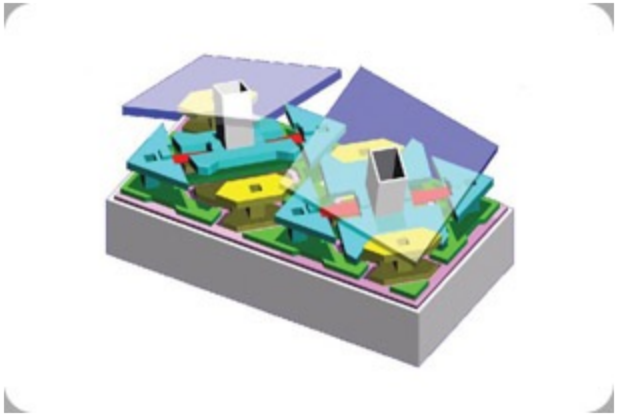
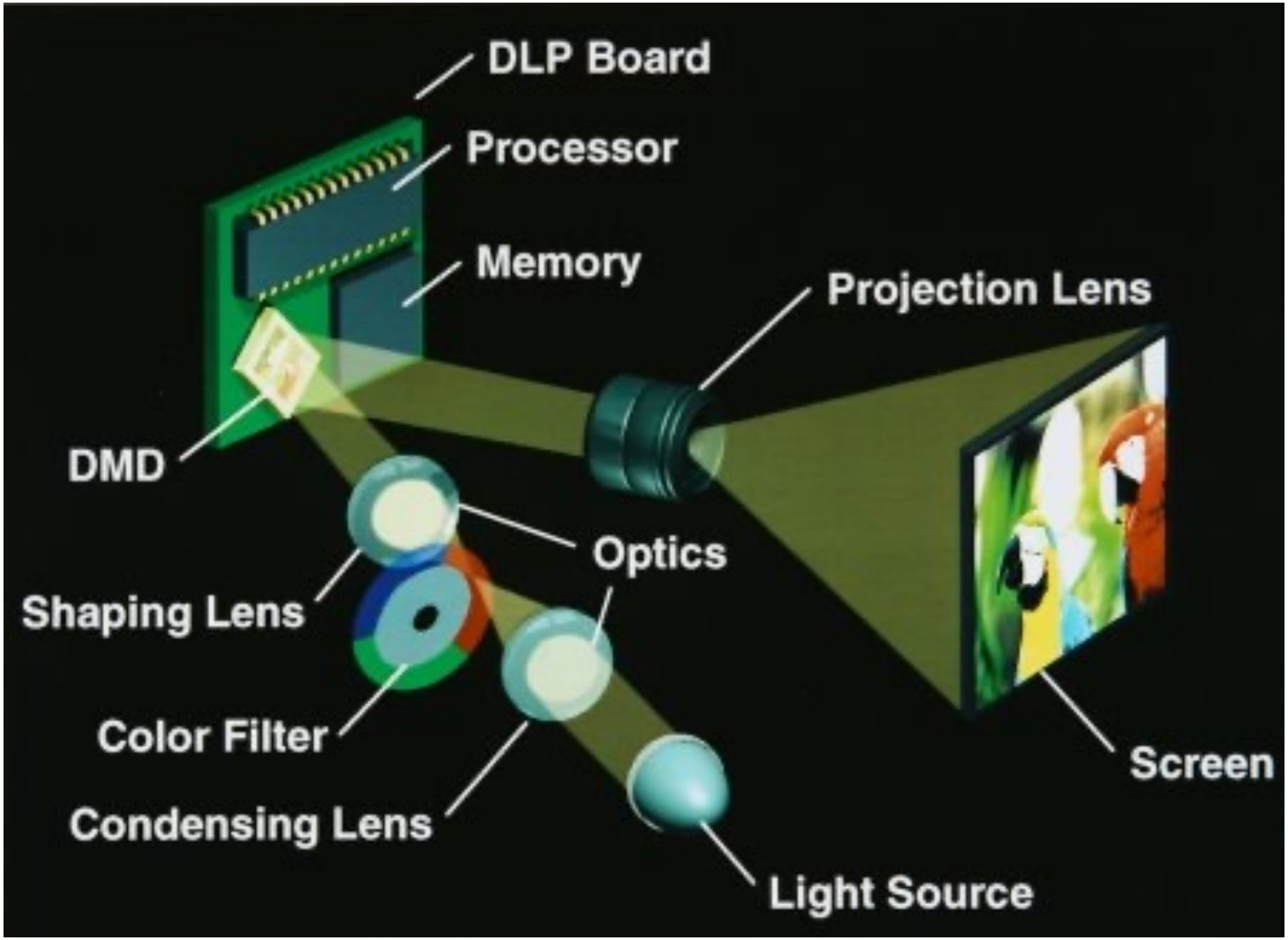
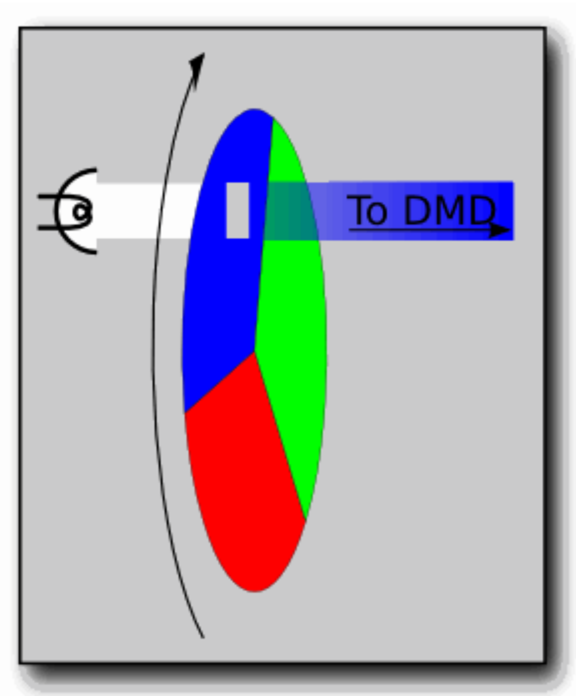


Figure 8. DMD pixel exploded view



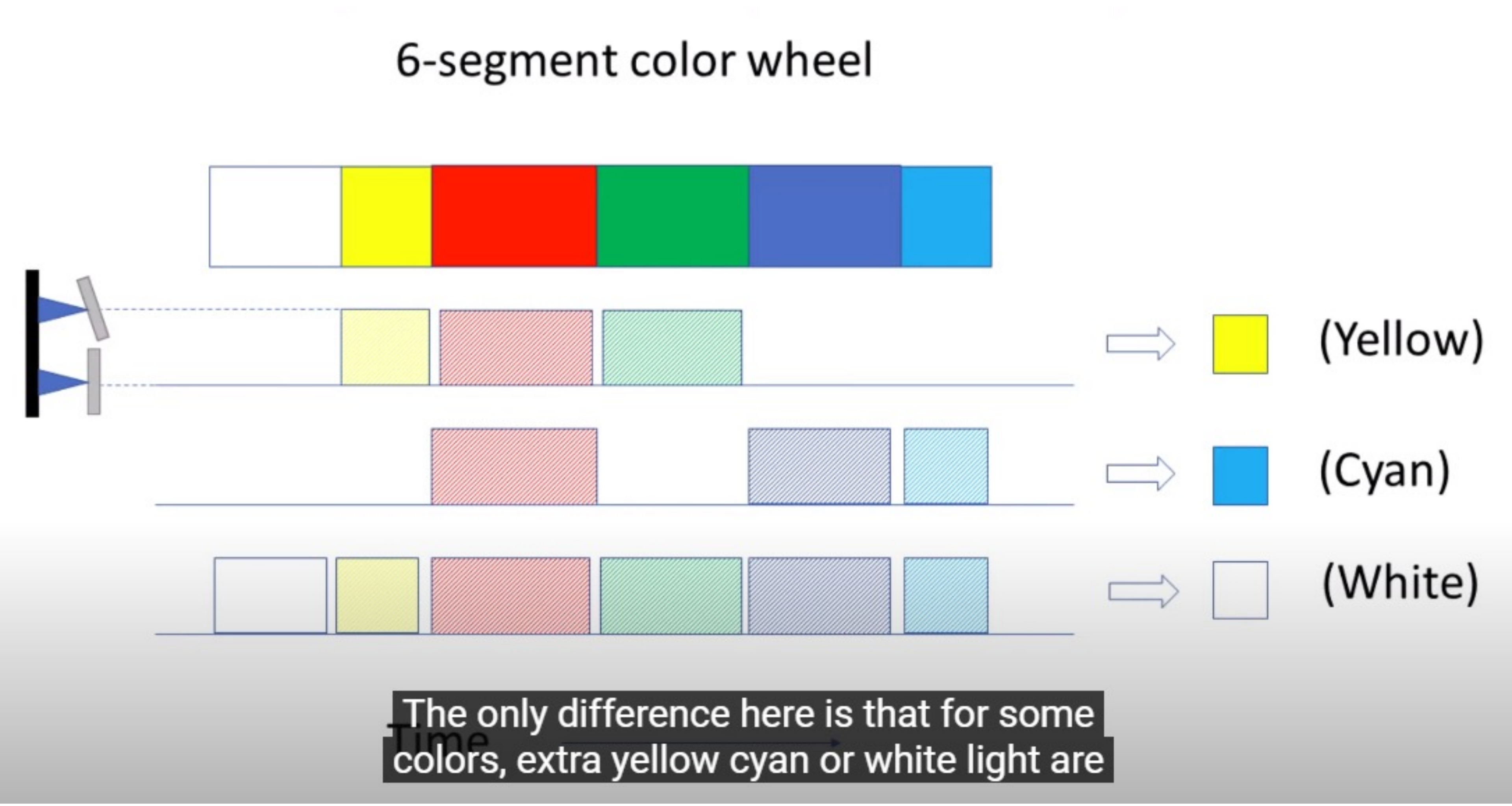
DLP


DLP Board
Processor
Memory
Projection Lens
DMD
Optics
Shaping Lens
Color Filter
Condensing Lens
Screen
Light Source


To DMD

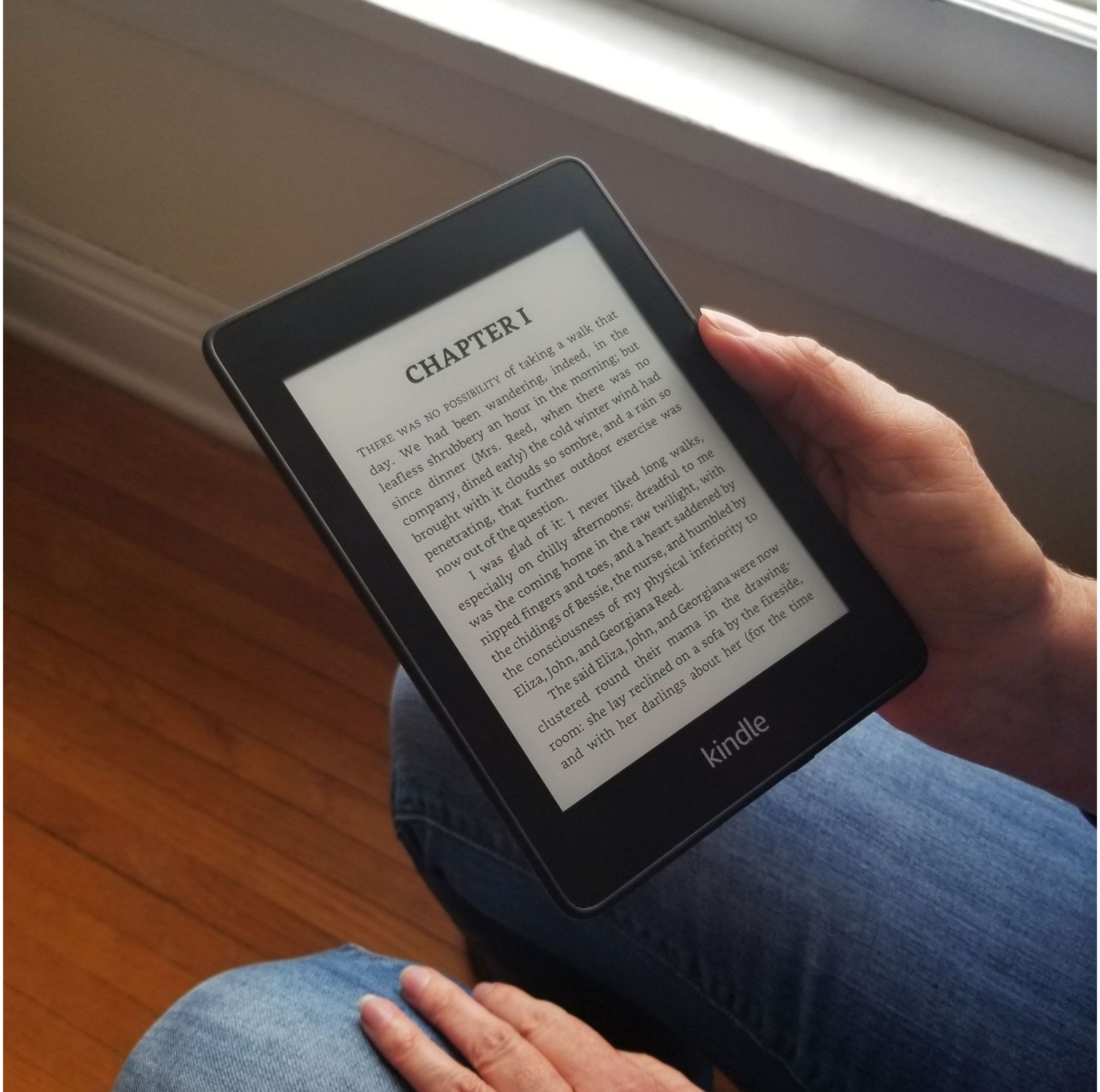
3-segment color wheel (primary colors only)

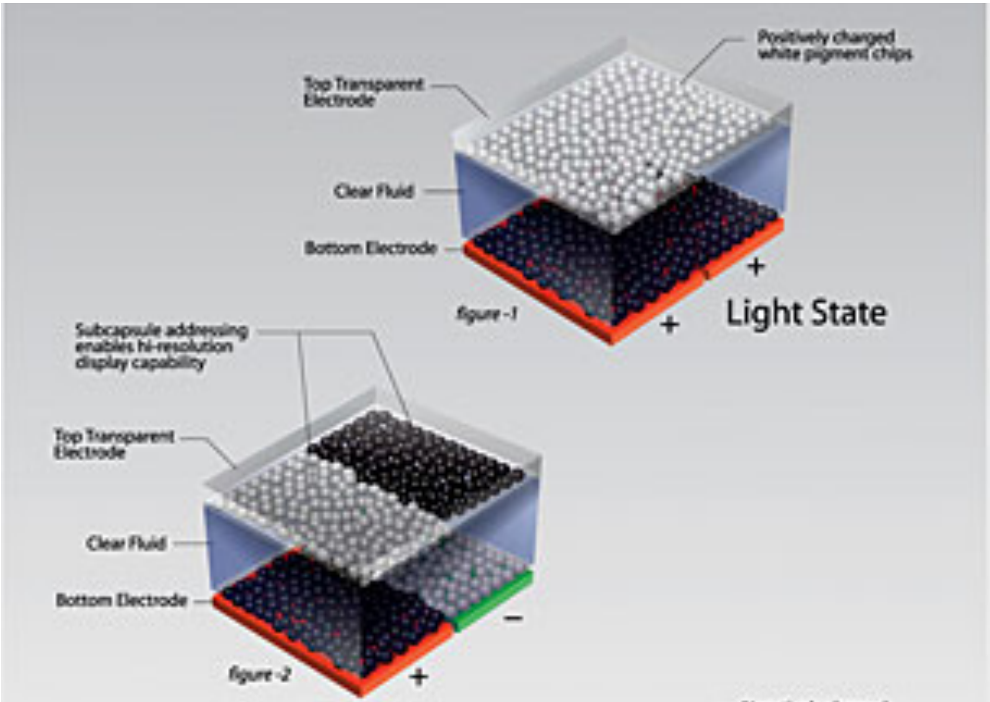

but 6. So in addition to the colors red green
and blue, we can also project white, yellow



https://www.youtube.com/watch?v=KpatWNi0__o

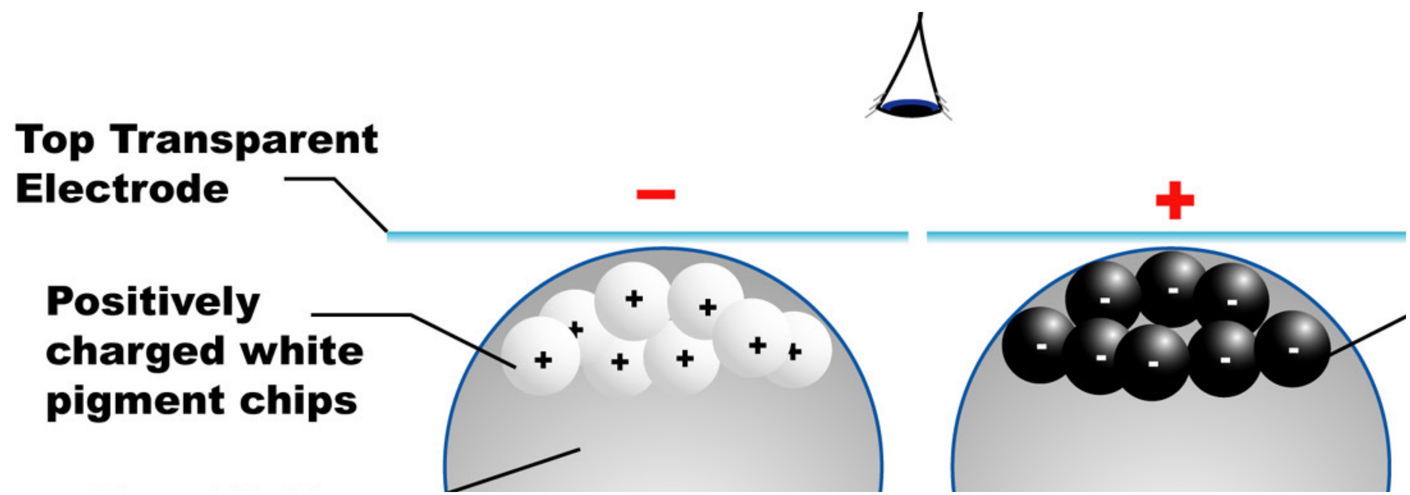
E-ink


CHAPTER I
THERE WAS NO POSSIBILITY of taking a walk that
day. We had been wandering, indeed, in the
leafless shrubbery an hour in the morning; but
since dinner (Mrs. Reed, when there was no
company, dined early) the cold winter wind had
brought with it clouds so sombre, and a rain so
penetrating, that further outdoor exercise was
now out of the question.
I was glad of it: I never liked long walks,
especially on chilly afternoons: dreadful to me
was the coming home in the raw twilight, with
nipped fingers and toes, and a heart saddened by
the chidings of Bessie, the nurse, and humbled by
the consciousness of my physical inferiority to
Eliza, John, and Georgiana Reed.
The said Eliza, John, and Georgiana were now
clustered round their mama in the drawing-
room: she lay reclined on a sofa by the fireside,
and with her darlings about her (for the time
kindle

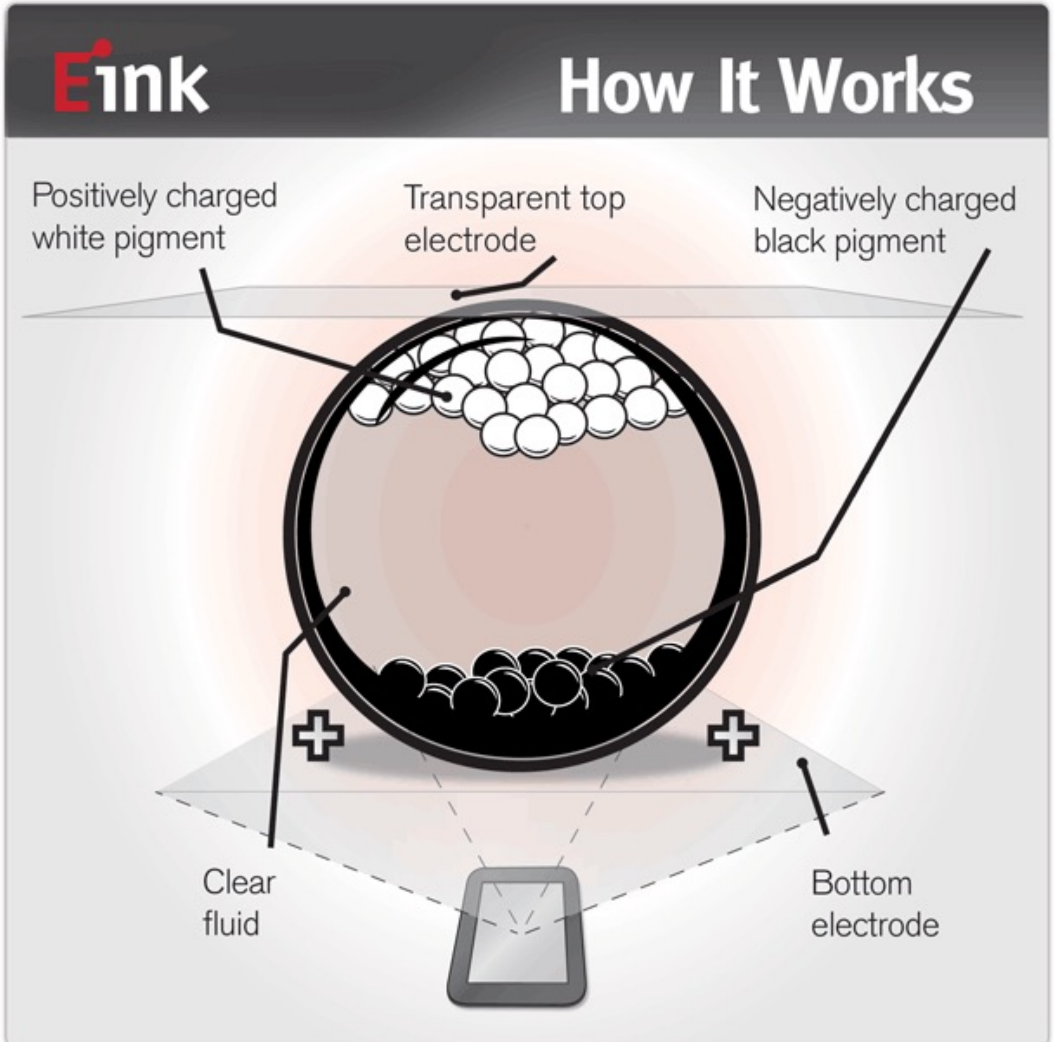


Positively charged white pigment chips
Top Transparent Electrode
Clear Fluid
Bottom Electrode
figure -1
+
+
Light State
Subcapsule addressing enables hi-resolution display capability
Top Transparent Electrode
Clear Fluid
Bottom Electrode
figure -2
+
−

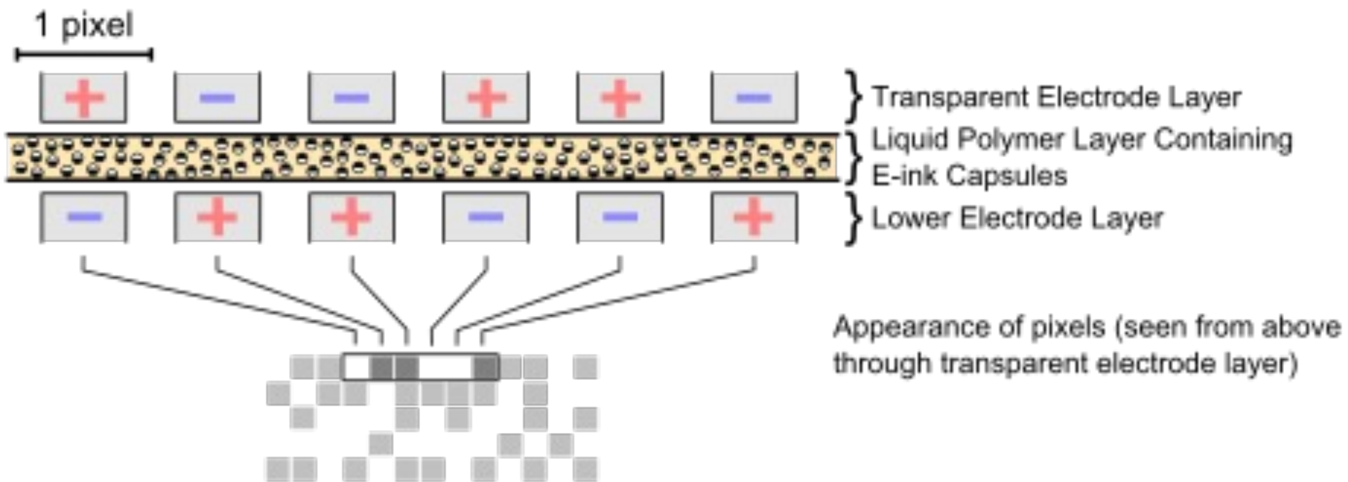
E
INK
PAPER
DISPLAY
ENABLING
TECHNOLOGY
EASY-TO-READ
1
2
3
4
5
6
7
8



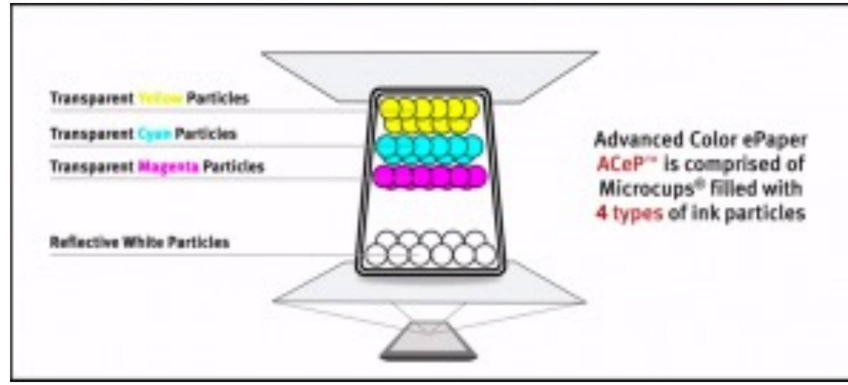
Top Transparent Electrode
Positively charged white pigment chips
−
+

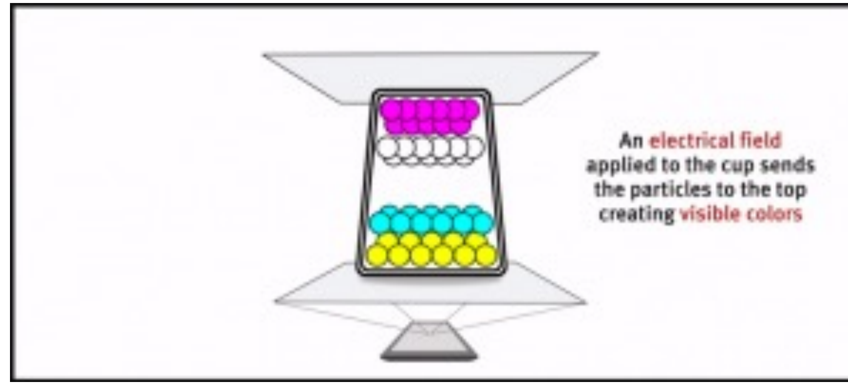


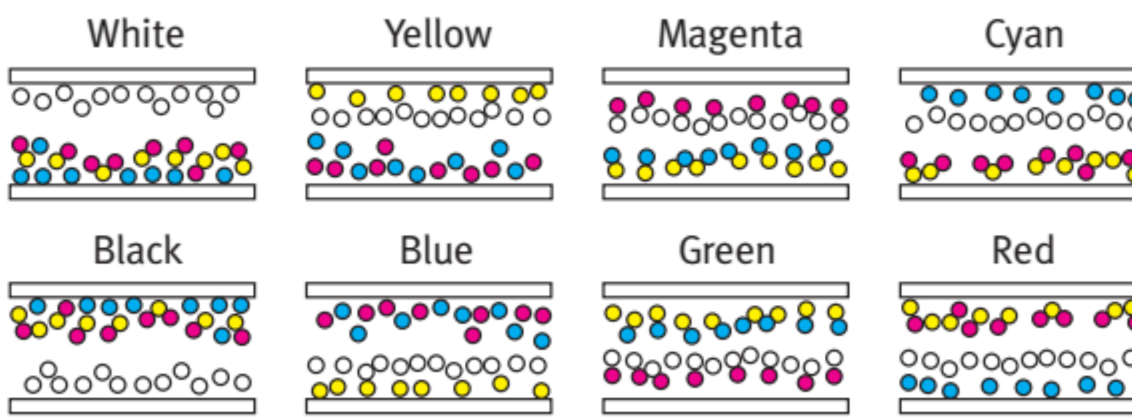
Electronic Ink is made up of millions of tiny microcapsules, about the diameter of a human hair. Each microcapsule contains positively charged white particles and negatively charged black particles suspended in a clear fluid.


1 pixel
Transparent Electrode Layer
Liquid Polymer Layer Containing
E-ink Capsules
Lower Electrode Layer
Appearance of pixels (seen from above
through transparent electrode layer)

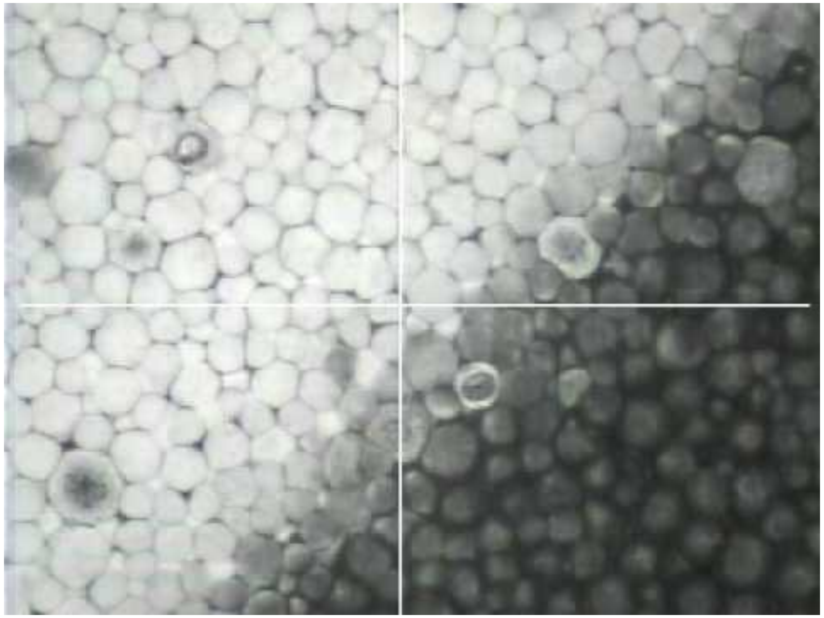
Color E-Ink



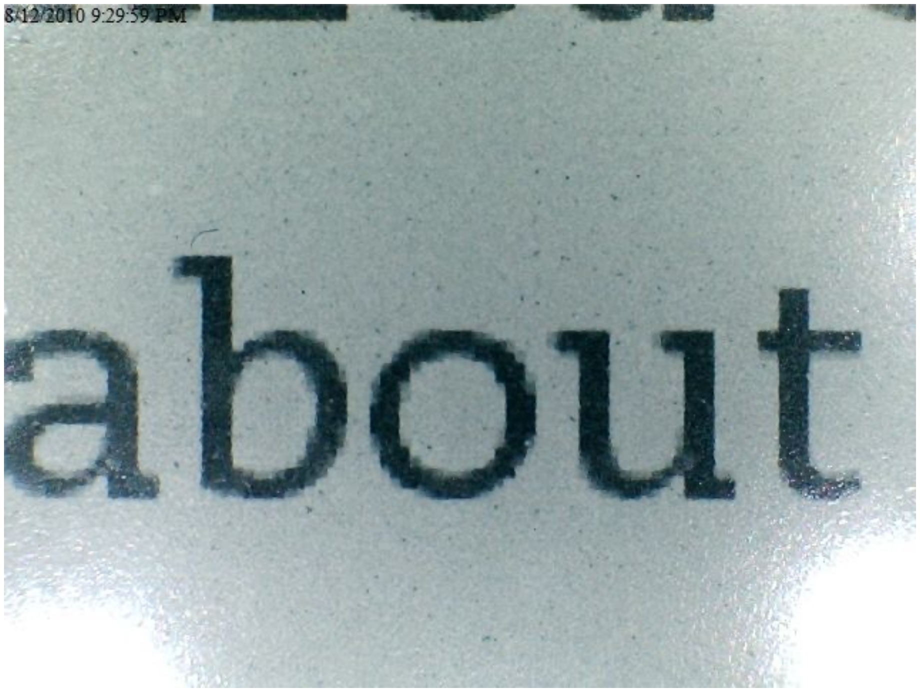


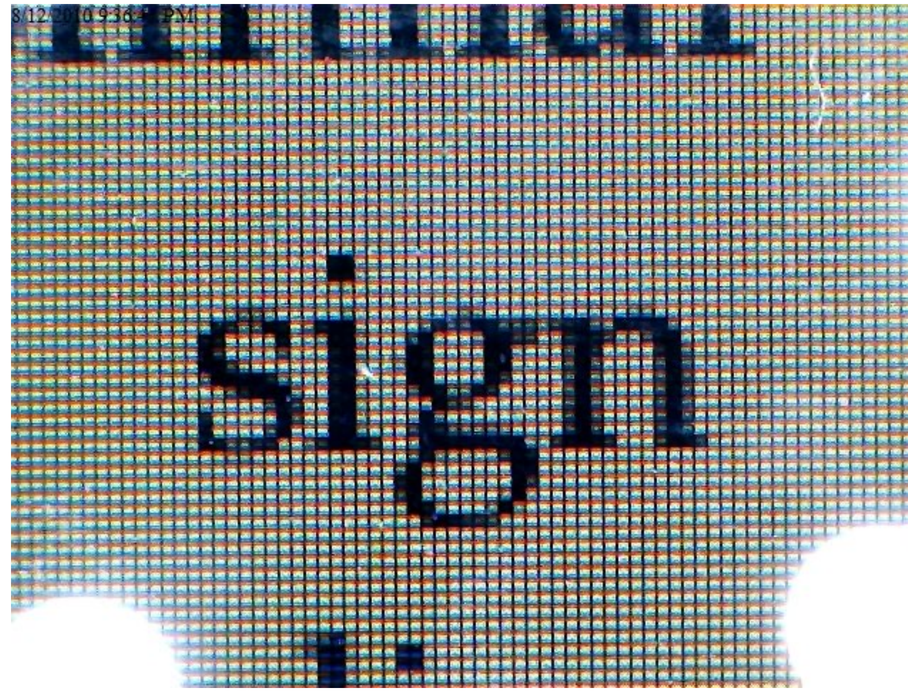


http://desres18.netornot.at/id/e-ink-technology/



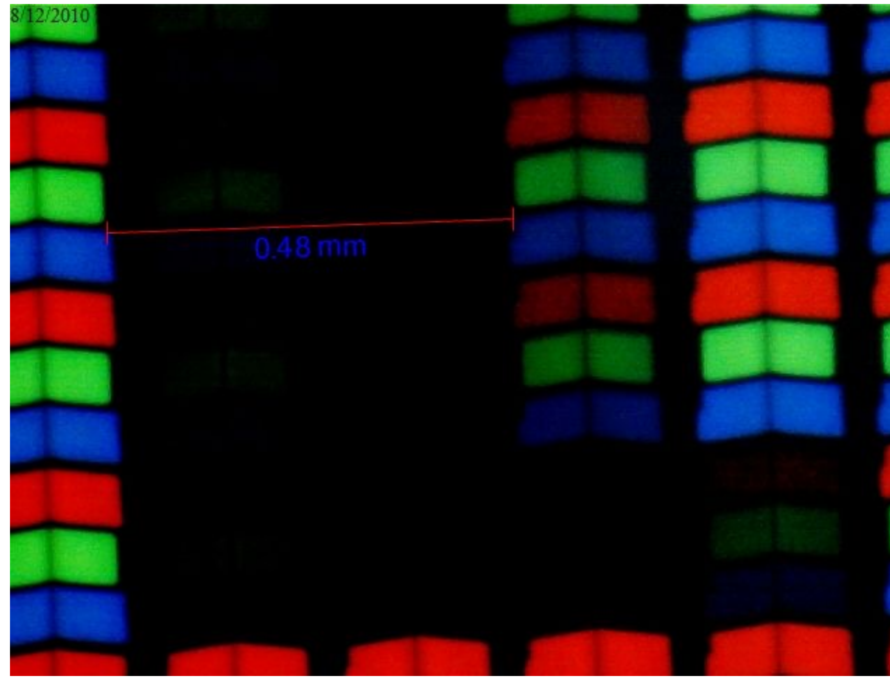
Kindle | At 26x | iPad





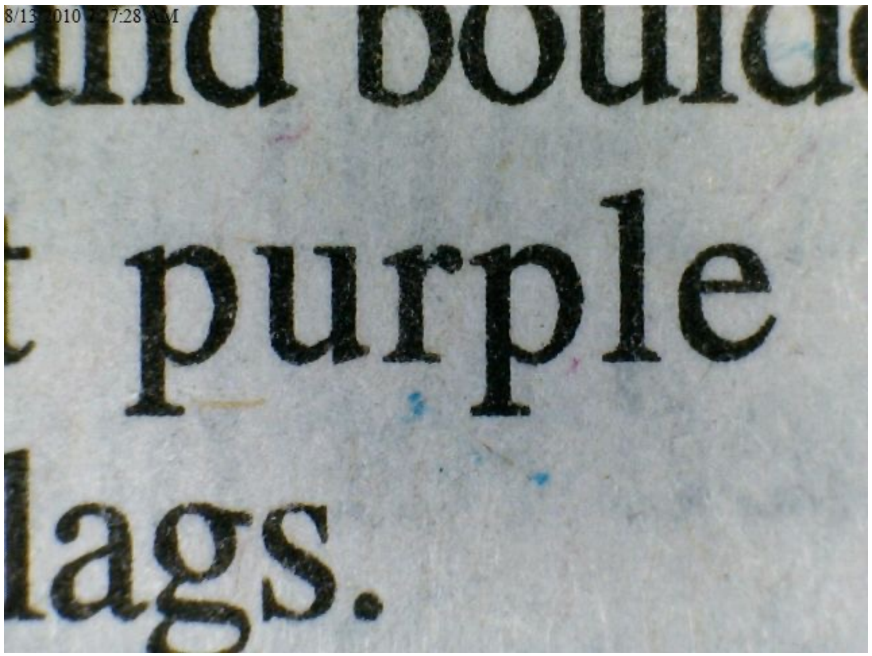
http://www.bit-101.com/blog/?p=2722

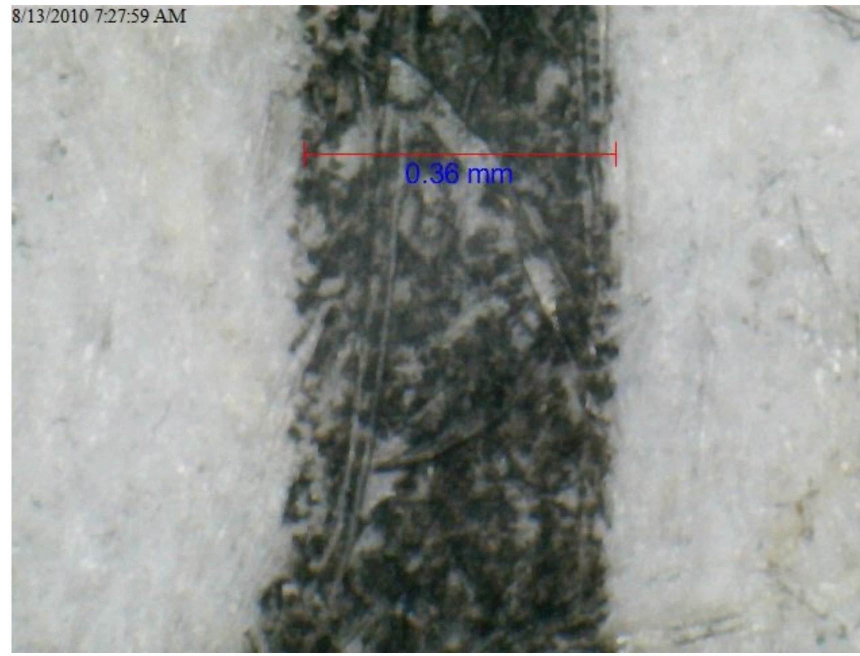
Kindle At 400x iPad



http://www.bit-101.com/blog/?p=2722

NewsPrint



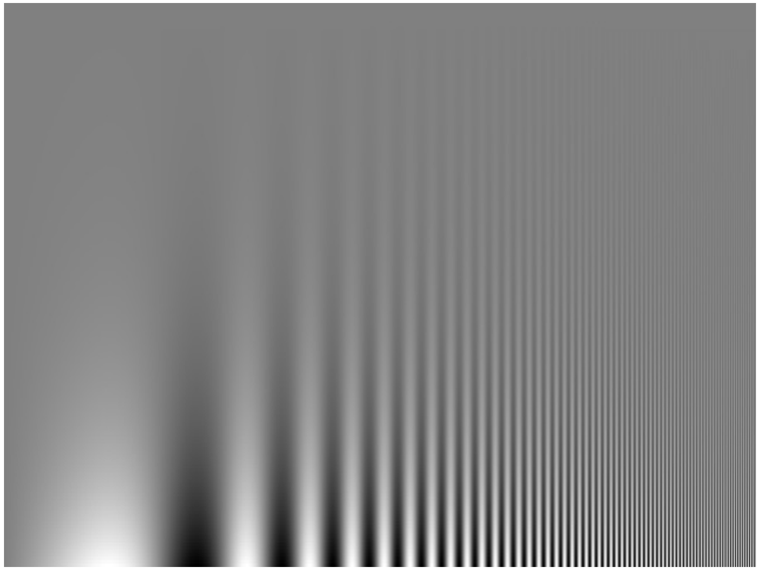


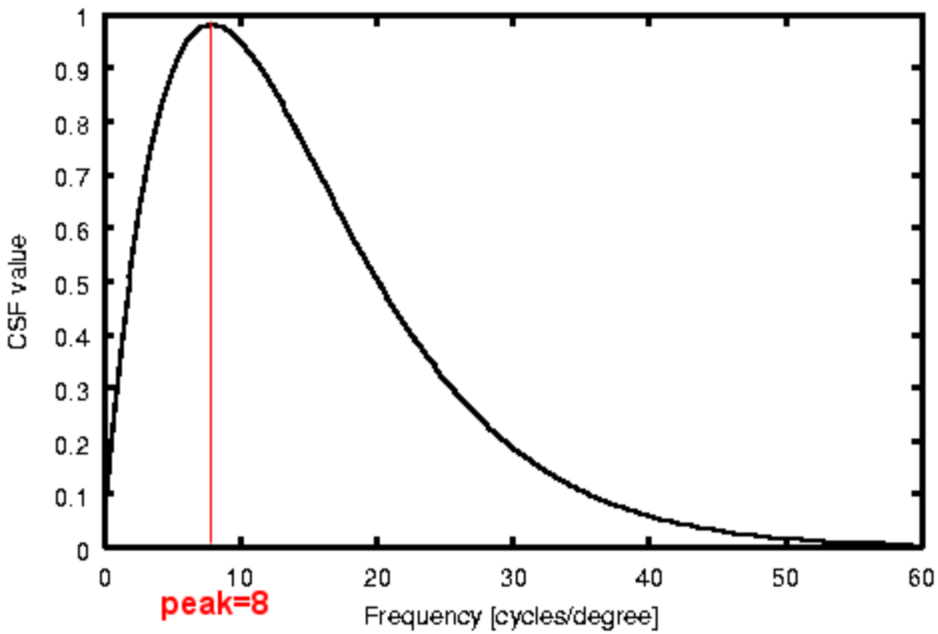
http://www.bit-101.com/blog/?p=2722

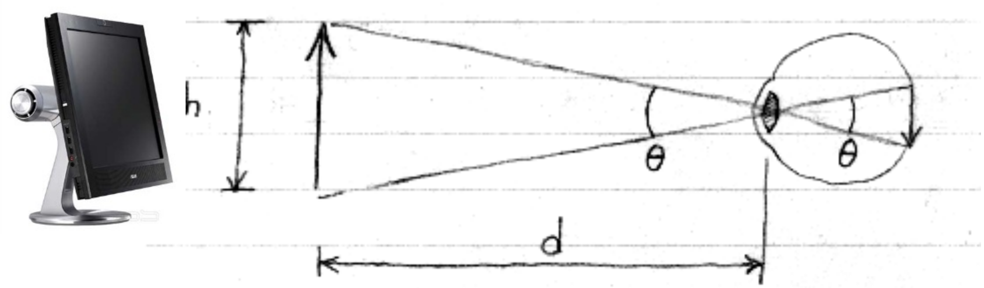
Perception

How much spatial resolution (pixels) do we need?

How much spatial resolution (pixels) do we need?







How much temporal resolution (frames per second) do we need?

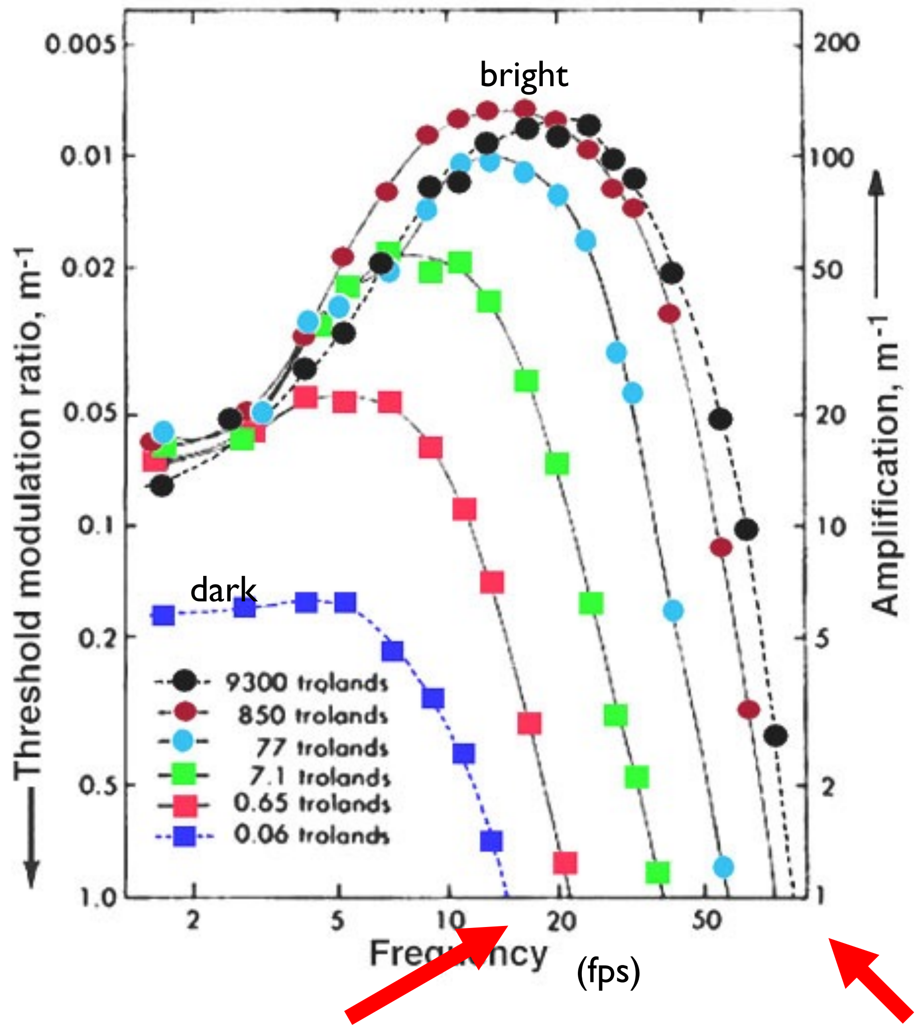
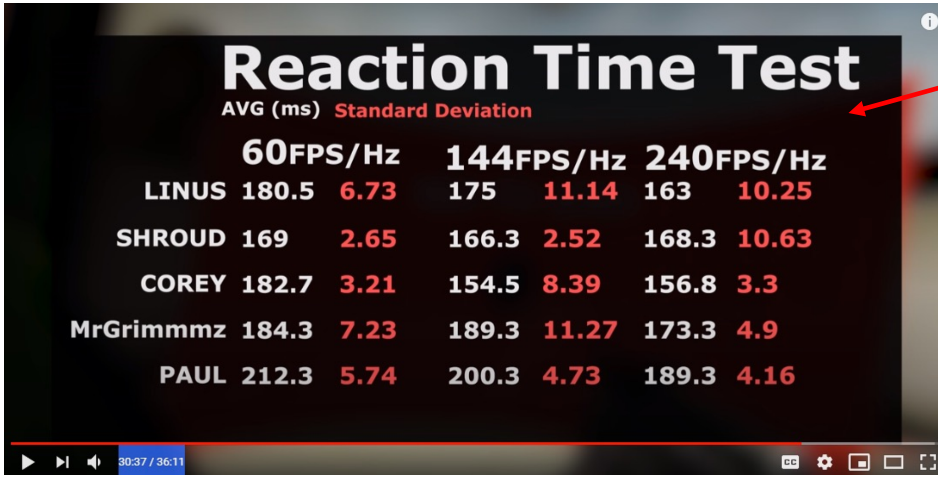


Fig. 11. Temporal Contrast Sensitivity Function (TSF) for various adapting fields. Kelly's data from Hart Jr, W. M., The temporal responsiveness of vision. In: Moses, R. A. and Hart, W. M. (ed) Adler's Physiology of the eye, Clinical Application. St. Louis: The C. V. Mosby Company, 1987.

Will an expensive GPU and monitor help you game?



Reaction Time Test

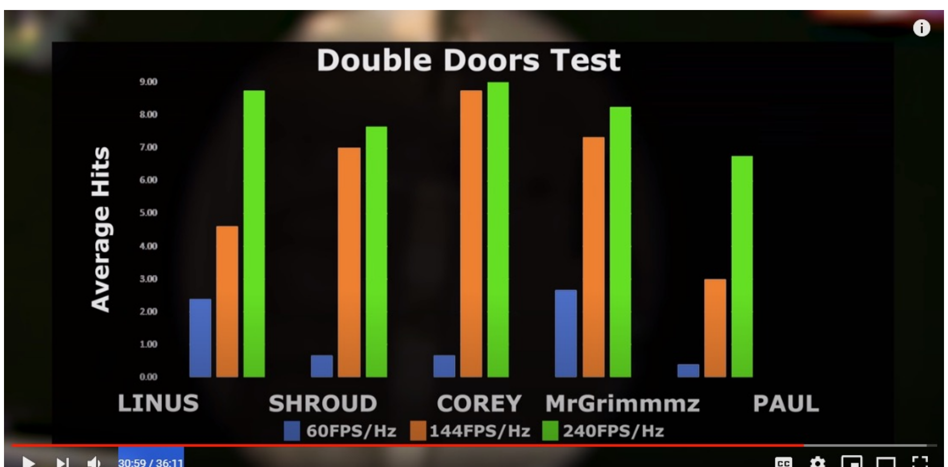
AVG (ms) Standard Deviation

	60FPS/Hz		144FPS/Hz		240FPS/Hz	
LINUS	180.5	6.73	175	11.14	163	10.25
SHROUD	169	2.65	166.3	2.52	168.3	10.63
COREY	182.7	3.21	154.5	8.39	156.8	3.3
MrGrimmmz	184.3	7.23	189.3	11.27	173.3	4.9
PAUL	212.3	5.74	200.3	4.73	189.3	4.16

30:37 / 36:11

15ms reaction time difference

Game State → Render Time (1/fps ms) → Display Time (1/Hz ms) → Data into your eye



60fps/Hz = 16ms
120fps/Hz = 8ms
240fps/Hz = 4ms
480fps/Hz = 2ms

2*12ms difference

An excellent 30 minutes if you are a gamer → https://www.youtube.com/watch?v=OX31kZbAXsA&feature=youtu.be

Participation Survey

Participation May 19

Form description

This form is automatically collecting email addresses for UC Santa Cruz users. Change settings

I was in class May 19

- Yes
- No

Roughly how long did you spend on HW4 (Viewing+Projection+Lighting)

- 0-1 hours
- 1-2 hours
- 2-4 hours
- 4+ hours

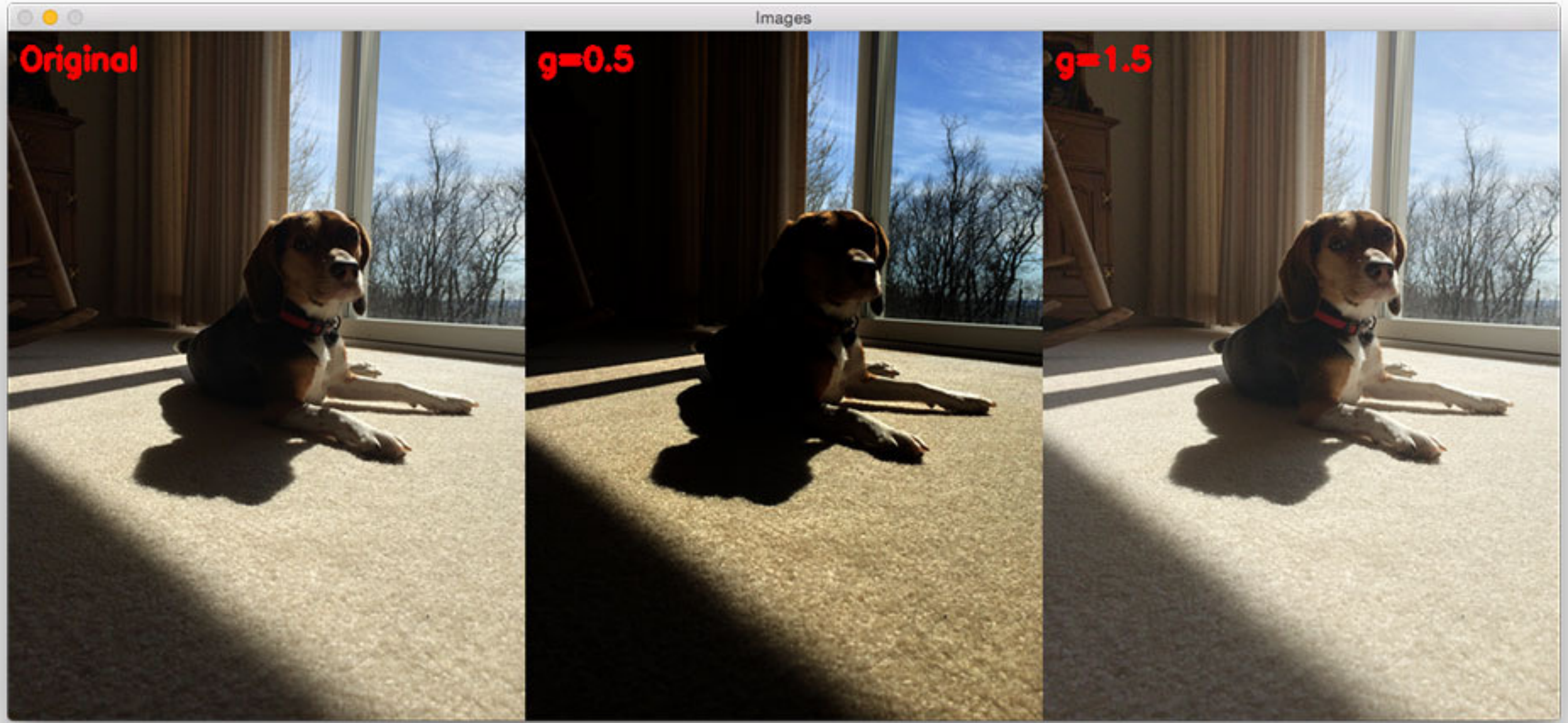
There are videos from Lucas introducing Lab 4

- I didn't watch it, I just started the assignment
- I watched it, but its NOT helpful
- I watched it, and it IS helpful
- Other...

There are videos from James introducing Lab 4

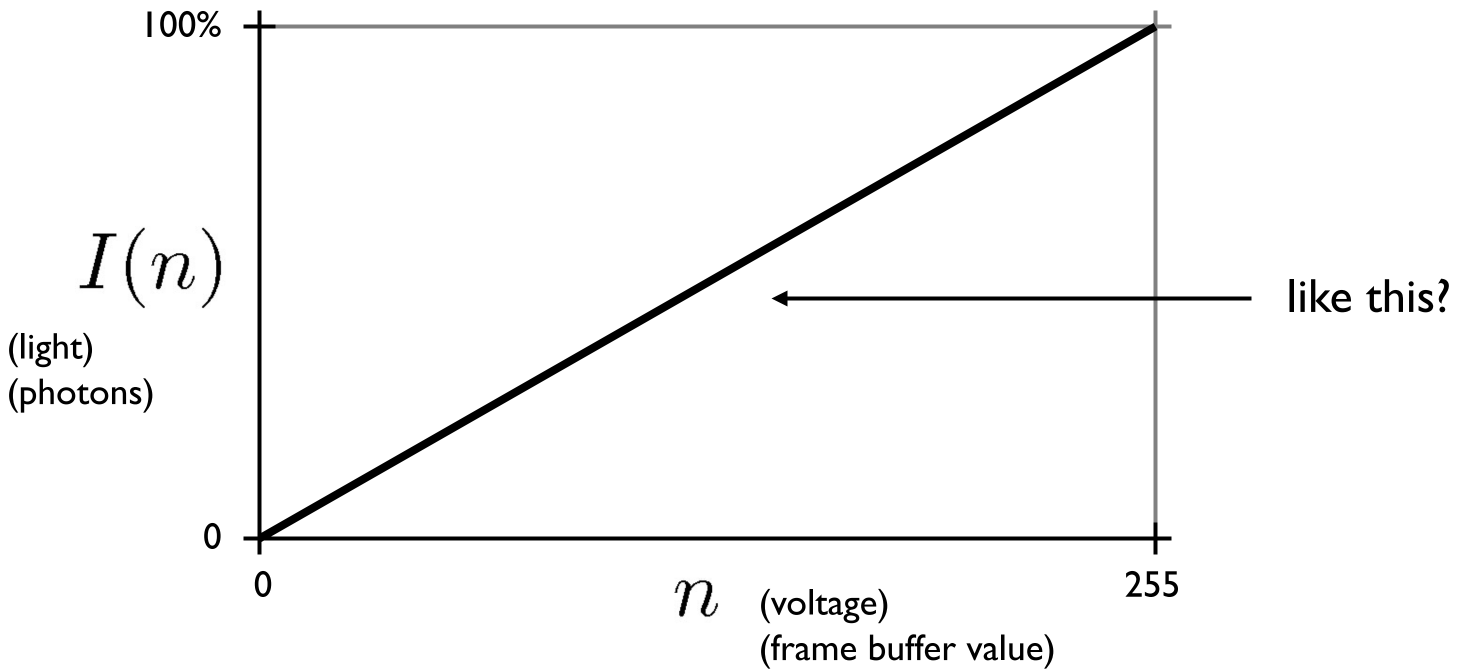
- I didn't watch them, I just started the assignment
- I watched them, but its NOT helpful
- I watched them, and it IS helpful
- Other...

Gamma

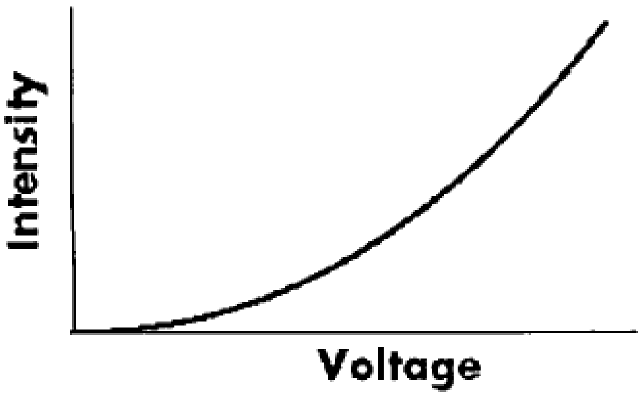

Images
Original
g=0.5
g=1.5

Transfer function of display

- Say pixel value is 123
  - this means the intensity is 123. 123 what?



Monitor Gamma



$$I = g \cdot (V - V_b)^{\gamma}$$

Monitor
 γ=2.5

Two knobs
 Black Level (Brightness): V_b
 Picture (Contrast): g

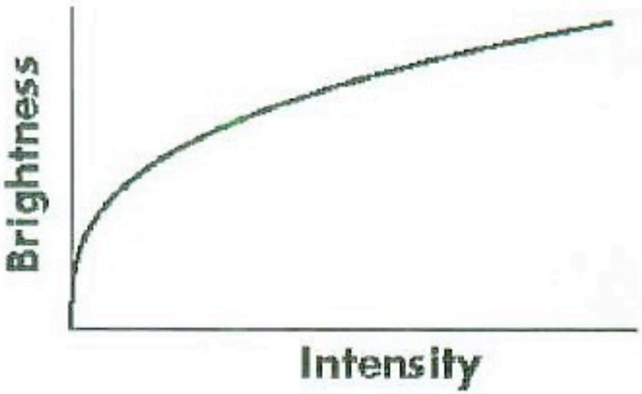
Adjustments
 1st adjust to full black
  Picture 0, adjust black-level
 2nd adjust brightness

Perception of Intensities

Steven's Law:

Sensation (S) vs. Intensity (I)

$$S = I^p$$



Experiments

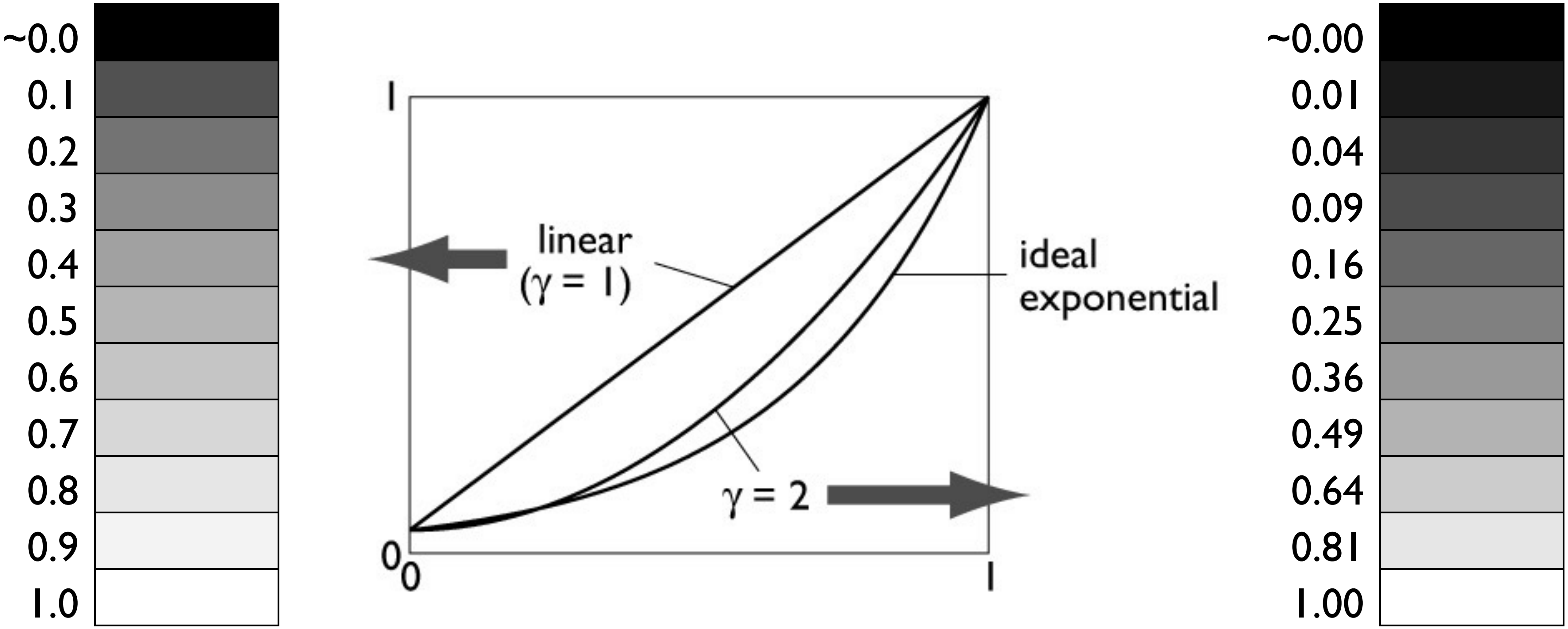
Sense	Exponent
Brightness	0.33
Smell	0.55
Loudness	0.60
Taste	0.80
Length	1.00
Heaviness	1.45

Stevens $B = I^{1/3}$

Weber $JND = \frac{\Delta I}{I} \approx 0.01$

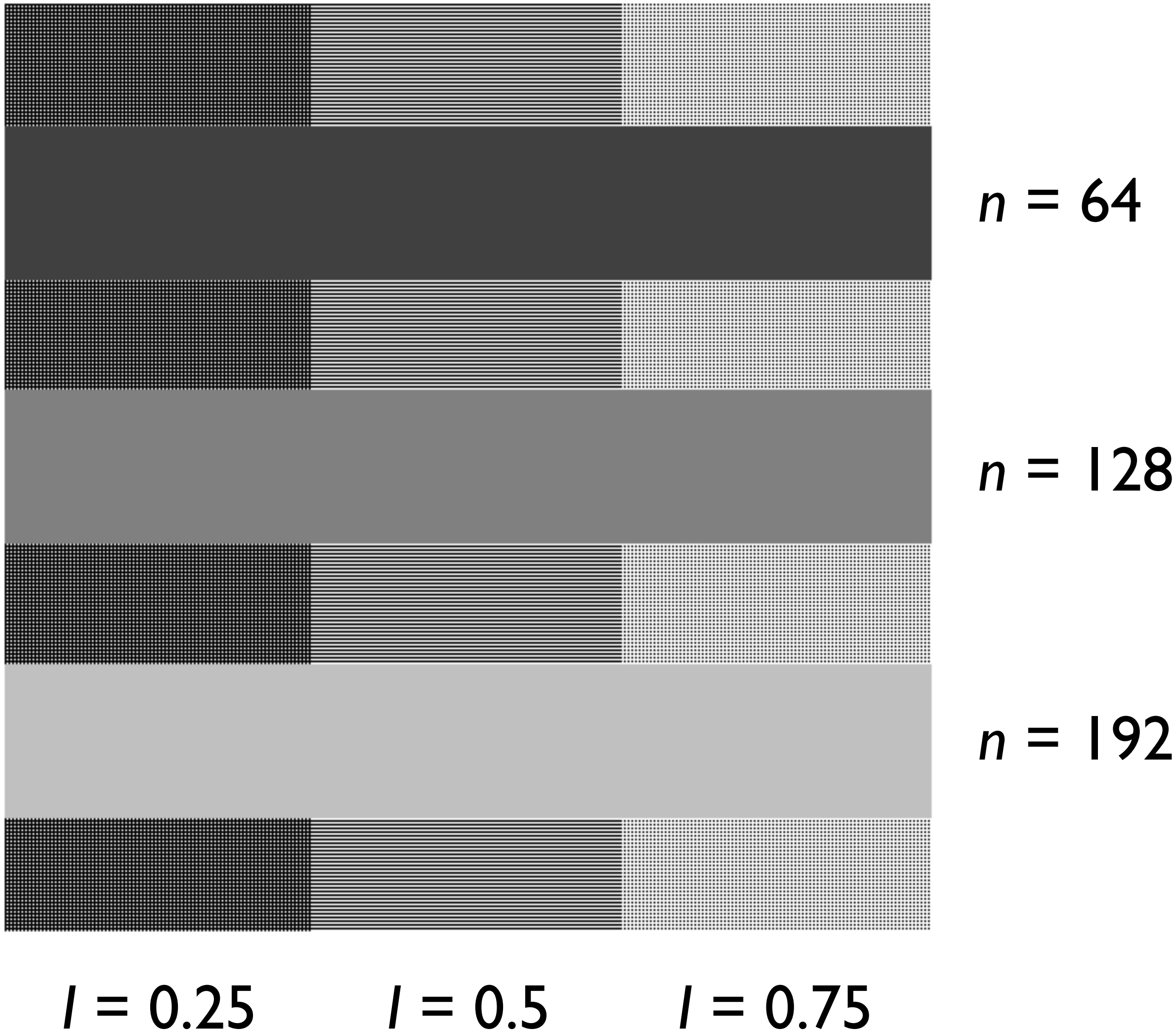
Fechner $B = k \log I$

Why nonlinear intensity?



- Closer to ideal perceptually uniform exponential

Checkerboard test



Gamma Correction

Goal: Operate in linear intensity space

How: Gamma correction table

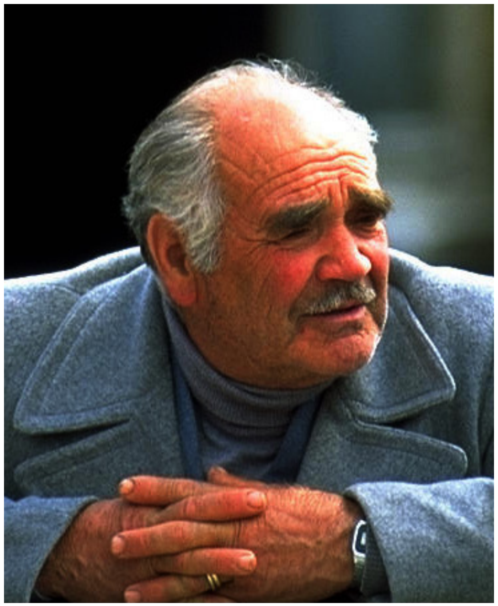
$$I = V^{\gamma}$$

$$V = P^{1/\gamma}$$

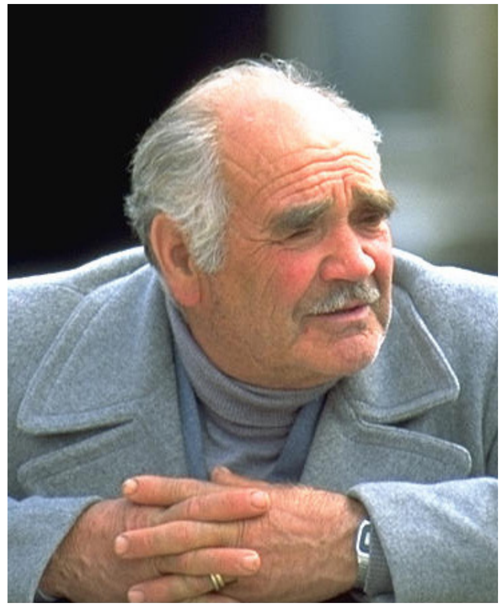
$$I = V^{\gamma} = \left(P^{1/\gamma}\right)^{\gamma} = P$$

Input	Output
0	0
1	16
2	23
3	28
4	32
...	...
...	...
251	253
252	253
253	254
254	254

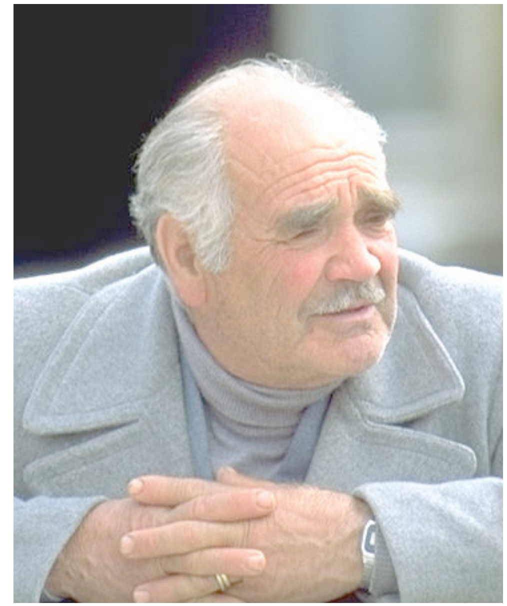
Gamma correction



corrected for
g lower than
display



OK

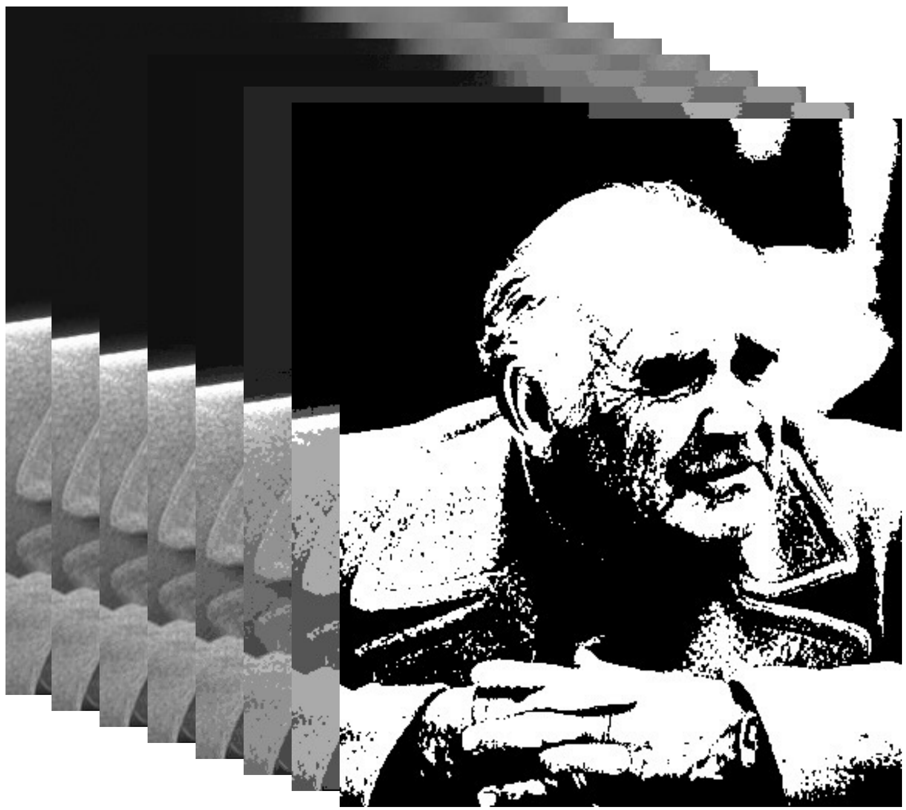


corrected for
g higher than
display

[Philip Greenspun]

Dithering

Quantization



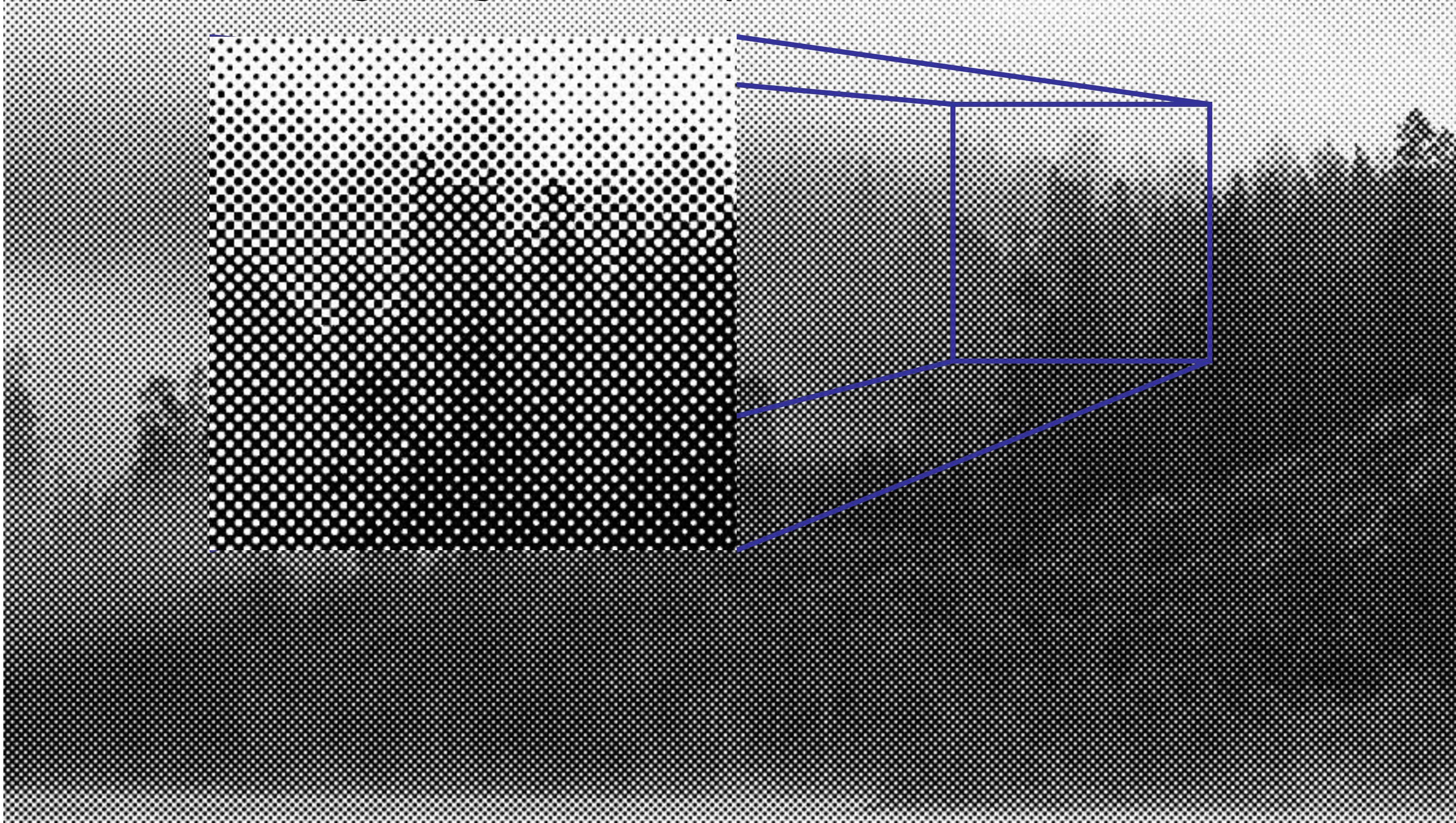
1 bpp (2 grays)

[Philip Greenspun]

- You make a black and white printer. You don't want your pictures to come out like this. Design a system for converting grayscale images to black/white that will look better than this. (You can only use black/white, what value goes in each pixel?)

Ordered dither example

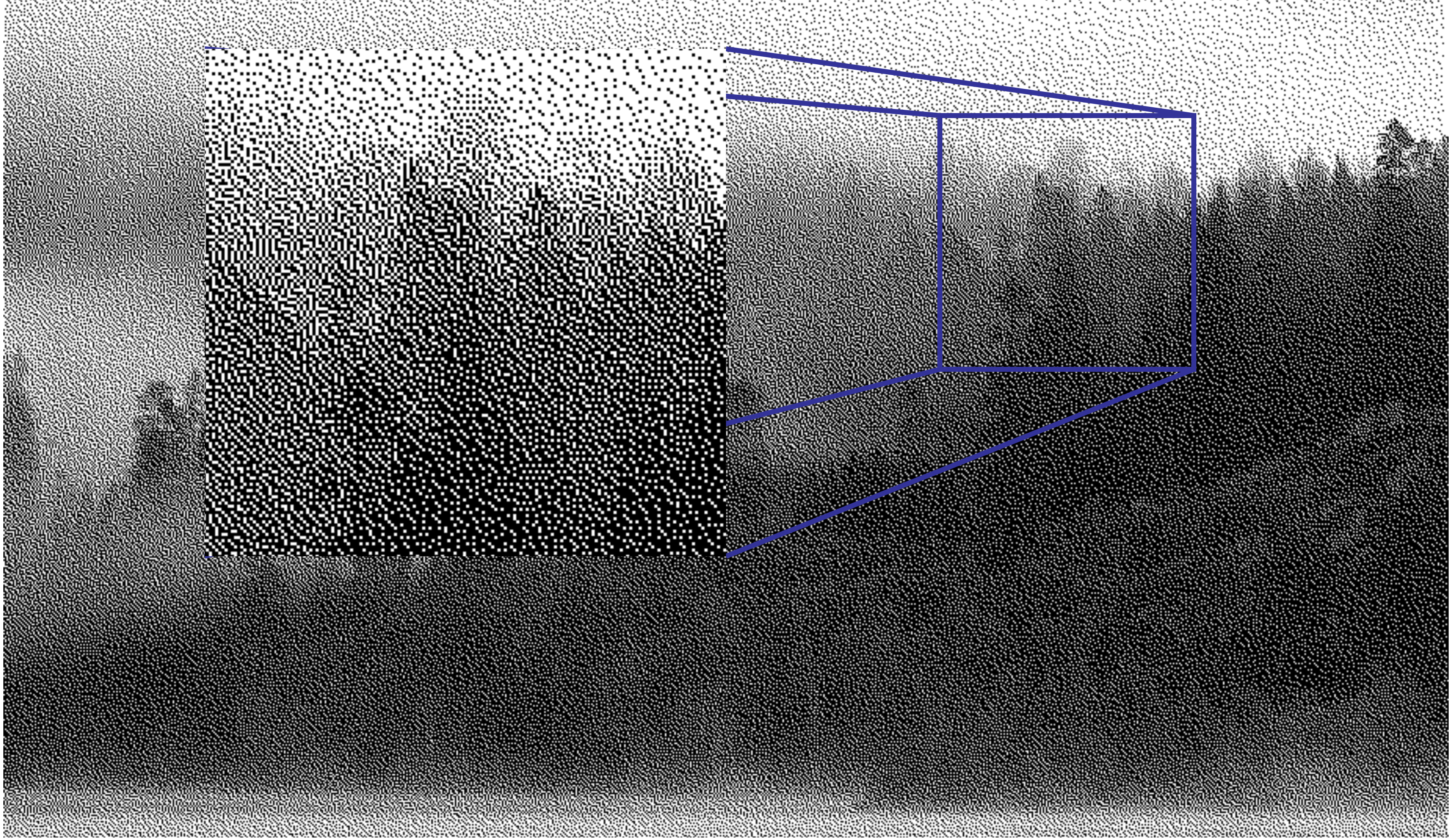
- Produces regular grid of compact dots



[Philip Greenspun]

Diffusion dither

- Produces scattered dots with the right local density



[Philip Greenspun]

Comparison

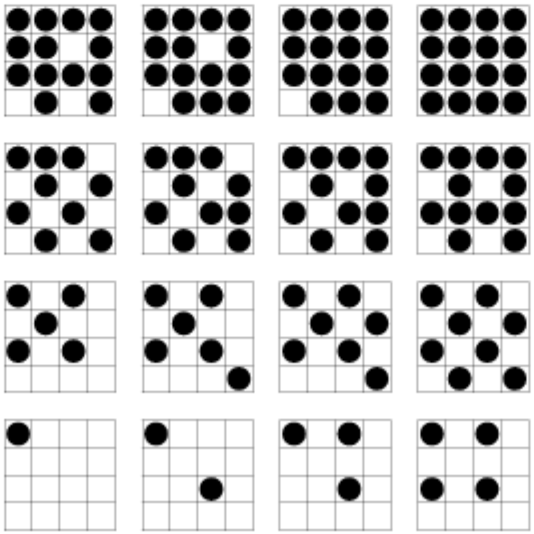
Blue Noise | Bayer Dither | Floyd-Steinberg

Bayer Ordered Dither Patterns

$$D_2 = \begin{bmatrix} 0 & 2 \\ 3 & 1 \end{bmatrix}$$

$$D_n = \begin{bmatrix} 4D_{n/2} + 0 & 4D_{n/2} + 2 \\ 4D_{n/2} + 3 & 4D_{n/2} + 1 \end{bmatrix}$$

$$D_4 = \begin{bmatrix} 0 & 8 & 2 & 10 \\ 12 & 4 & 14 & 6 \\ 3 & 11 & 1 & 9 \\ 15 & 7 & 13 & 5 \end{bmatrix}$$



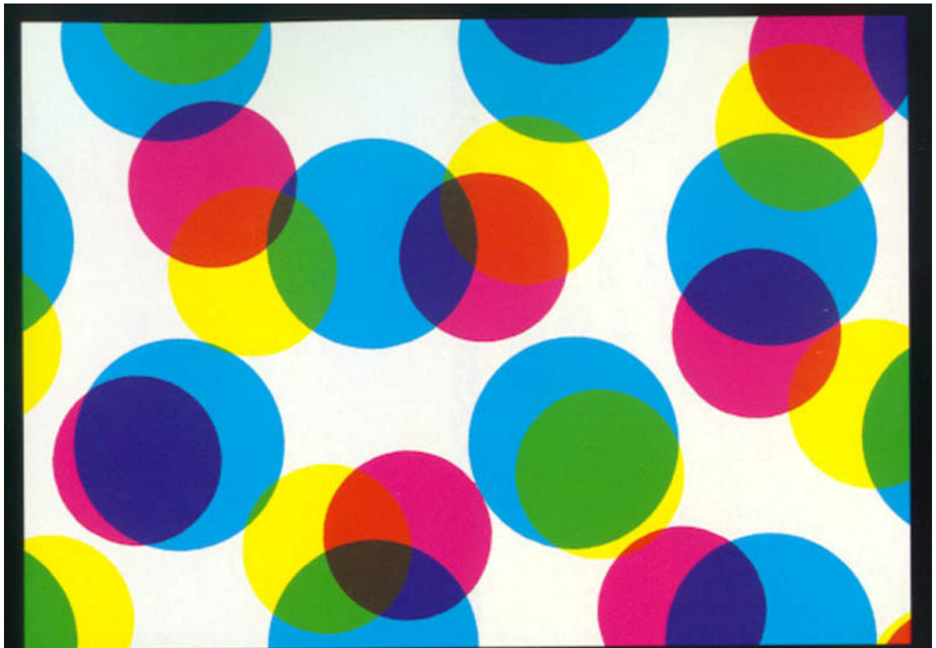
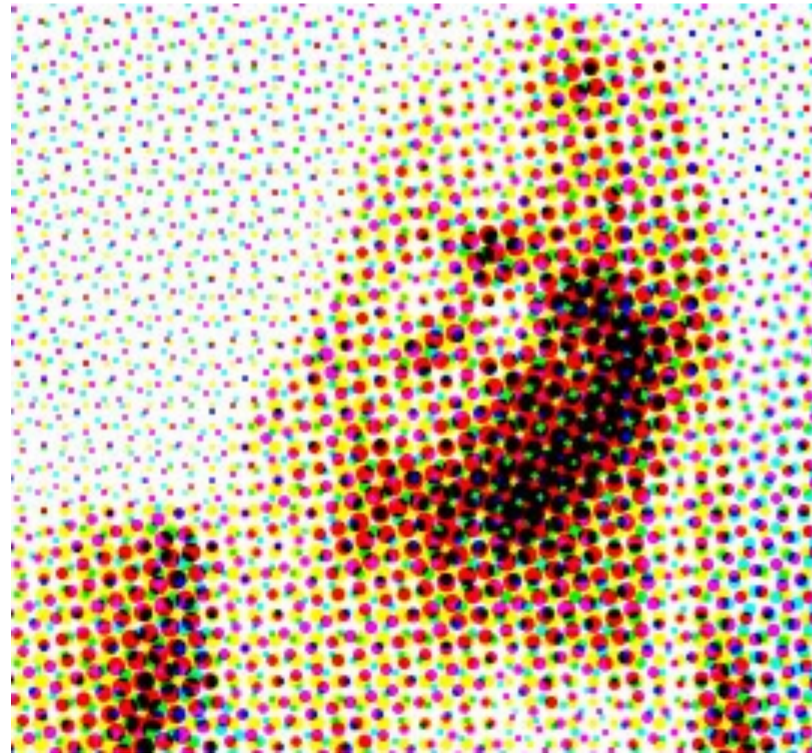
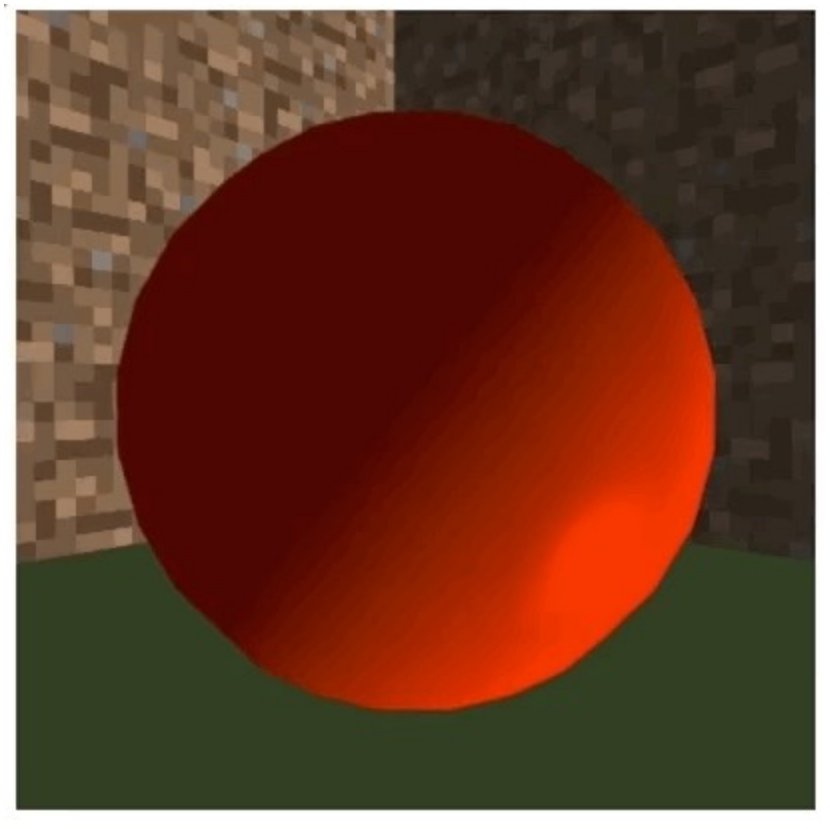


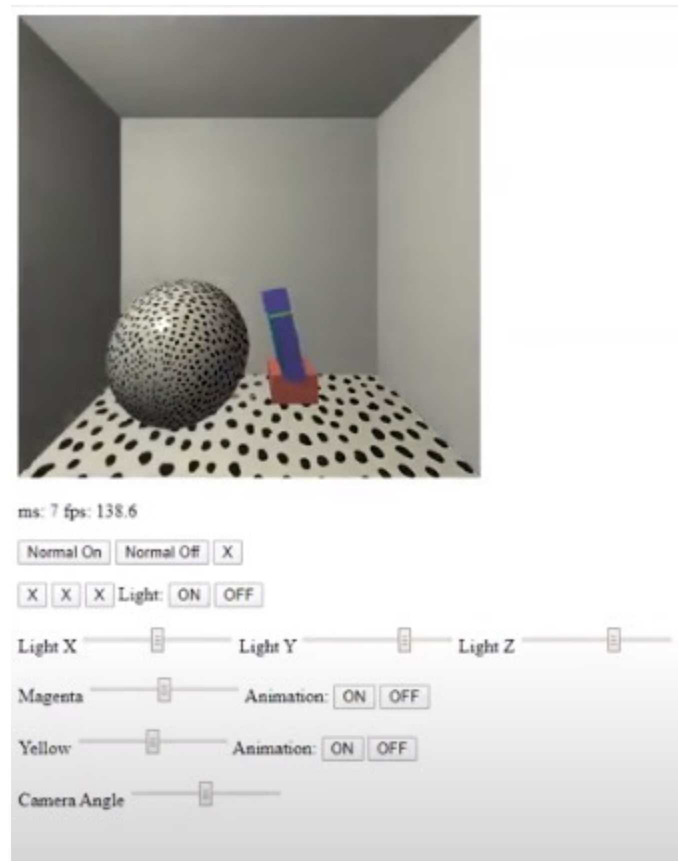
Plate 6 Magnified view of the magenta, cyan, and yellow dots used in color printing. (Courtesy of Hammermill Papers Group, Division of Hammermill Paper Company)



Administrative

Lab4 - Lighting





Q&A

End