

# Liquid Crystal Displays

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Practical Optics Seminar  
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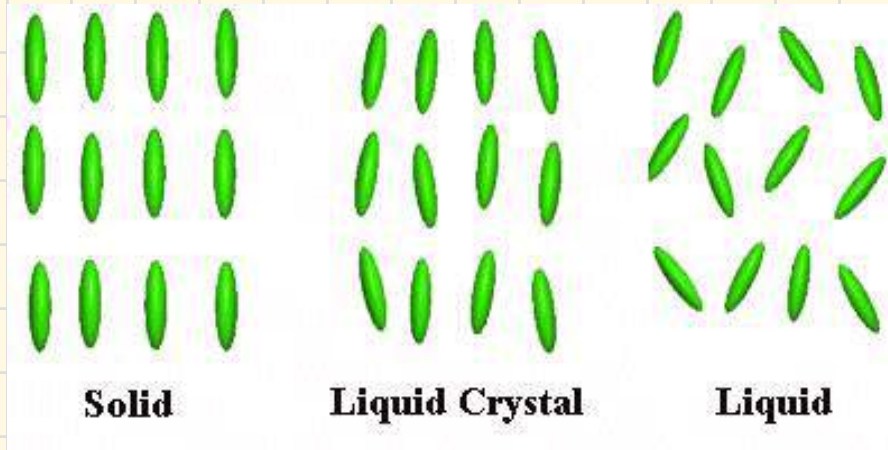
# Overview

- LC basics
- LC types and applications
- Grayscale LCD
- Color LCD “reverse engineering”
- Conclusion



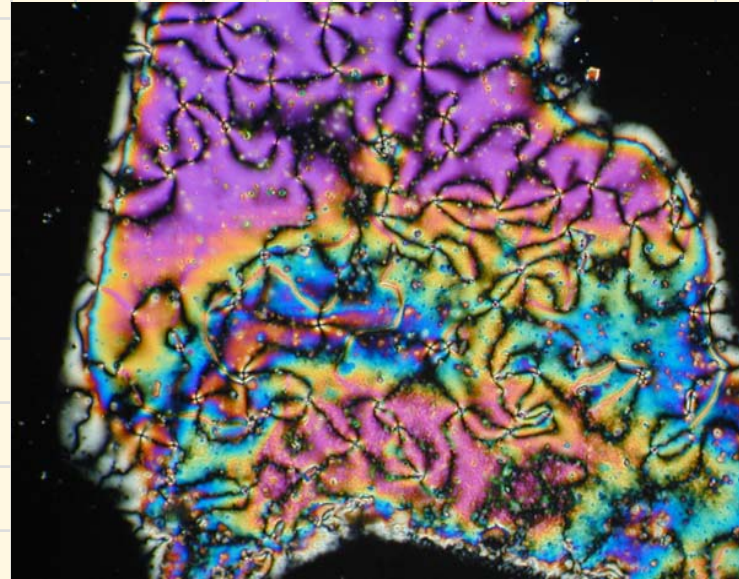
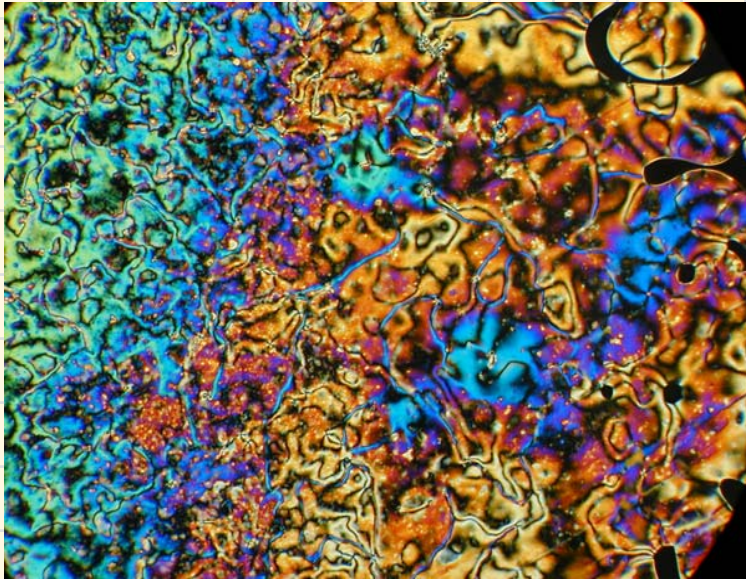
# Liquid crystals

- 1888—Friedrich Reinitzer discovered two melting points of cholesteryl benzoate
- LCs are anisotropic without a 3D crystal lattice



# Why do we care?

- Liquid crystals have interesting and useful optical properties



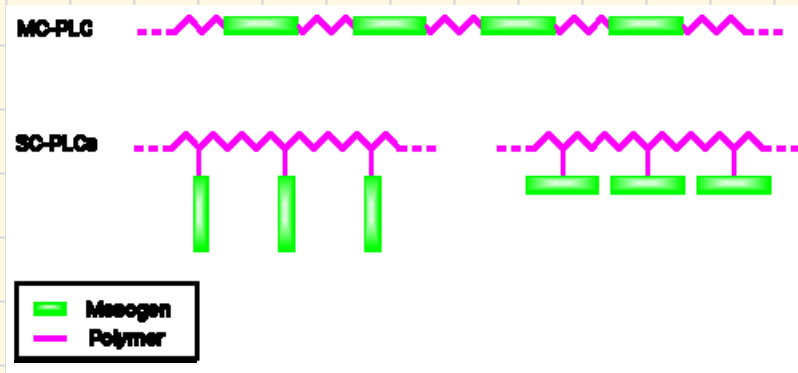
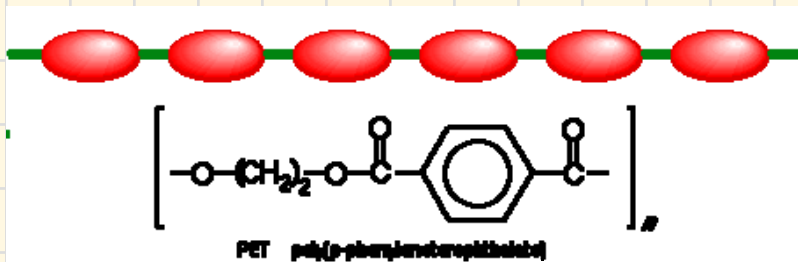
# Liquid crystal classifications

- Thermotropic
- Lyotropic





# Polymer LCs



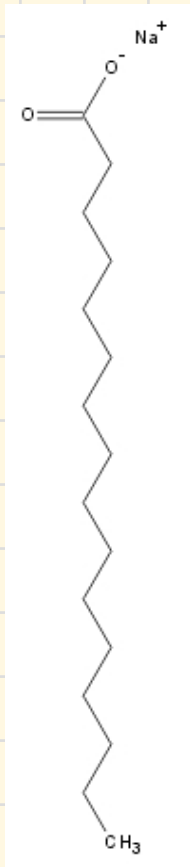
- Flexible long chain organic molecules
- Mesogens added to polymers introduce rigid structure, prevent tangling
- Found in displays, waveguides, EO modulators, Kevlar!

# Thermotropic LCs



- Temperature sensitive
- Molecule twists as  $f(T)$
- $R=f(\lambda, T)$
- $\mu=\mu(\lambda, T)$
  
- Found in mood rings, thermometers

# Lyotropic LCs



- Temperature sensitive
- LC properties induced with introduction of sufficient solvent concentration...

# Lyotropic LCs

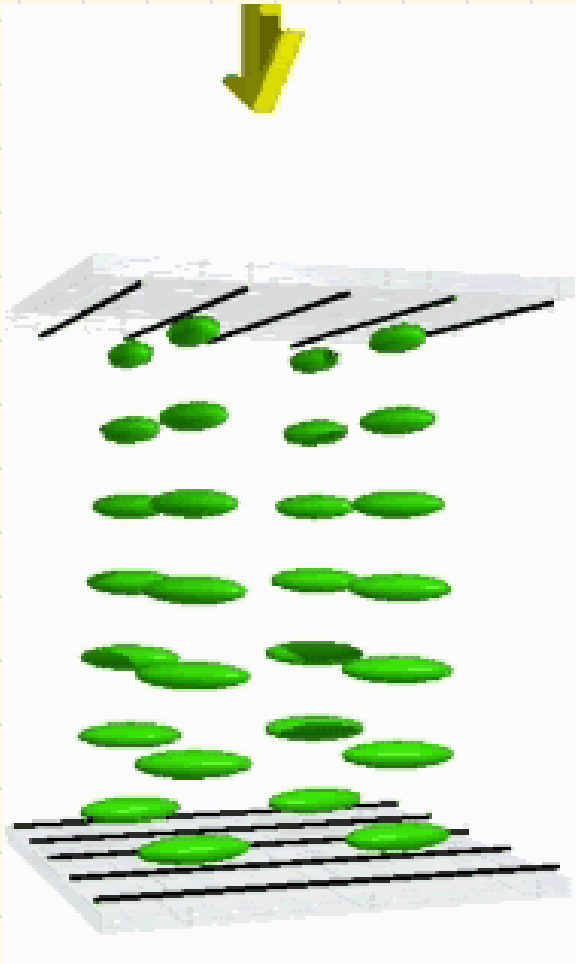


- Temperature sensitive
- LC properties induced with introduction of sufficient solvent concentration...
- Found in soap sludge, cake batter, biological membranes

# Grayscale LCD operation



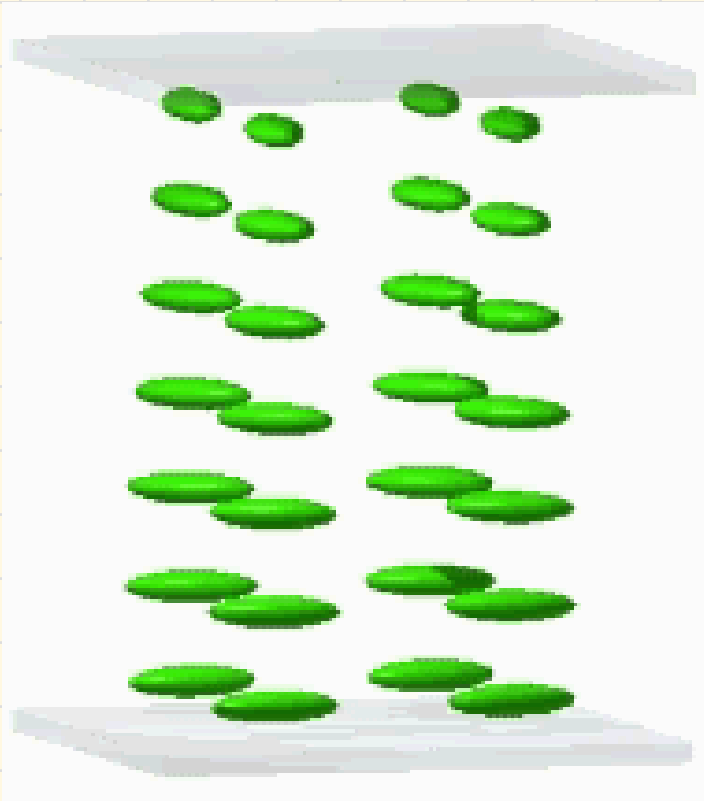
# LCD operation



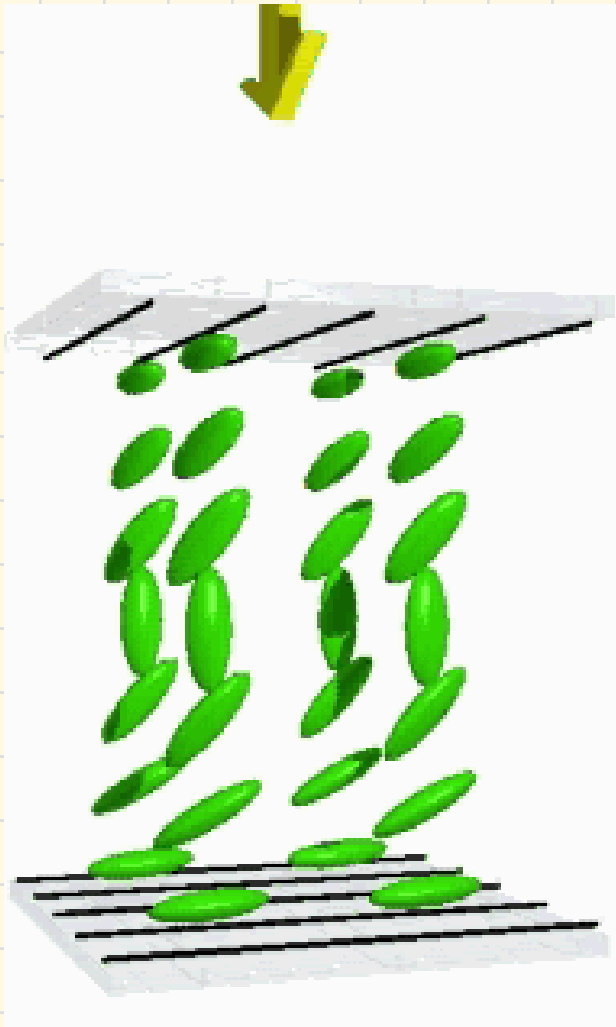
- Liquid crystal placed between grooved crossed polarizers
- Crystal orientation twists through bulk
- Liquid crystal acts as half wave plate

# LCD operation

- Application of electric field across plates causes LC rotation



# LCD operation



- Application of electric field across plates causes disorder in LC twists
- Light cannot pass through second polarizer
- 50% transmission

# Dissecting an LCD



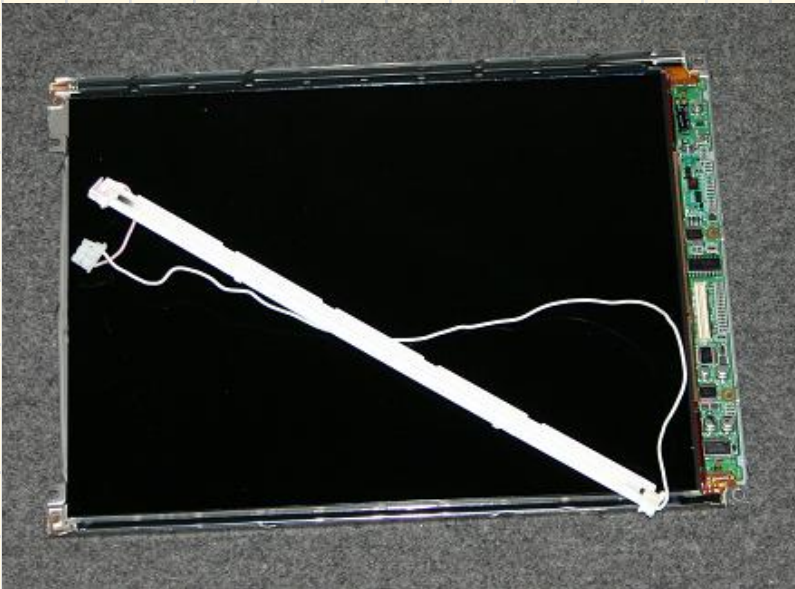
# Dissecting an LCD

how to make a mess in under 30 minutes...

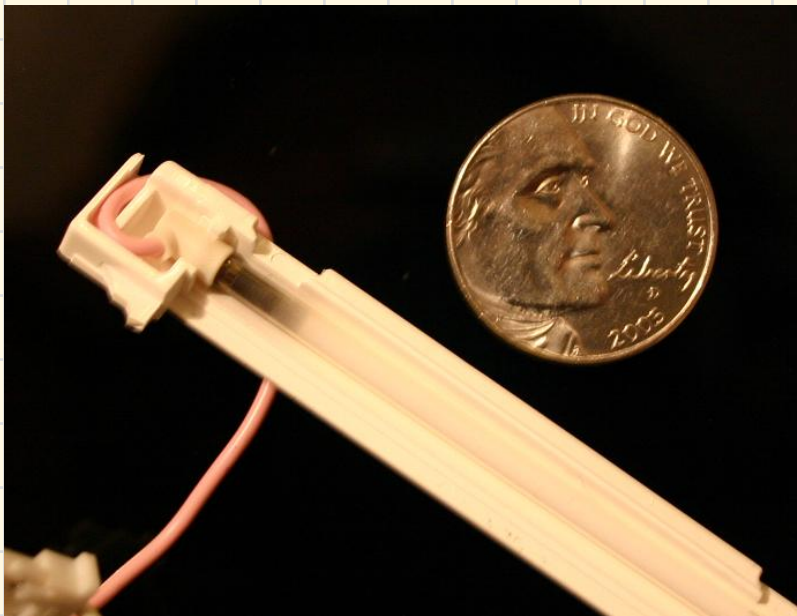


# Illumination

- LC panel backlit by fluorescent bulb



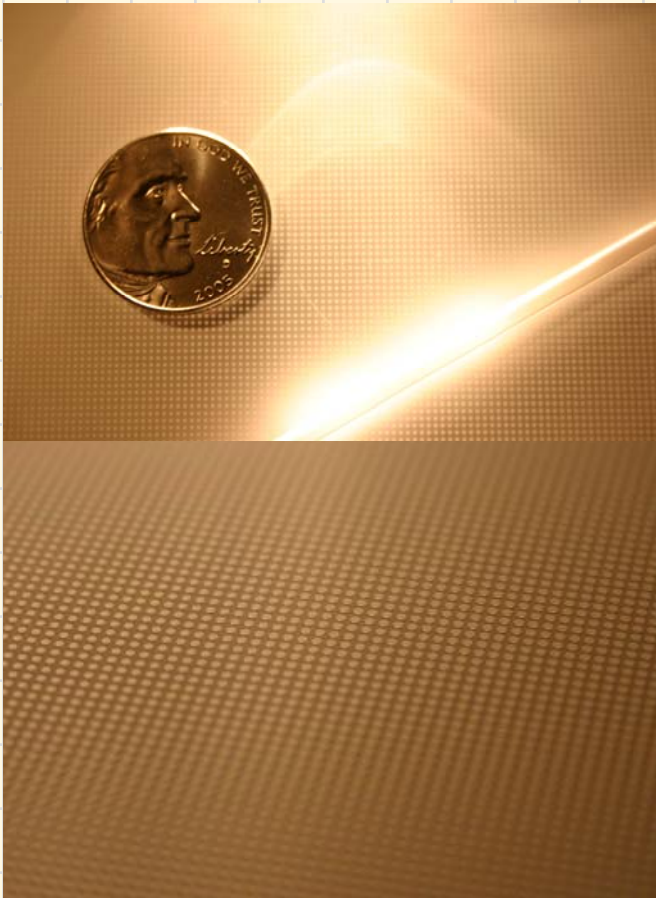
# Illumination



- LC panel backlit by fluorescent bulb
- 2-3 mm diameter x length of display
- 30k-40k cd/m<sup>2</sup>



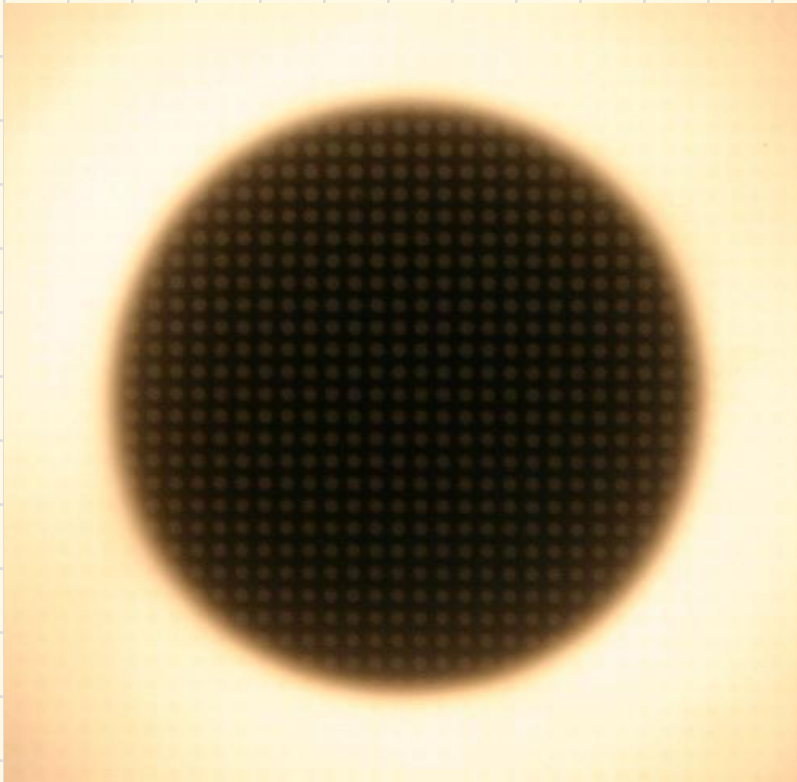
# Dispersive elements



- Waveguide with scattering spots



# Dispersive elements

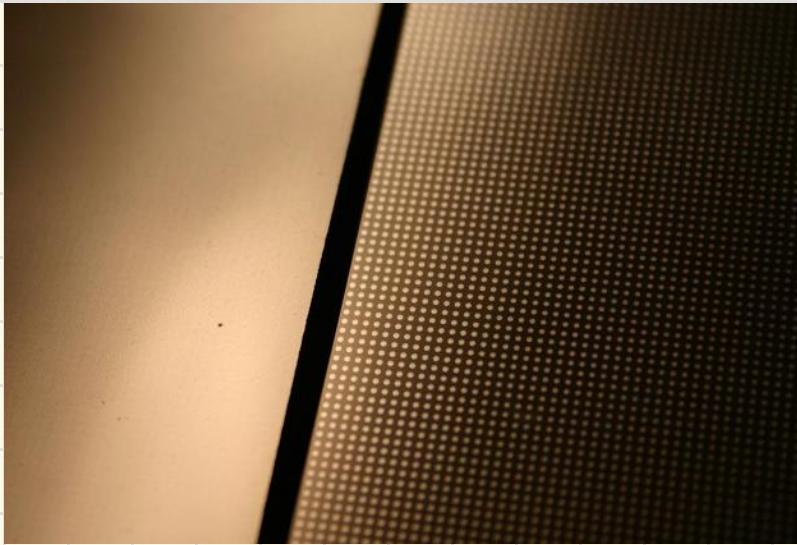


- Waveguide with scattering spots



# Dispersive elements

- Waveguide with scatter spots
- Diffusing layer



# Dispersive elements



- Waveguide with scatter spots
- Diffusing layer
- Two sheets of funny looking plastic...



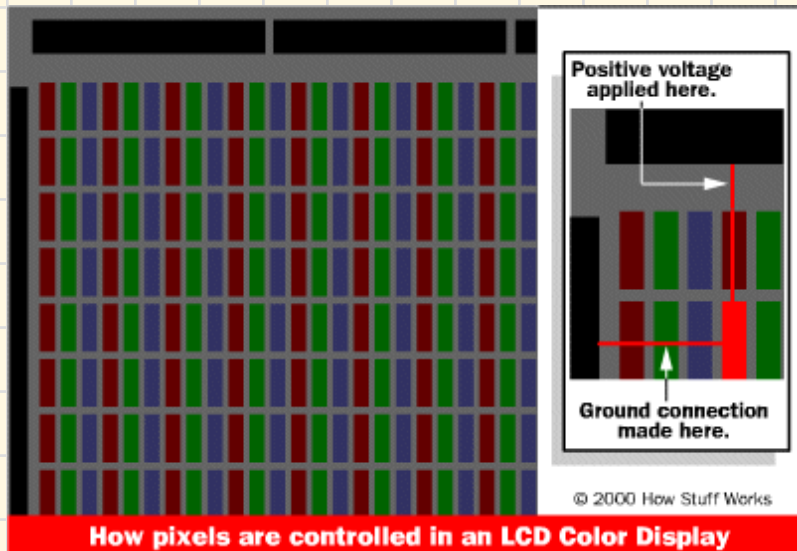
# Dispersive elements



- Waveguide with scatter spots
- Diffusing layer
- Two sheets of funny looking plastic...  
crossed diffraction gratings!

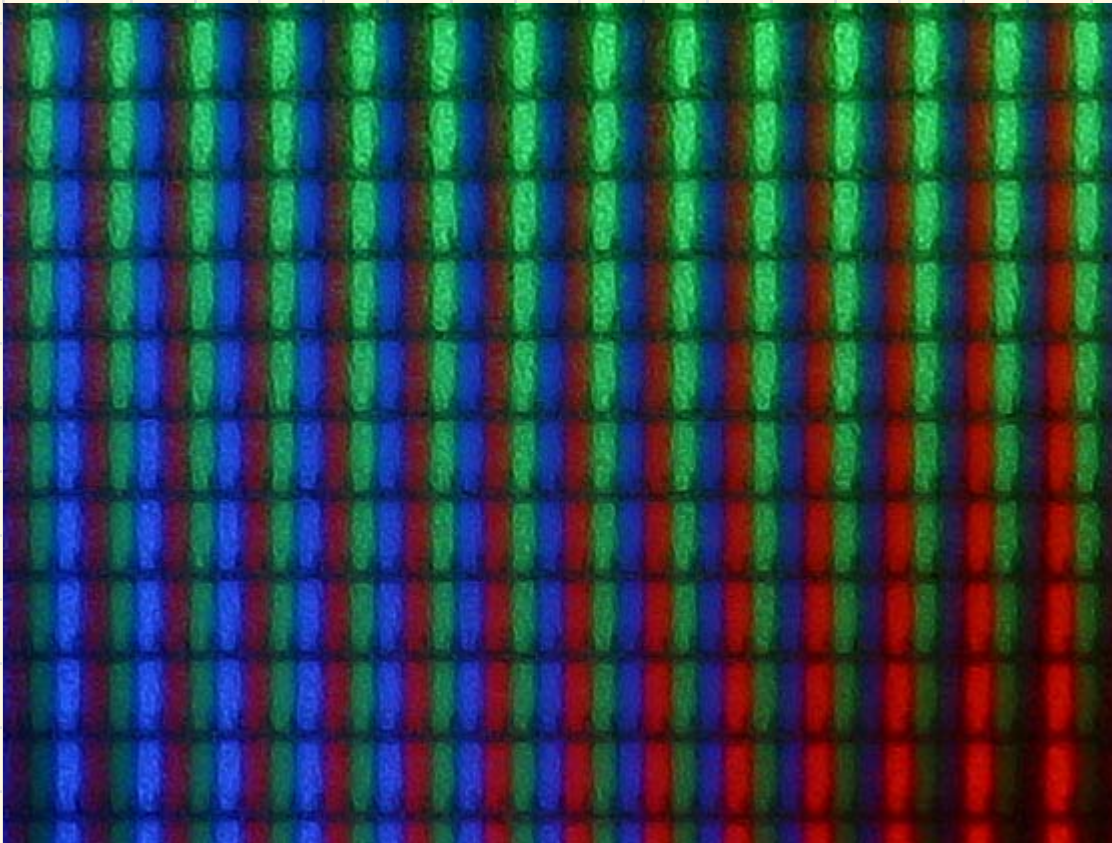


# Active matrix panel



- RGB triad/pixel
- Individually turned on/off
- Eye blends colors
- Amount of activation controls brightness
- Color filters reduce transmission

# Active matrix pixels



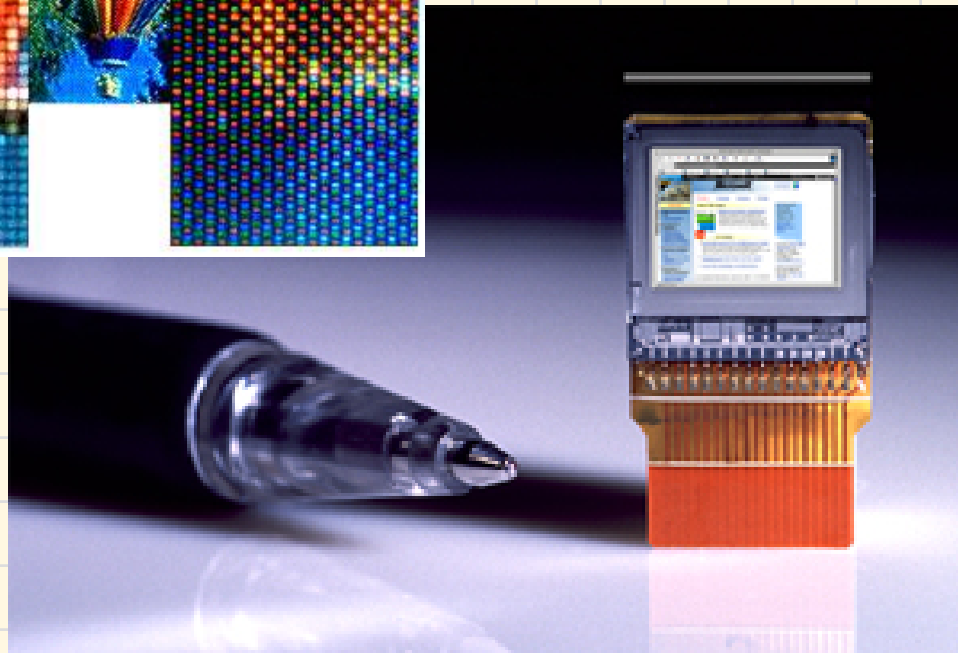
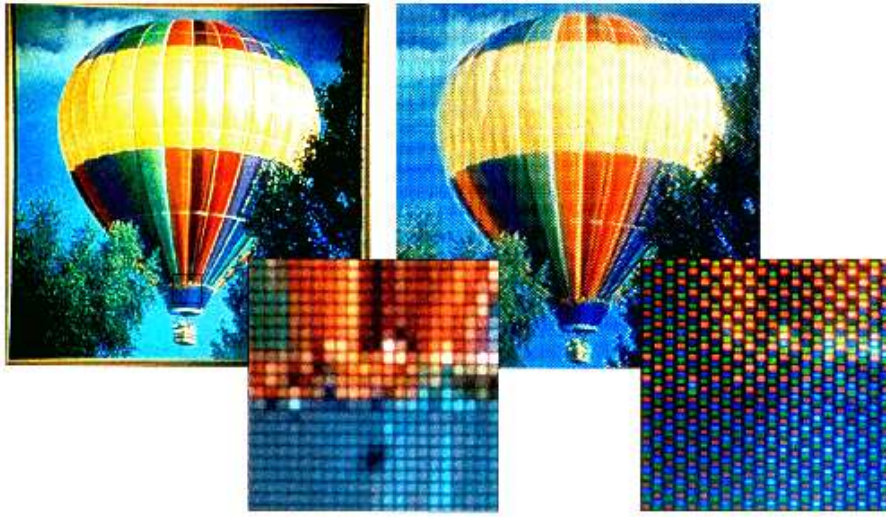
<http://www.dansdata.com/images/sm152b/subpixels560.jpg>

# FLC displays

- Ferroelectric LCs used as active color filters (field-sequential color)
- Fast switching time ( $\sim 70 \mu\text{sec}$ )
- Eye “integrates” individual colors
- Whole pixel appears as one color
- Better transmission/pixel
- Can make microdisplays with LCoS



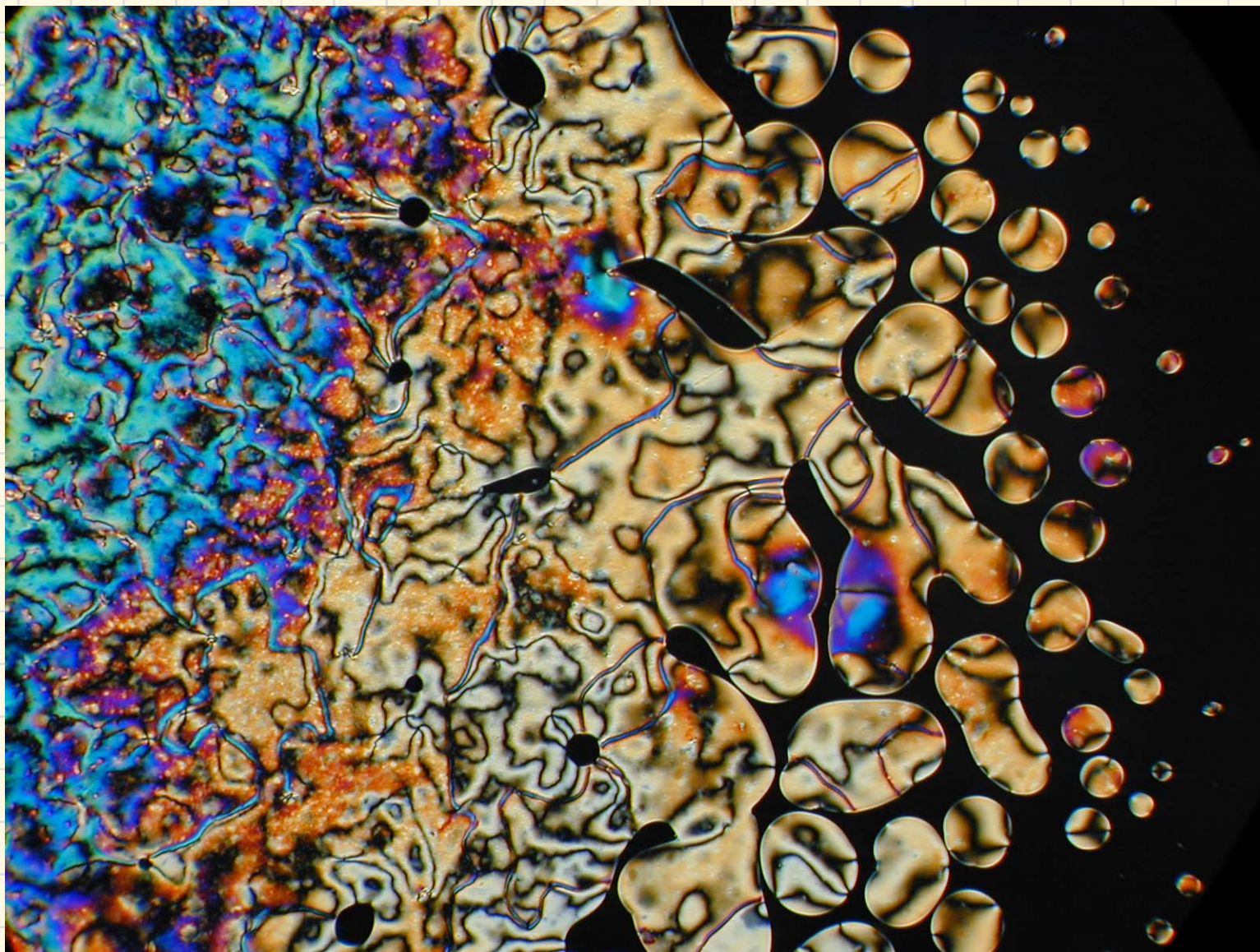
# FLC pixels



# Conclusions

- Liquid crystals have many optical applications
- LCDs combine illumination, polarization optics to optimize performance
- FLCs have improved color/intensity performance, small footprint





*Liquid Crystal Art Gallery*  
<http://www.sfu.ca/chemistry/faculty/Williams/research/art%20gallery.html>

# References

- Pochi, Yeh, and Claire Gu. Optics of Liquid Crystal Displays. New York: Wiley, 1999.
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