Washtenaw County Elementary Science Olympiad

Photon Phun Workshop 4

Color Mixing

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Presented at Scarlett Middle School

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What will we learn today?

- How do we see colors of light?
- Components of white light (demo)
- Primary colors that adds to white light
- Additive color mixing (Activity #1)
- Why does a red apple appear red?
- Subtractive color mixing (Activity #2)
- Primary colors for paints (Activity #3)
- Color paddles & transmission (Activity #4)

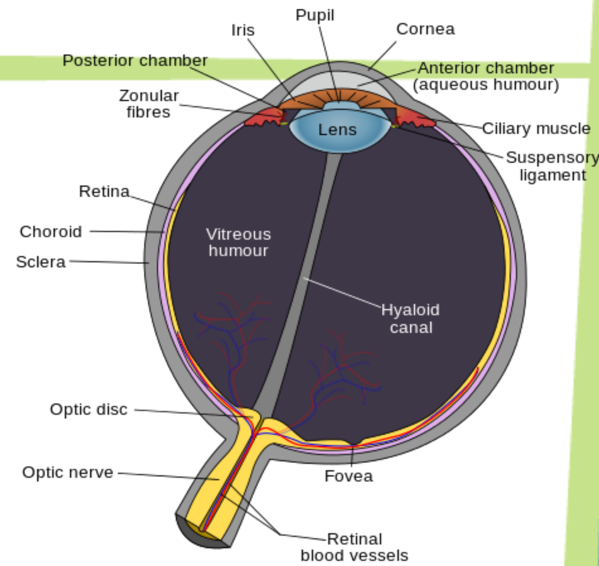
See materials section at the end for the supplies for activities

Review/Summary: What's in white light?

- White light has multiple colors in it!
- You can make a white light by shining red light, blue light, and green light on a spot!
- You can split white light into multiple colors! (Workshop #2)

How do we see colors?

- The image is focused by the lens onto the "screen"
- The "screen" has receptors that are more sensitive to specific colors (cone cells)



Cone type	Sensitivity range	"Nickname"
S-cone	400-500nm	Blue receptor
M-cone	450-630nm	Green receptor
L-cone	500-700nm	Red receptor

How do we mix colors? Additive primary colors

- Additive = they add up
- When you mix the red light, green light, and blue light, you get white
- RGB: Red, Green, Blue primary color system: mixing red, green, and blue in different proportion creates a wide range of colors

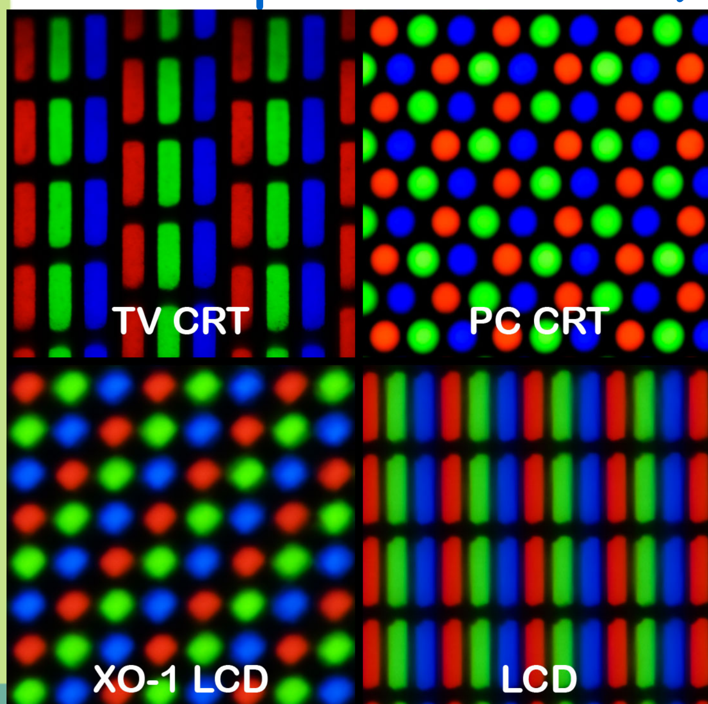
Image: https://en.wikipedia.org/wiki/Color_mixing

Activity #1

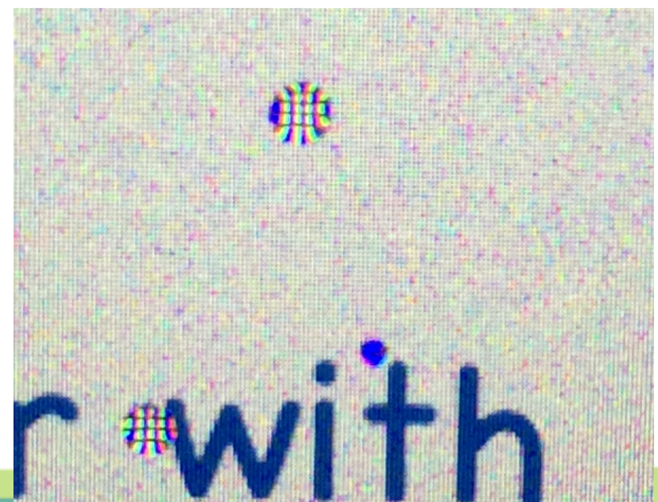
- Put tiny water droplet(s) – less than 1mm – on the plastic sheet provided (to make a magnifier)
- Turn up your parent/coach's phone brightness and look at different colors
- Fill out the worksheet page 1

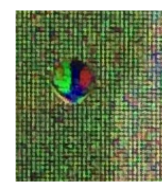
Screens

- Screens are made of little dots ("pixels" from picture cells) of colors



"Droplet magnifiers" on my computer screen

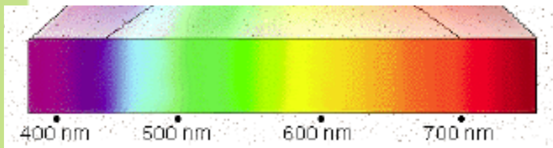




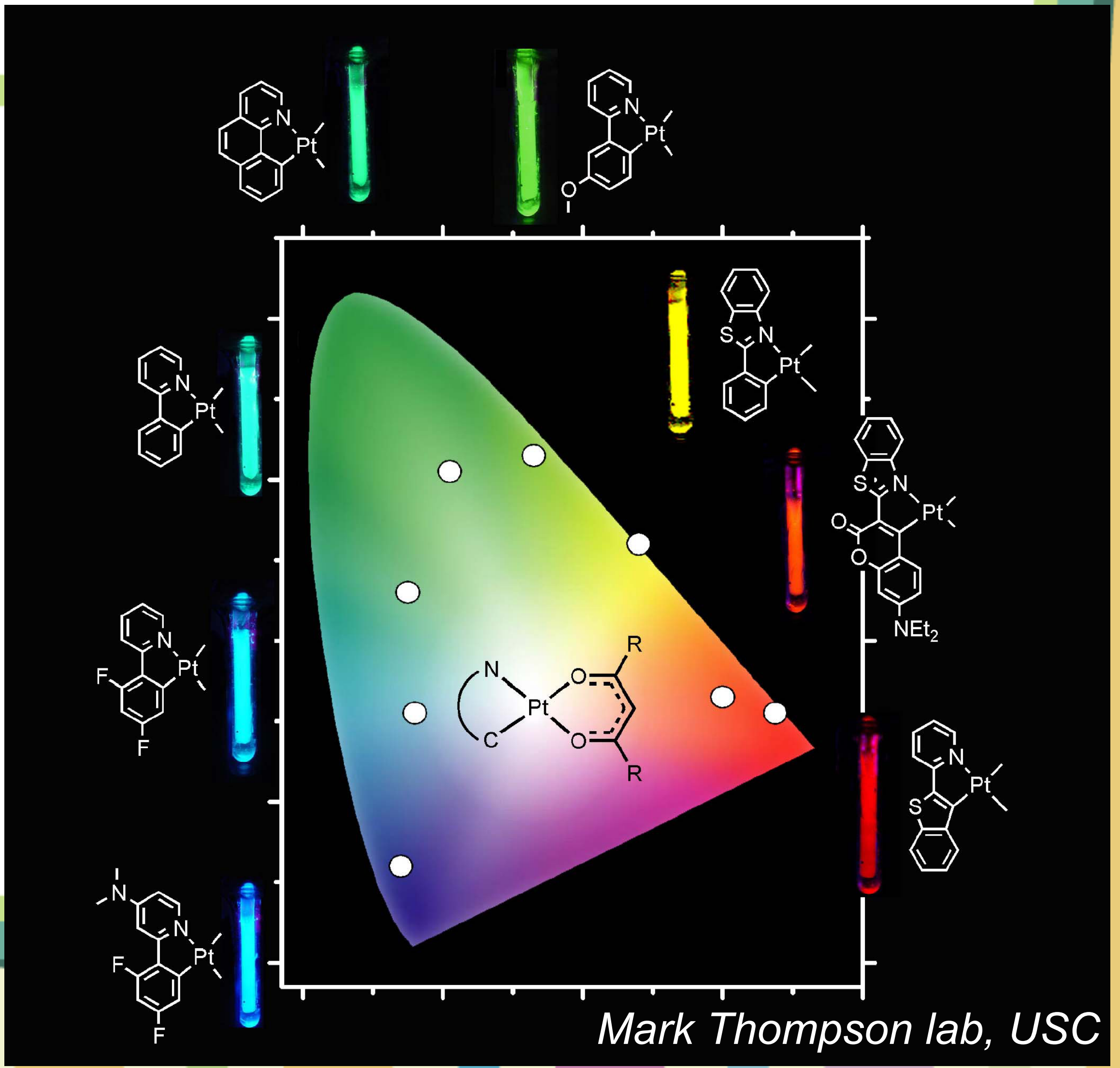
Left image: https://en.wikipedia.org/wiki/Pixel

Many molecules available to control color and brightness of emission

$E = h\nu = h \cdot c/\lambda$

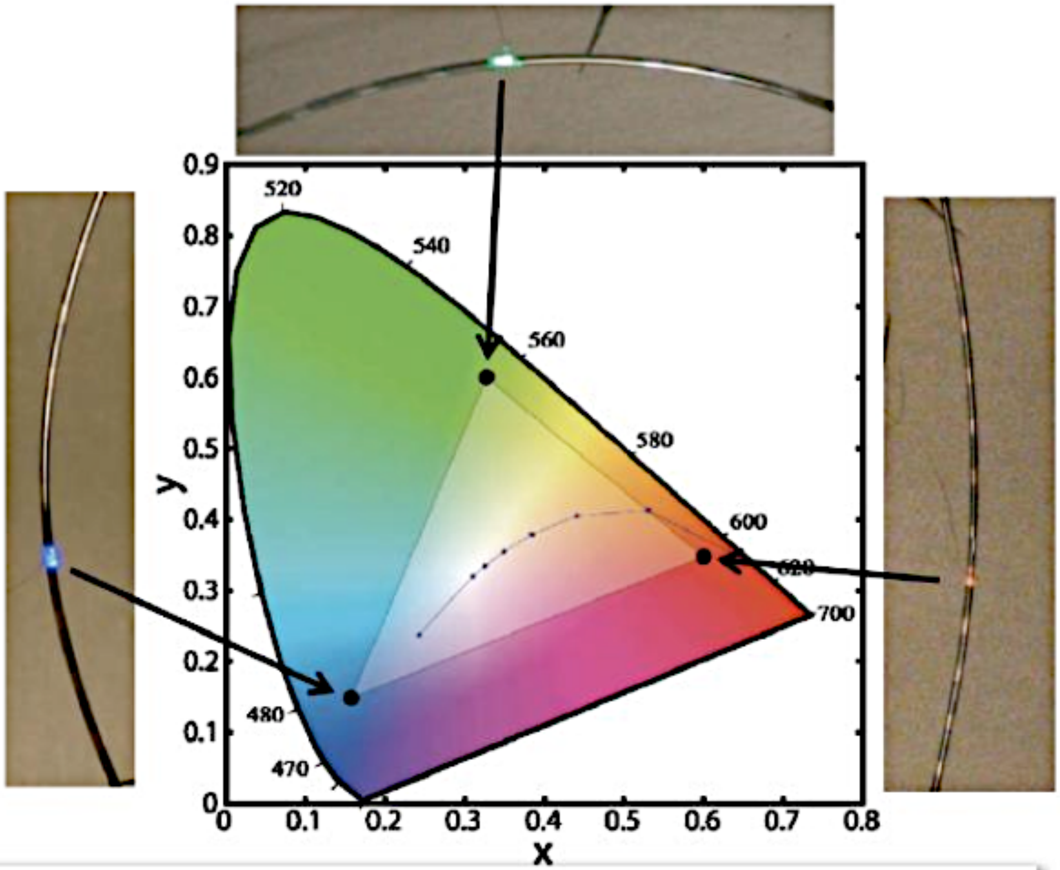


λ increases



Extend to Red, Green, and Blue-emitting OLEDs on fibers

Al
LiF
Alq_3
BCP
NPD
MTDATA
Ni
Al
Kapton
Glass



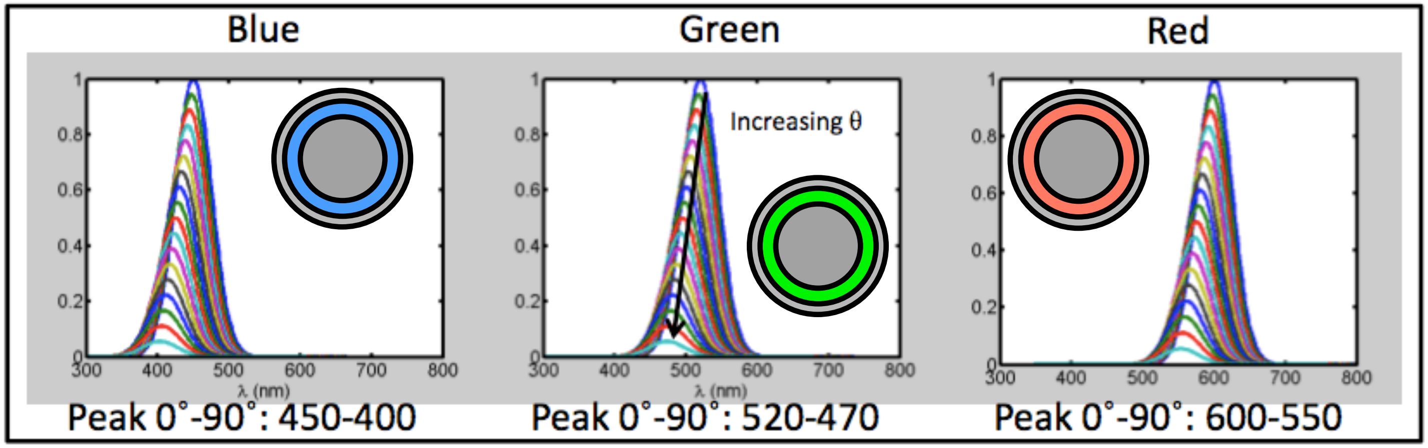
Al
LiF
Alq_3
PtOEP:Alq_3
NPD
CuPc
Ni
Al
Kapton
Glass

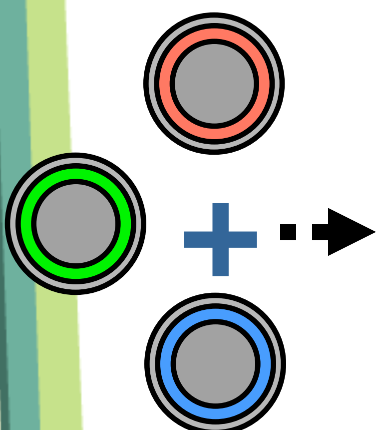
Nothern et al., (in preparation)

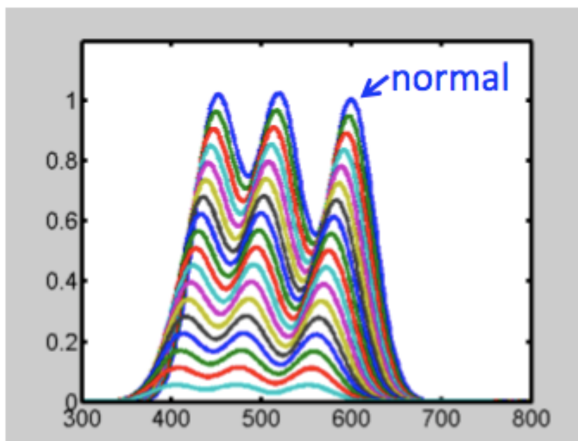
- ✓ Prototype devices can be made
- ?? How can we optimize the fiber OLED?
- ?? How can we predict what fiber bundles will do?

D. Nothern et al., (*manuscript in preparation*)

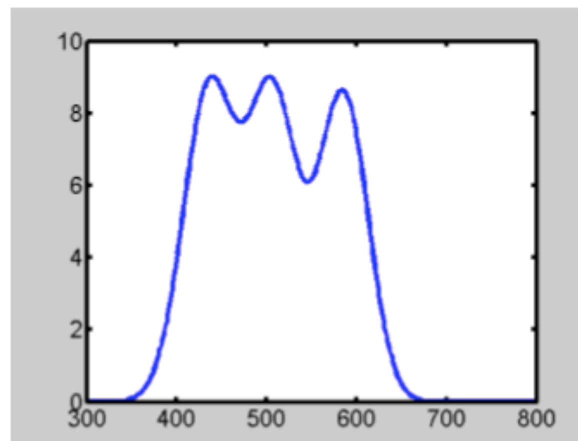
Bundling R, G, B emitting fibers to get white light:







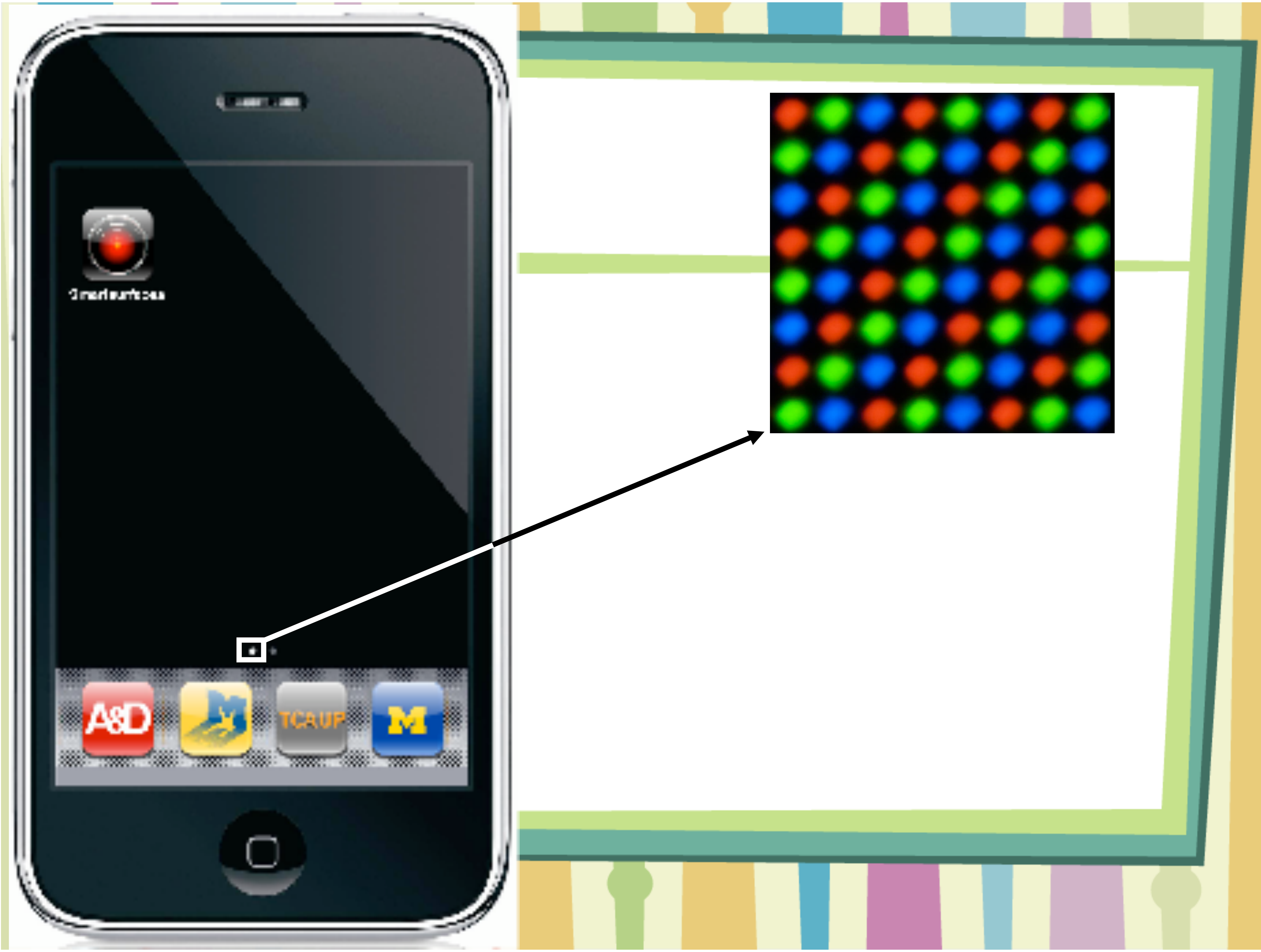
CRI at normal = 93.66
lm/$W_{optical}$ = 300.4

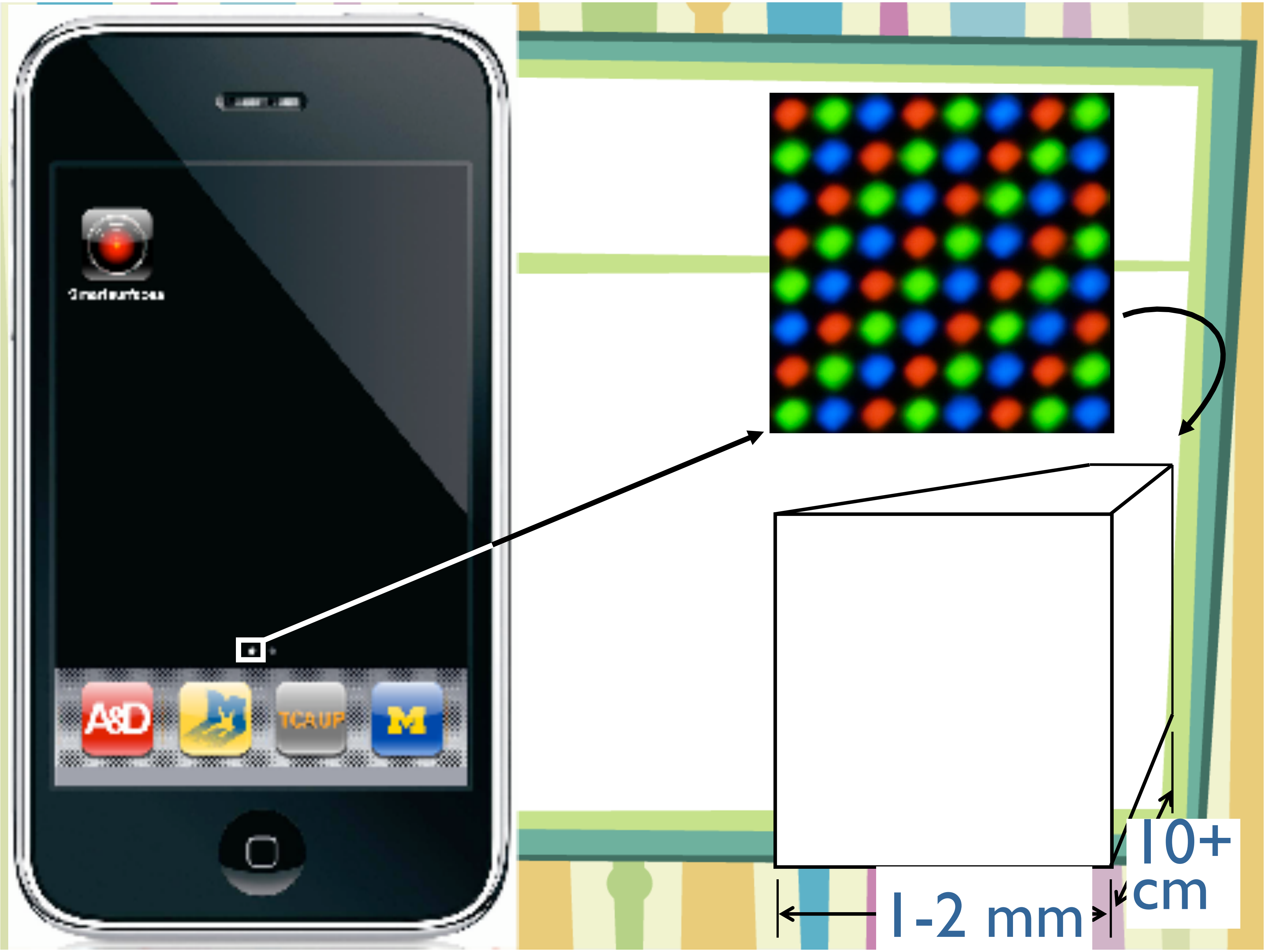


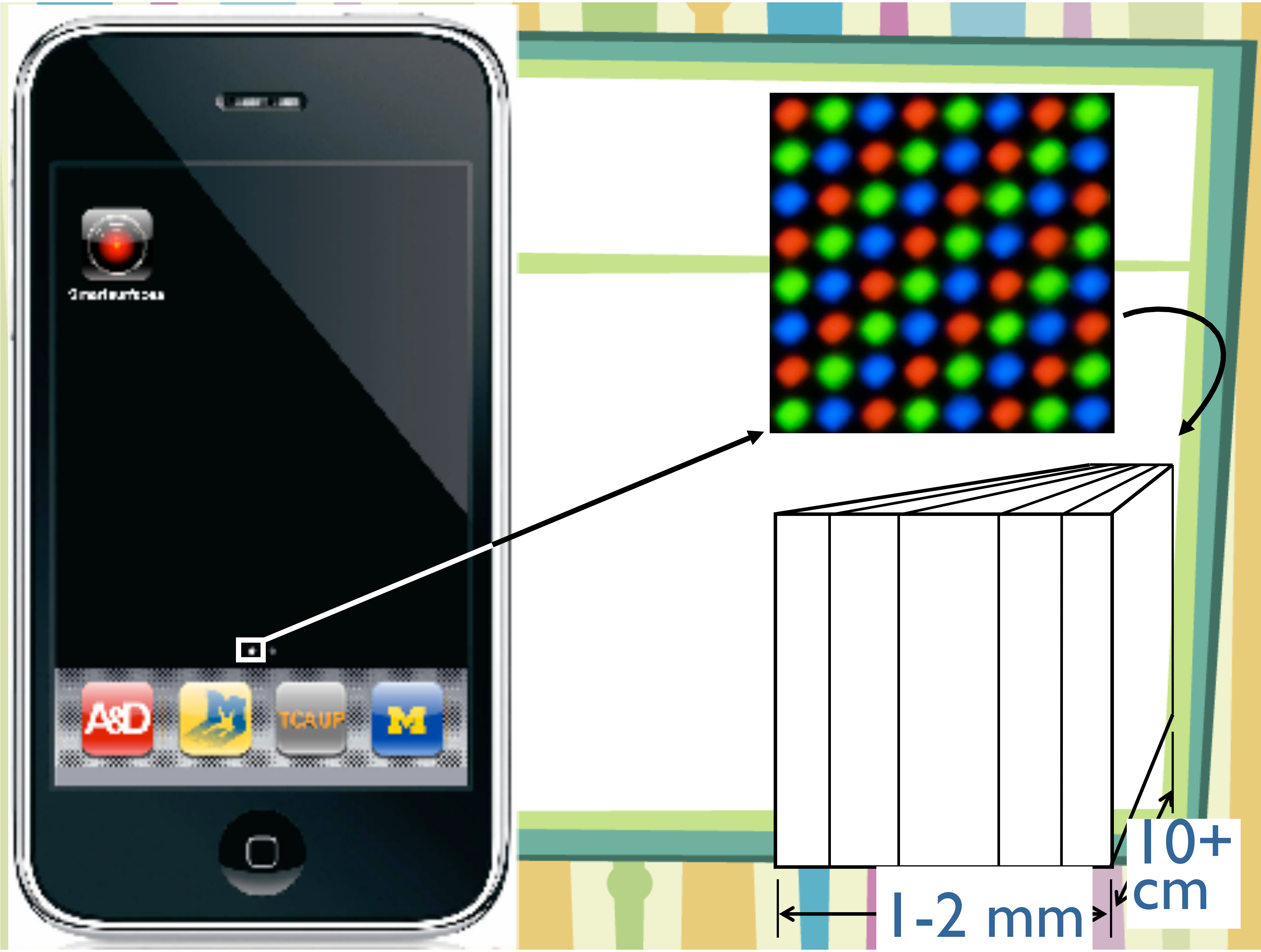
CRI summing 0°-90° = 81.29
lm/$W_{optical}$ = 282.63

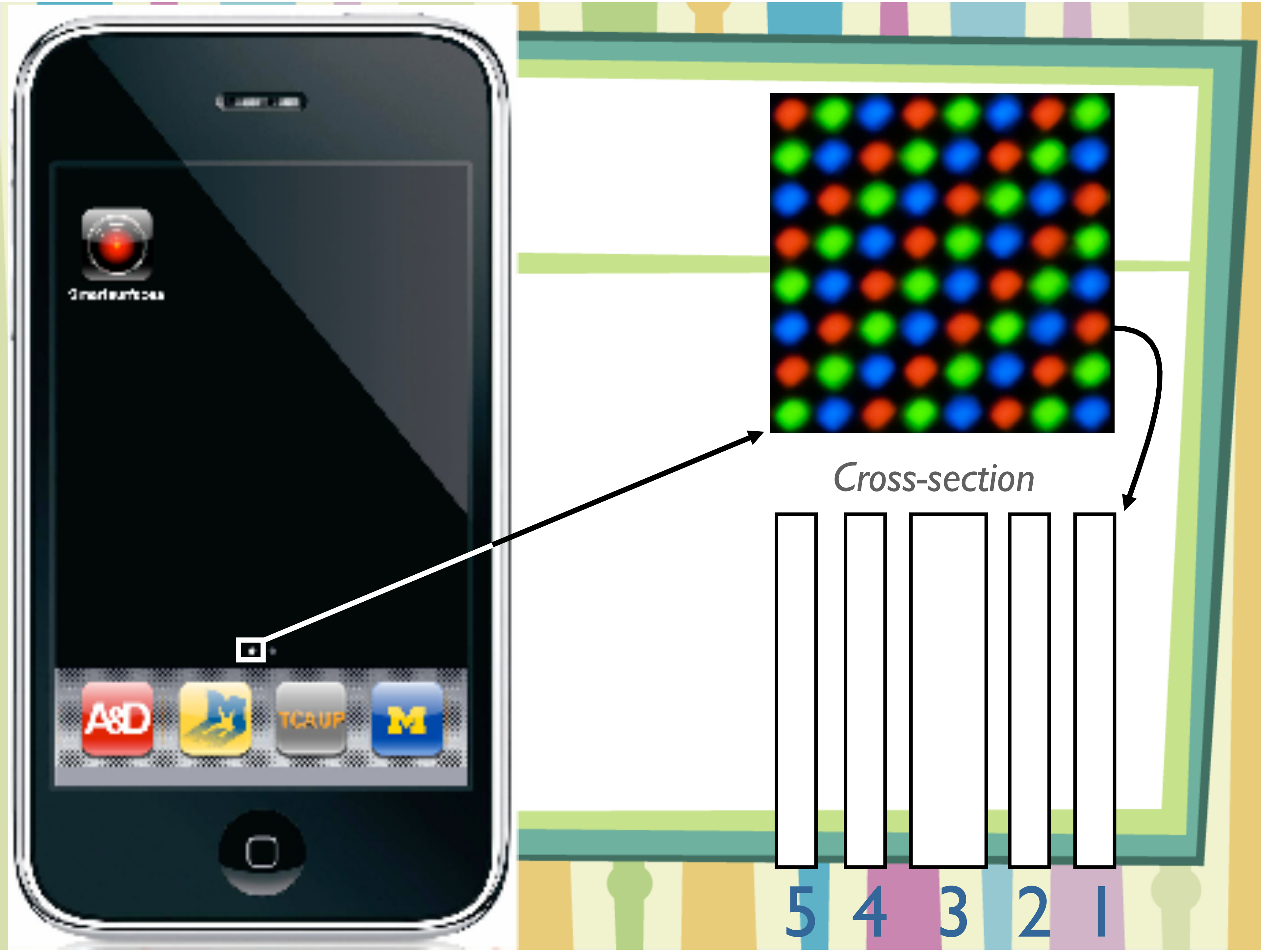
This approach results in very high Color Rendering Index (CRI)

...but still have some work to do to increase light outcoupling

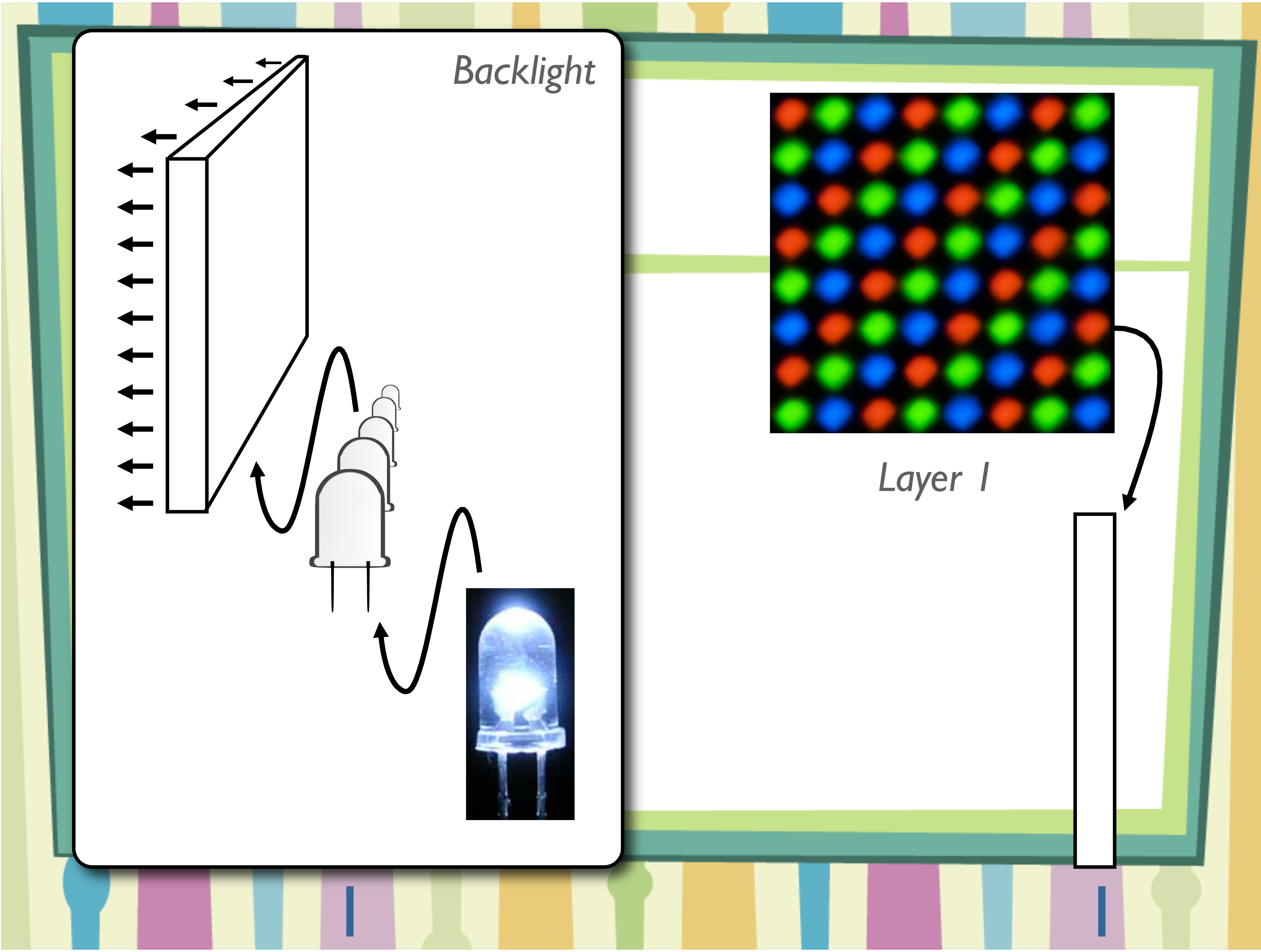

A&D
TCAUP
M


A&D
TCAUP
M
1-2 mm
10+
cm

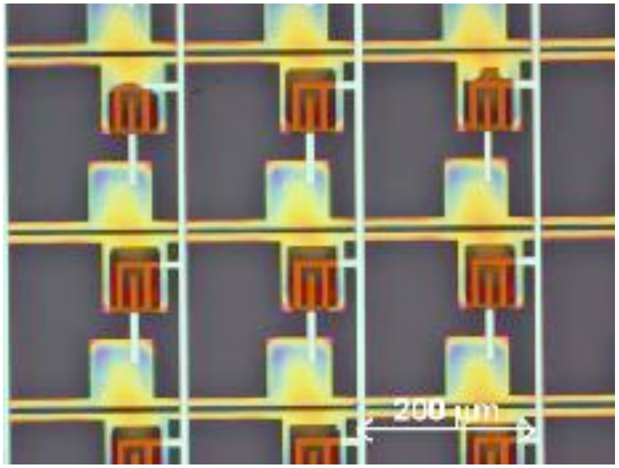

A&D
TCAUP
M
1-2 mm
10+
cm

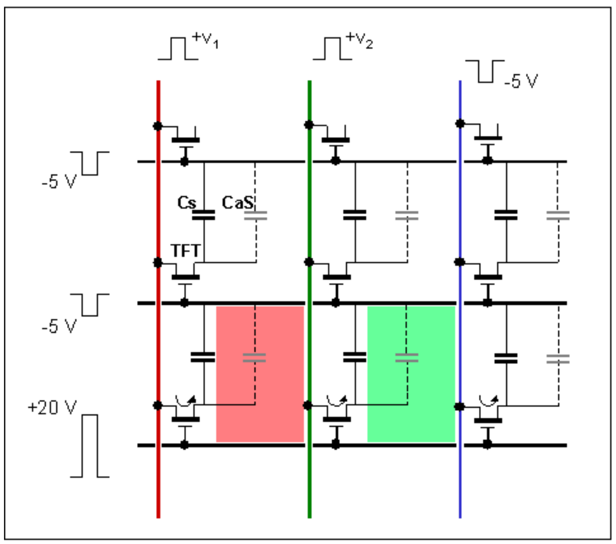


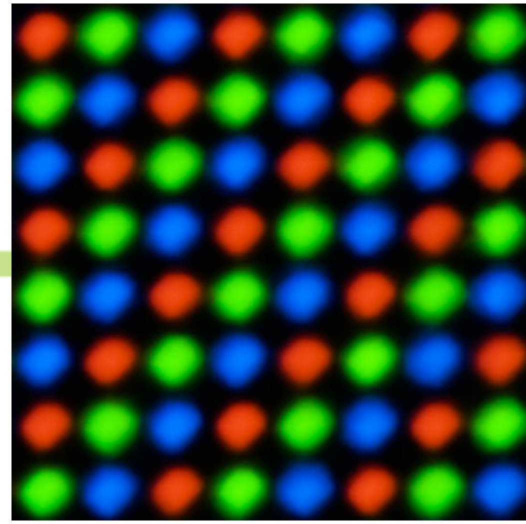
Cross-section
5
4
3
2
1


Backlight
Layer 1

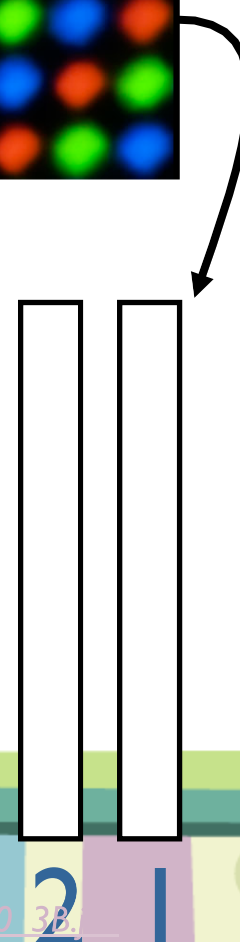
TFT Backplane Array (driver)







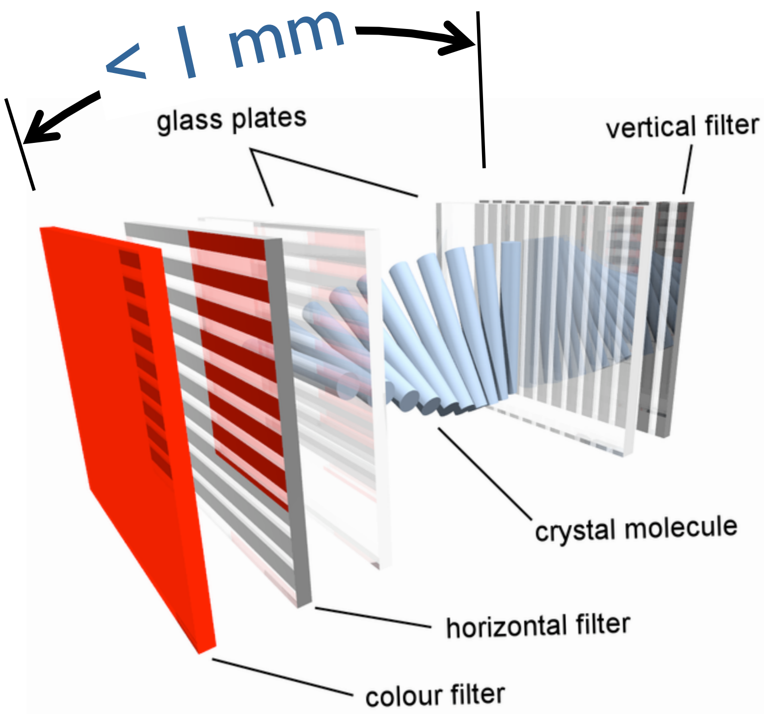
Layer 2

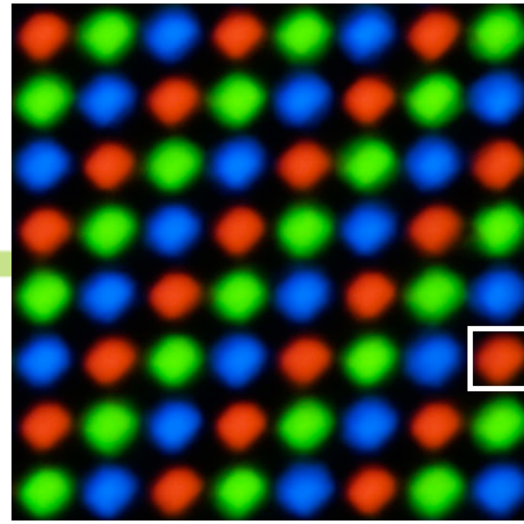


http://...nikkeibp.co.jp/english/NEWS_EN/20080610/153102/thumb_230_3B.j...

2

Liquid Crystal Pixel



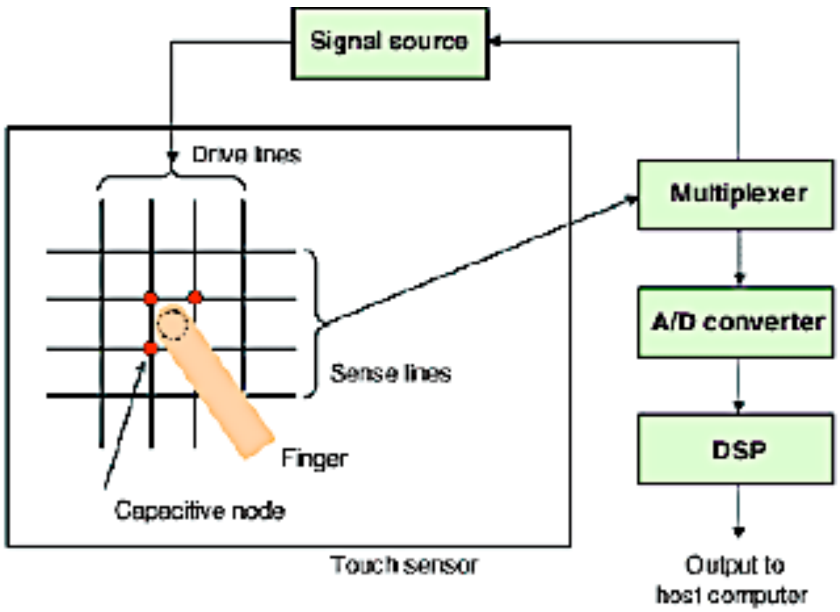


Layer 3 - red pixel

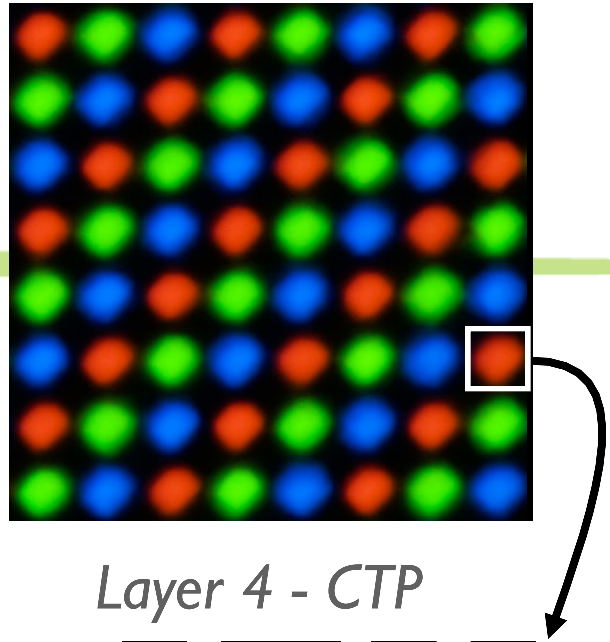
3

3 2 1

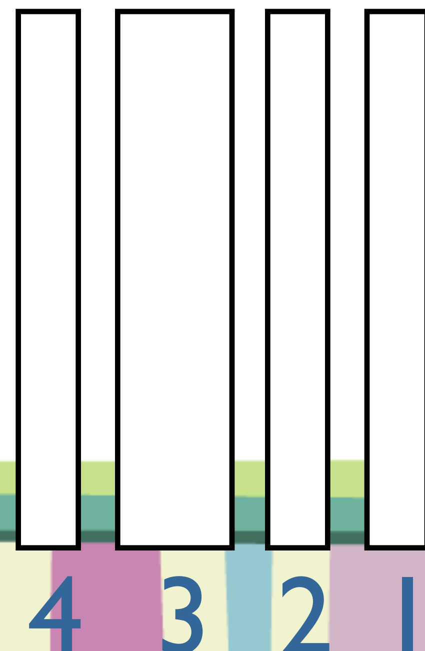
Projected Capacitive Touch Array



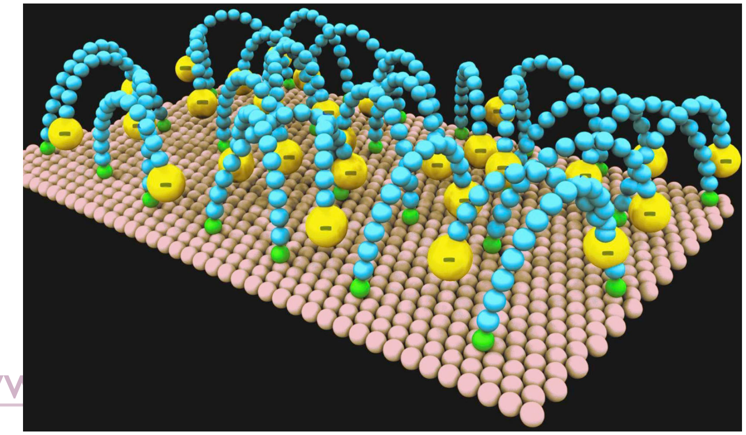
4



Layer 4 - CTP

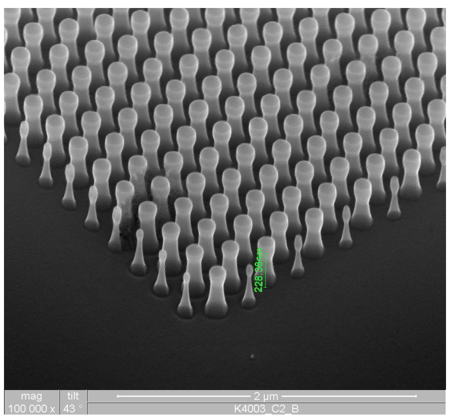


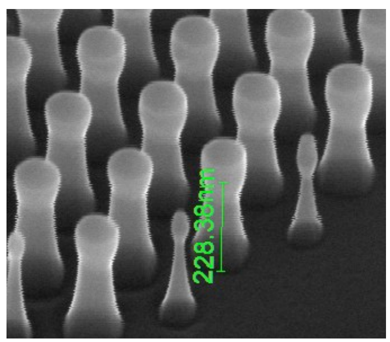
Oleophobic coating



http://www.engin.umich.edu/research/lahann/

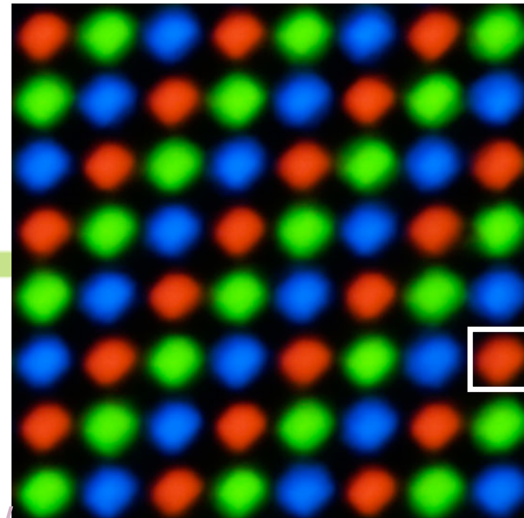
Anti-reflection coating



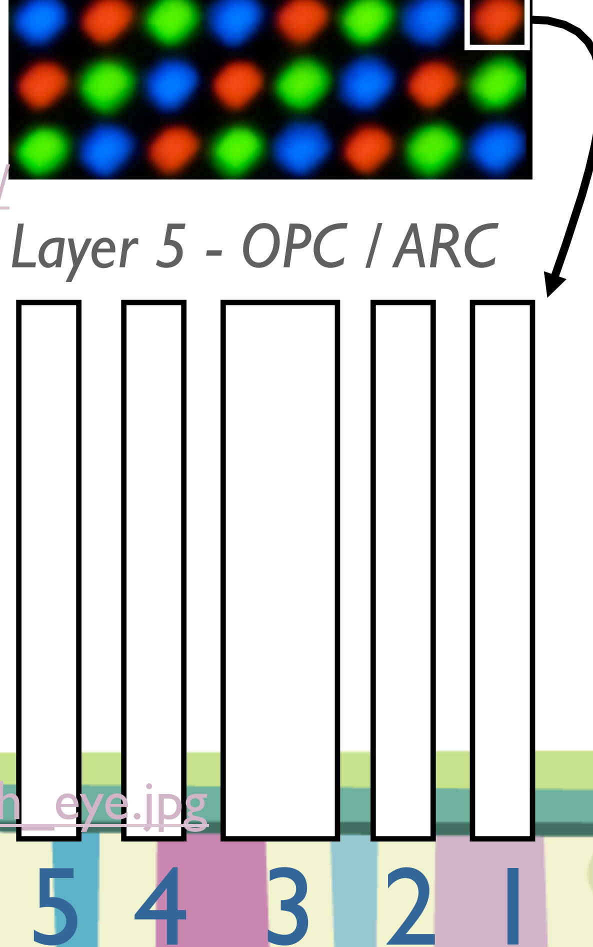


http://users.ecs.soton.ac.uk/dmb/images/moth_eye.jpg

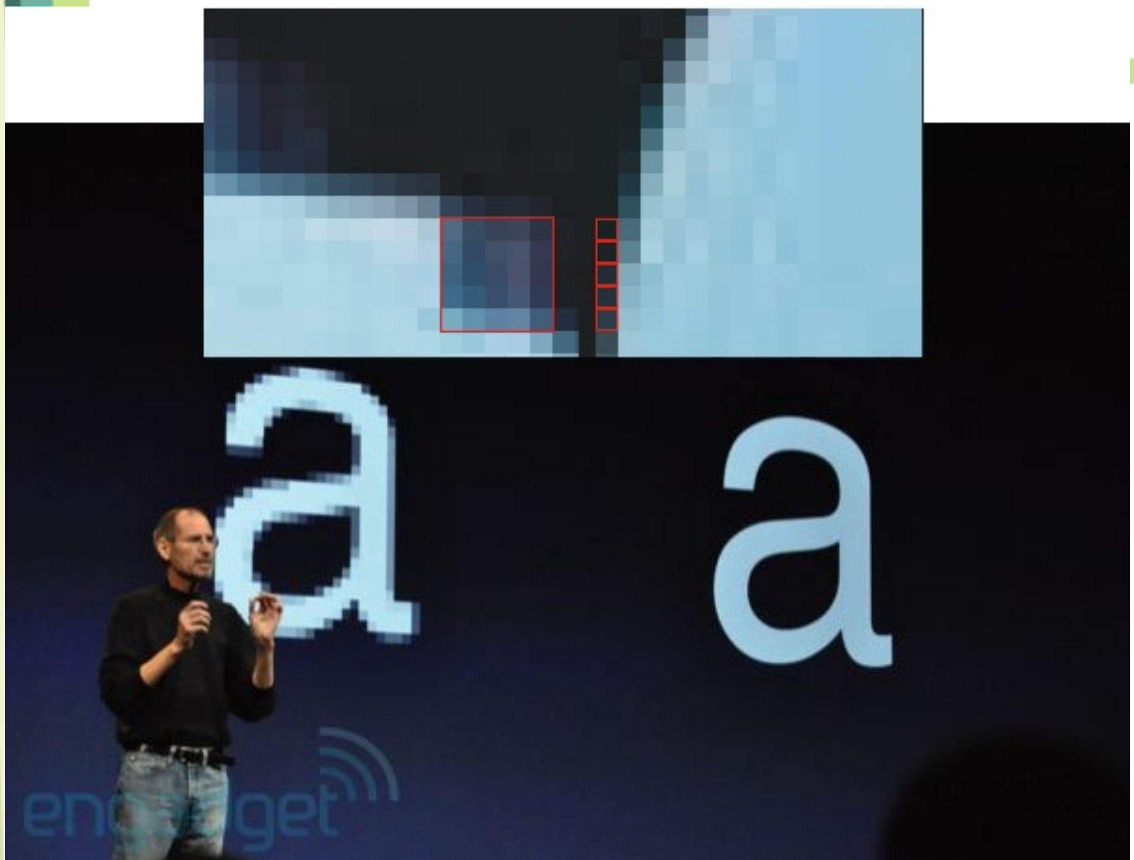
5

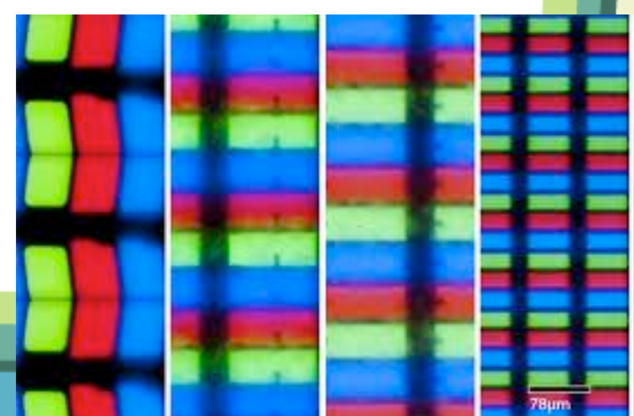


Layer 5 - OPC / ARC



High resolution RGB display...





Switching the gear: Most material do not emit light

- So, how do we see different colors?
- Let's review what we learned in earlier sessions!

Review: What happens when light hit a material?

- Reflect (session 1)
- Transmitted & refract (session 3)
  - Refraction (bending) when index is different
- Absorbed (not reflected; not transmitted)

Absorption of Light

- Some light has just the right energy to cause electrons in molecules to jump to a higher energy state
- The photon energy gets converted to vibration of the atoms

Why does a red apple look red?

- White light has all colors in it
- White light hit the apple, and only red colors bounce back ("reflect")!
- Other colors are absorbed into the apple

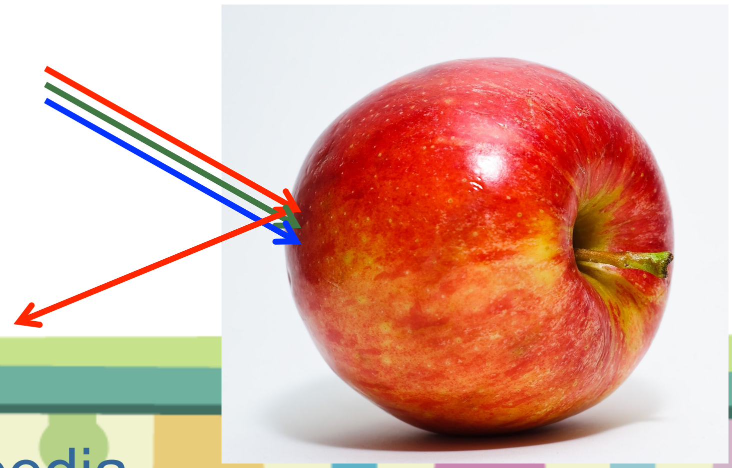
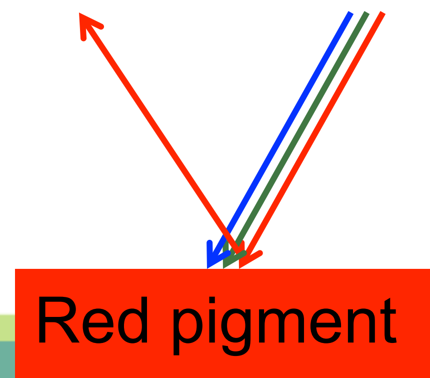


Image of apple from Wikipedia

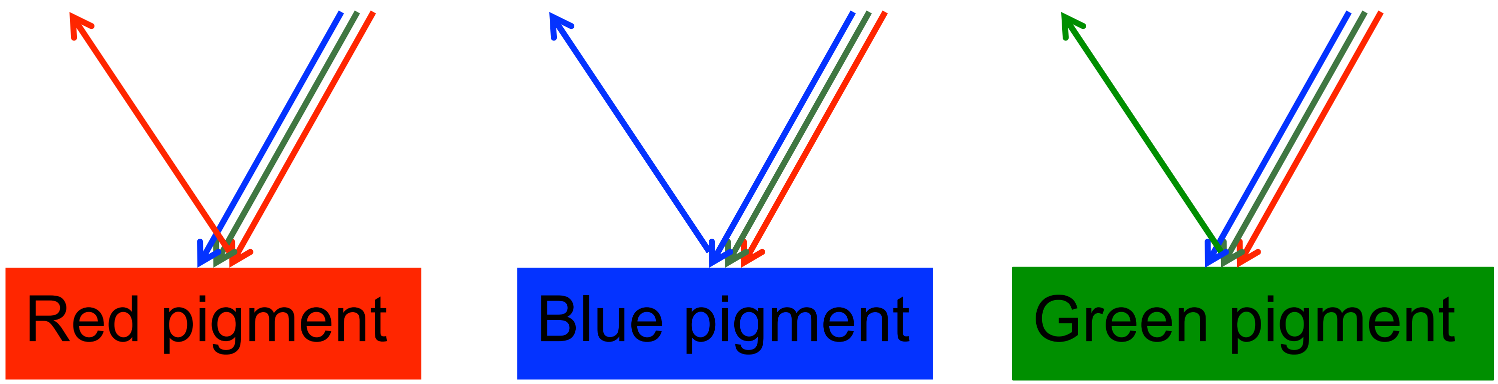
Subtractive color mixing

- When you mix pigments, you are mixing chemicals that absorb colors
- By mixing different pigments, you are actually subtracting colors, rather than adding



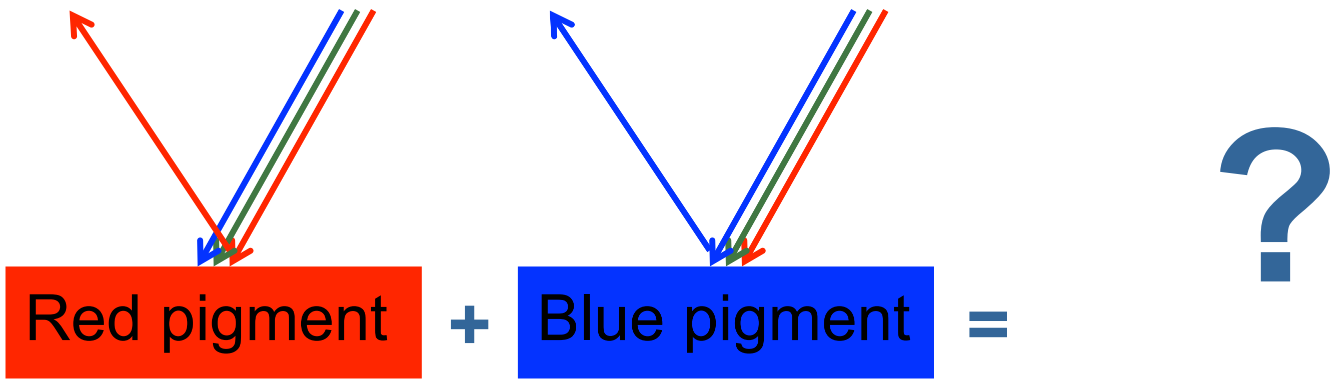
Blue and green are absorbed, or subtracted from white light!

RGB System



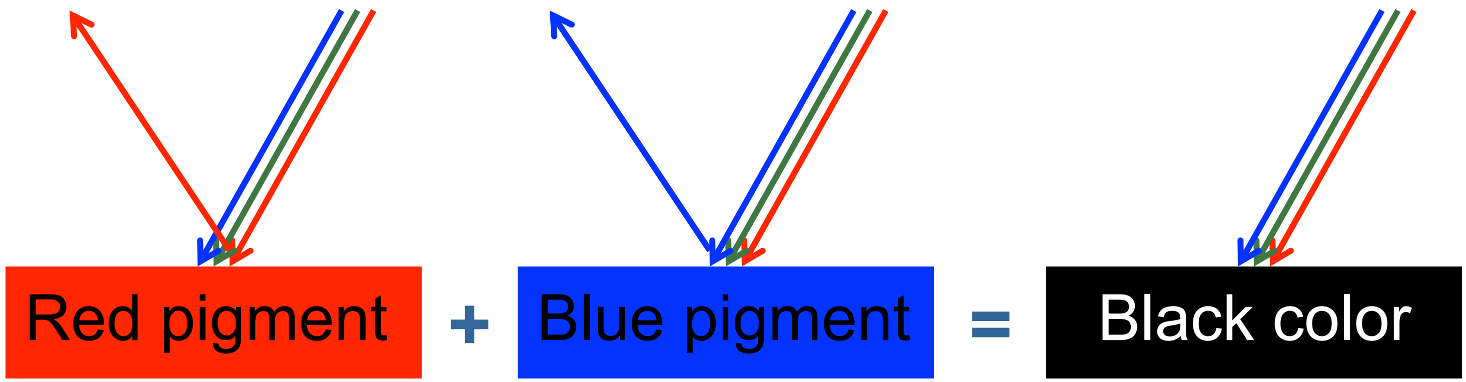
- What's the problem with mixing these colors?

Think about an example…



- In this **thought-experiment**, assume the pigments are perfect absorbers

Think about an example...



- Red pigments absorb blue and green light, and blue pigments absorb green and red light, so no light will come off the surface!

What do you actually see?

- Activity #2: Color mixing of red and blue paint

What do you actually see?

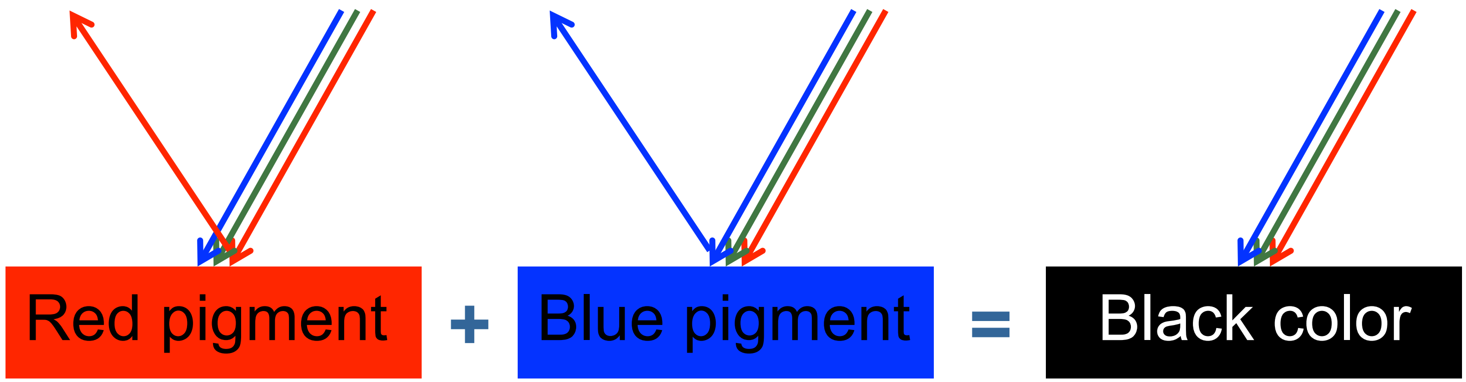
- Dark purple!
- Depending on how much of each is mixed, you may see more blue or red shades

Why do you see dark purple, not black?

Why do you see dark purple, not black?

- This is because the pigments are not perfect absorbers
- Although red pigments mostly reflect red light, there are still some other colors that you don't detect because its overwhelmed by the red light

Problem with using RGB as primary colors for pigments



- Since each color absorbs two (not one) of the colors, you CANNOT generate a wide range of colors!

Solution

- Can we come up with colors that only lacks one of the color component, R, G, or B?
- Yes! Cyan, Magenta, Yellow (CMY system)!

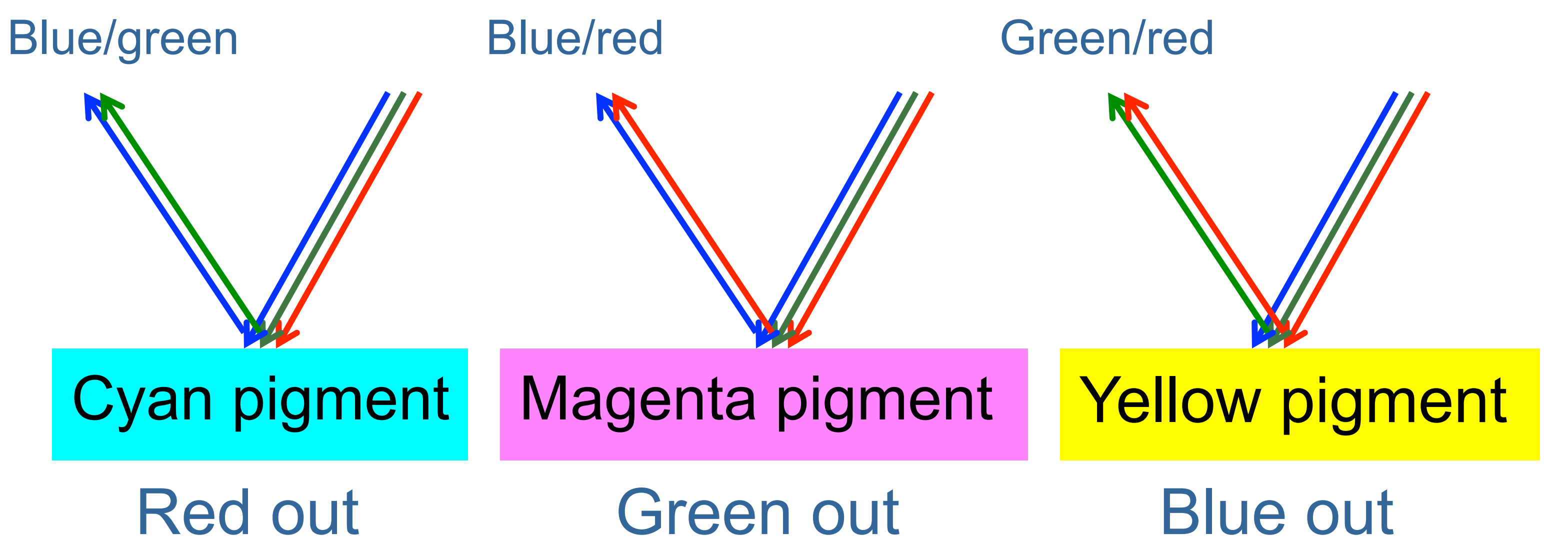
Yellow

Cyan

Magenta

CMY System: A prime color only takes out one color

- Along with black (K), they are often used as printer inks

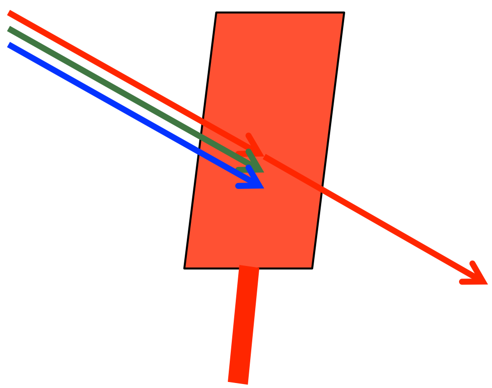


Activity #3: Color mixing with CMY

- Obtain the plate with cyan, magenta, and yellow paint
- Mix about equal amounts of each combination, and describe the resulting color
- Fill out the worksheet

Color Paddles & Transmission

- Color paddles have sheets that transmit only certain colors
- Example: a red paddle



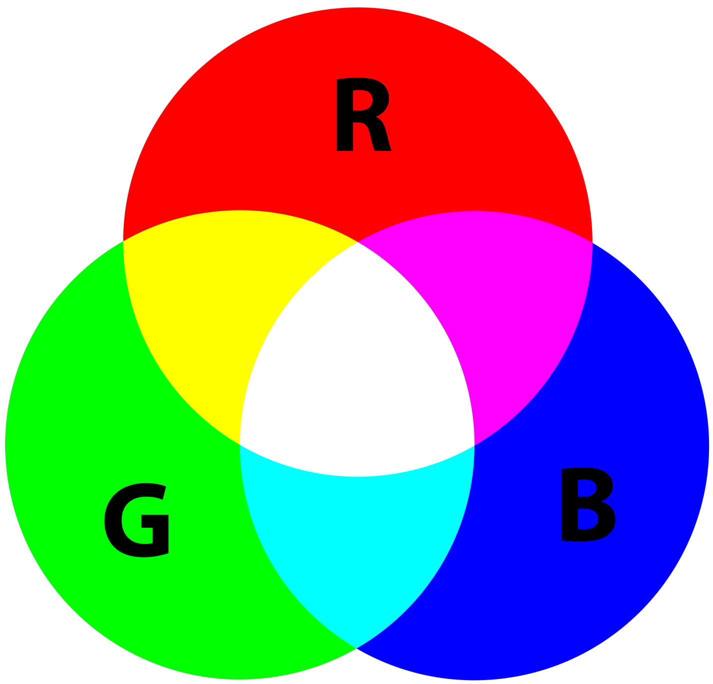
Are colors on paddles additive or subtractive?

- Activity #4

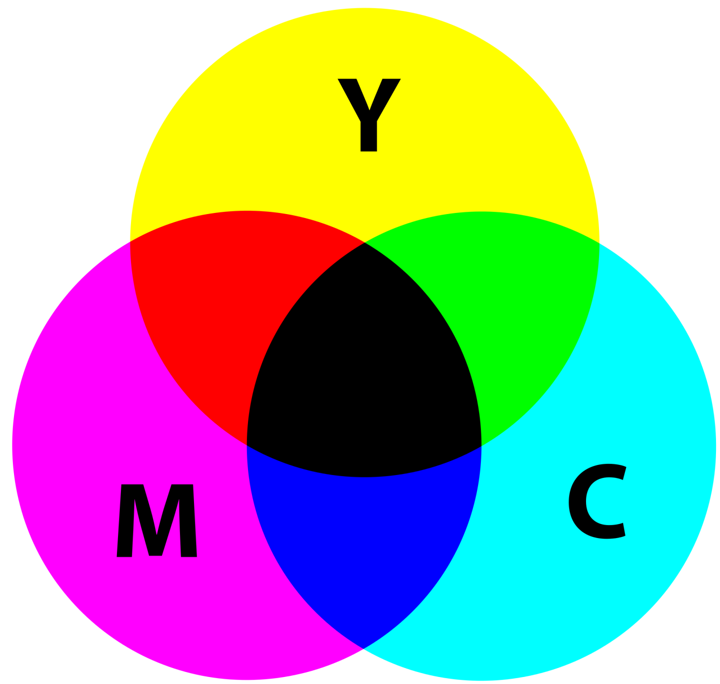
In the News

- https://www.youtube.com/watch?v=QjocalycuiQ

Primary Color Systems: Summary



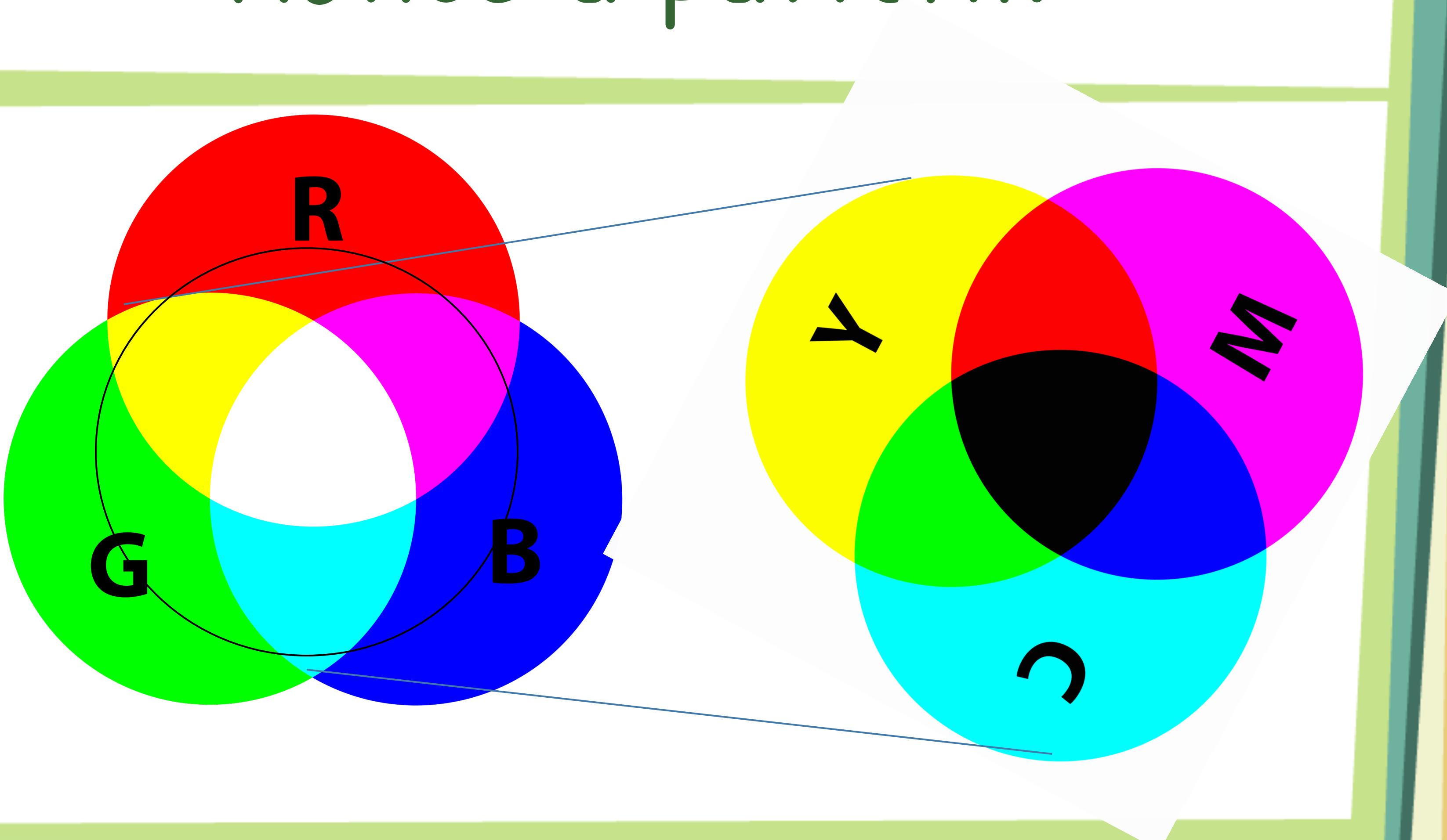
This is how light mixes



This is how pigments mix

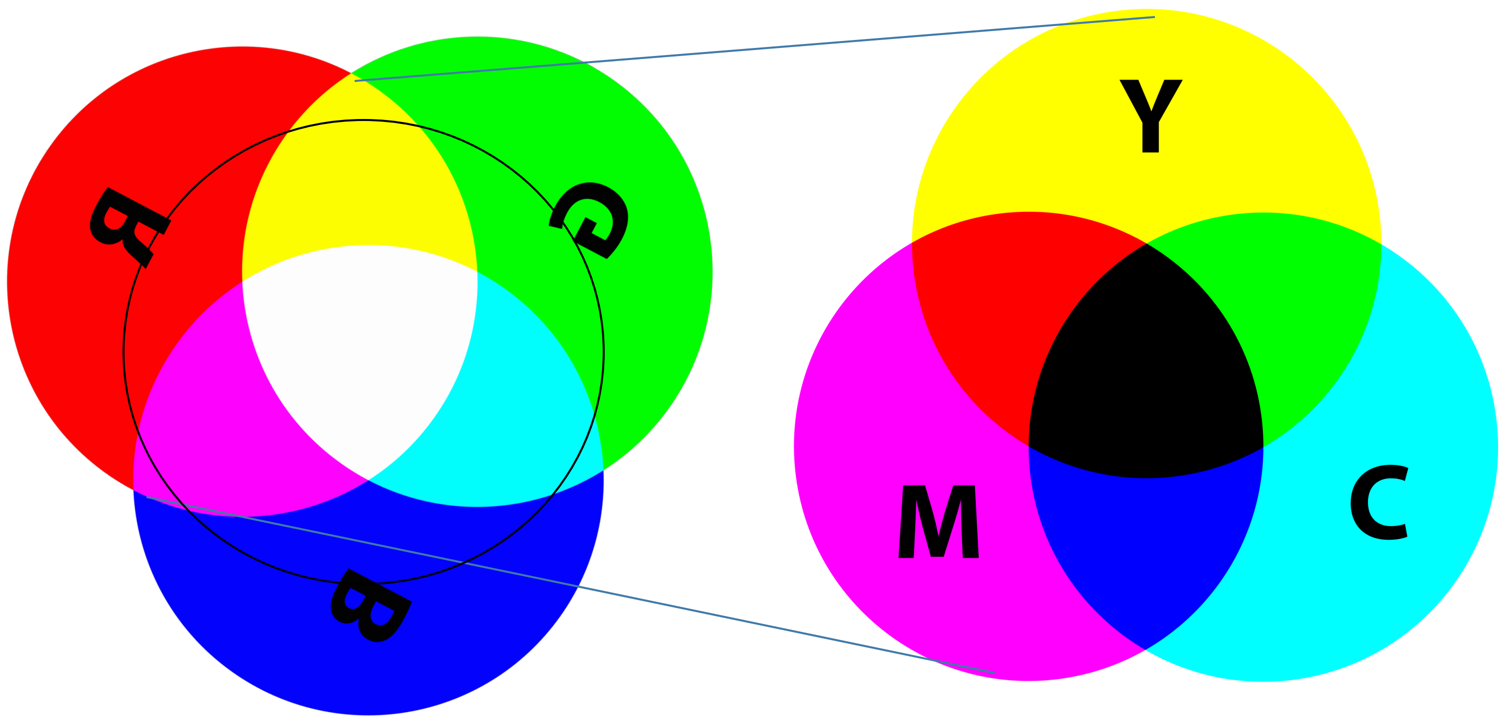
Images from Wikipedia

Notice a pattern?



Images from Wikipedia

Notice a pattern?

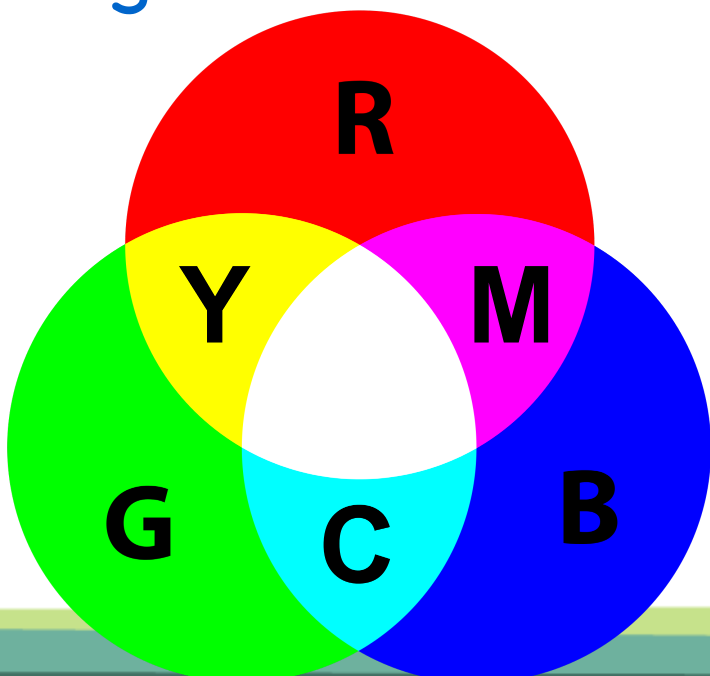


RGB and CMY are complementary colors!

Images from Wikipedia

Complimentary colors

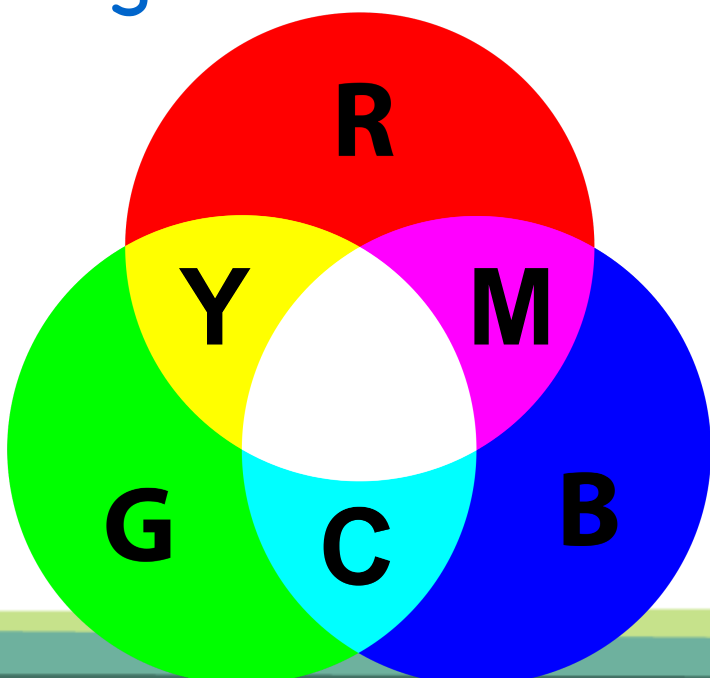
- Complimentary colors are colors of light that adds up to white



Which colors are complementary?

Complimentary colors

- Complimentary colors are colors of light that adds up to white



For primary colors:

- Red & Cyan
- Blue & Yellow
- Green & Magenta

Takeaway…

- White light is composed of multiple colors
- **Red, blue, and green** light add to **white** (light is additive; additive color mixing)
- Pigments of cyan (red absorber), magenta (green absorber), and yellow (blue absorber) can mix to generate a wide range of colors (pigments subtract light of certain colors; subtractive color mixing)
- Colored cellophane sheets (on color paddles) work the same way as the pigments, but what you see is **transmitted**, rather than reflected

Thank you
for your attention and
support for science
education!

Questions?

Work supported by Division of Materials Research,
Condensed Matter and Materials Physics Program

Supplementary Materials for Coaches and Parents

Activity Materials

- Activity 1: Heavyweight vinyl envelopes, a phone or computer screen
- Activity 2 & 3: Washable non-toxic paint, paper plates, cup of water, and paper towels for cleanup
- Activity 4: Flashlight & color paddles