“Field Sequential Color in Mobile Applications”

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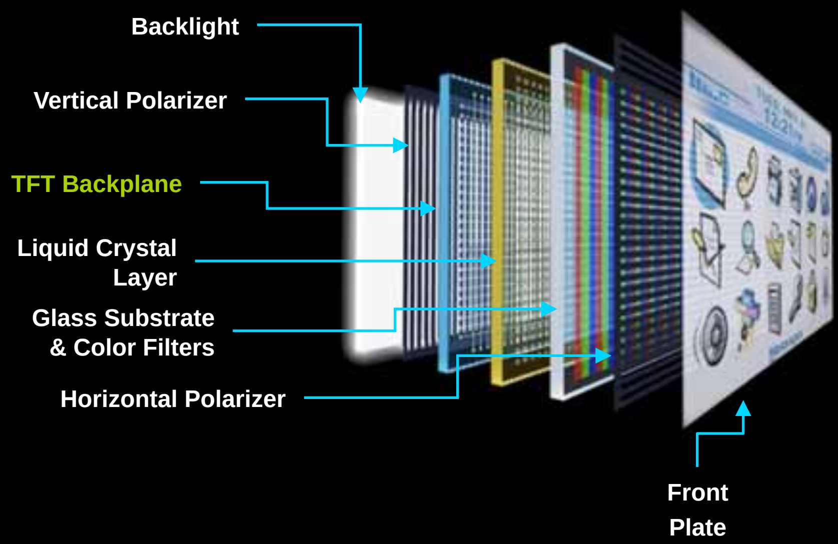
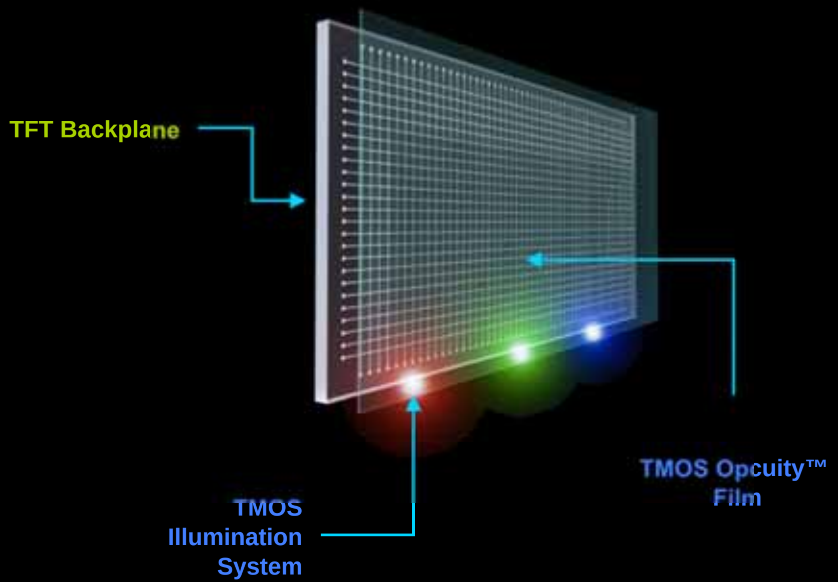
Discussion Points

- Time Multiplexed Optical Shutter (TMOS)
  - Technology Overview
  - Performance Advantages
- Field Sequential Color (FSC)
  - Challenges and Solutions

Technology Overview

Layer Comparison





LCD Layers

TMOS Layers

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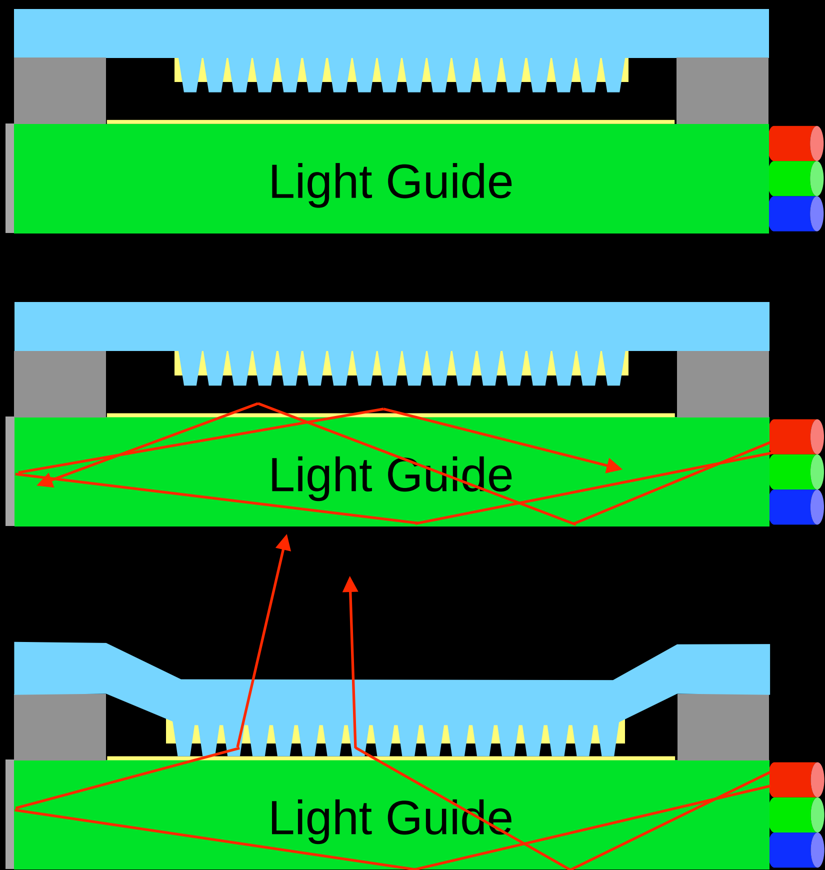
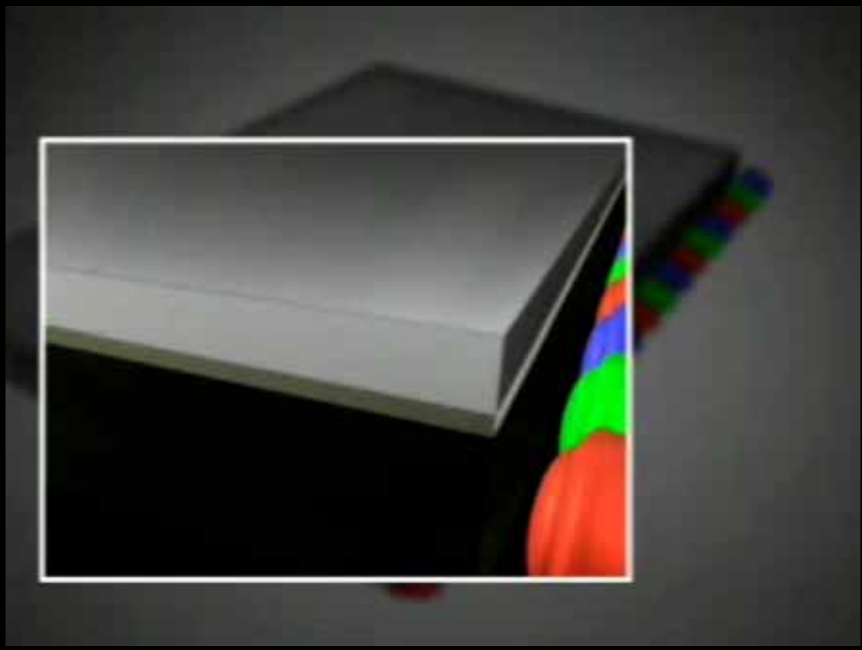
Pixel and Light Guide Operation

Single Pixel Activation – Electrostatic Attraction





NOTE: Layers and Deformation Not to Scale

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TMOS Prototypes

Demonstrated three prototype architectures

Active Matrix

(See next slide for video)

Direct Drive – Dot Matrix

Direct Drive – Segment

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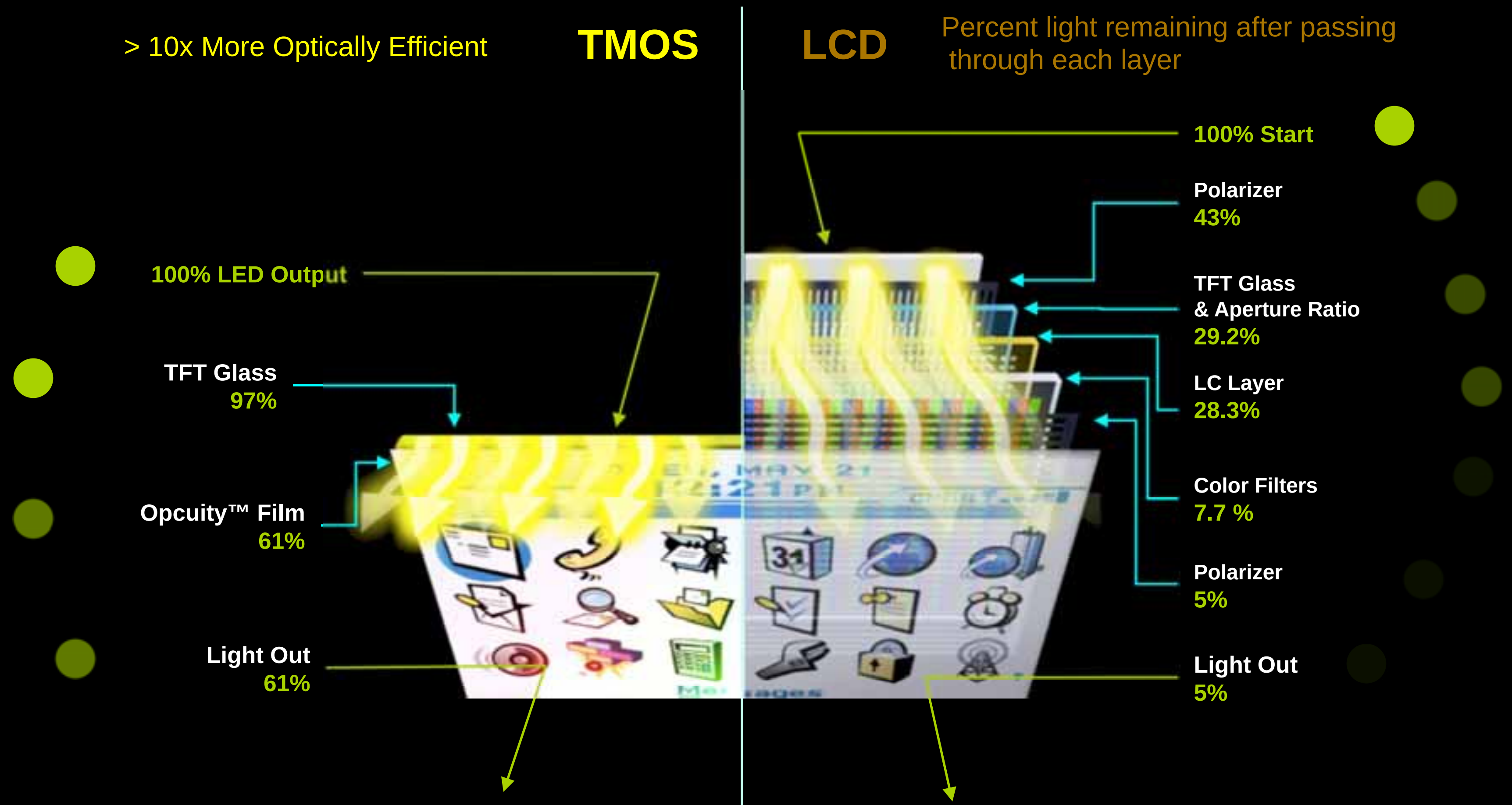
TMOS Active Matrix TFT Display

Performance Advantages

Optical Efficiency: TMOS* vs. LCD



* Estimated performance of TMOS based on modeling and empirical measurements to date

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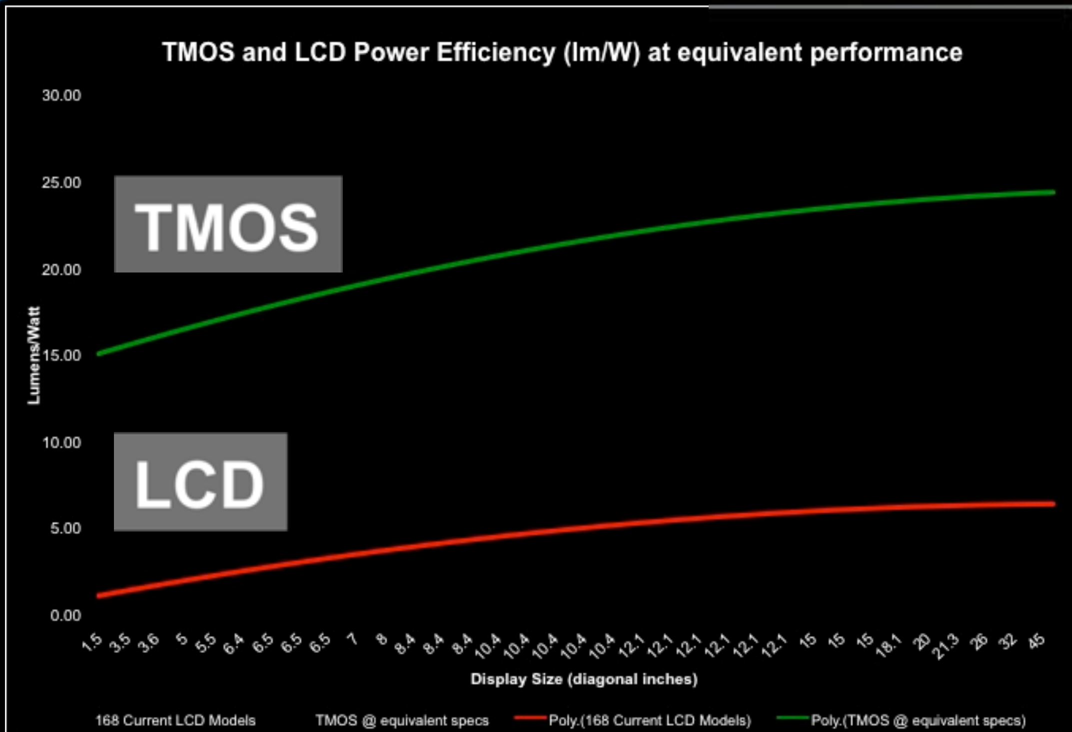
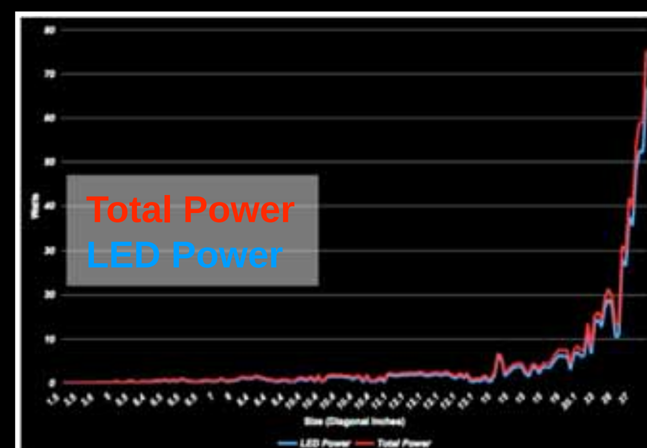
Power Efficiency (lm/W): TMOS* vs. LCD



6x to 10x more efficient (with identical specs.)

LEDs consume majority of energy in TMOS



* Estimated performance of TMOS at 20V pixel operation

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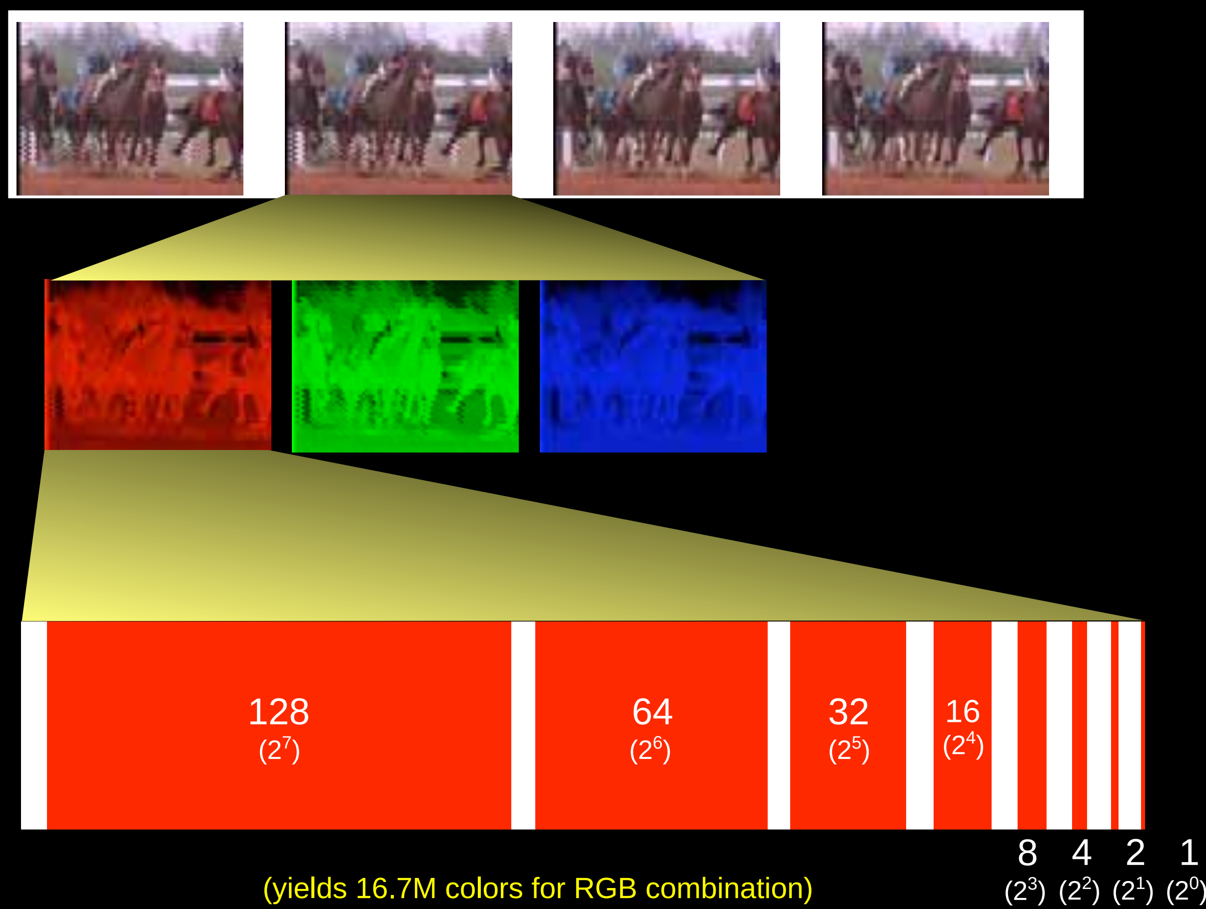
FSC Challenges and Solutions

Field Sequential Color

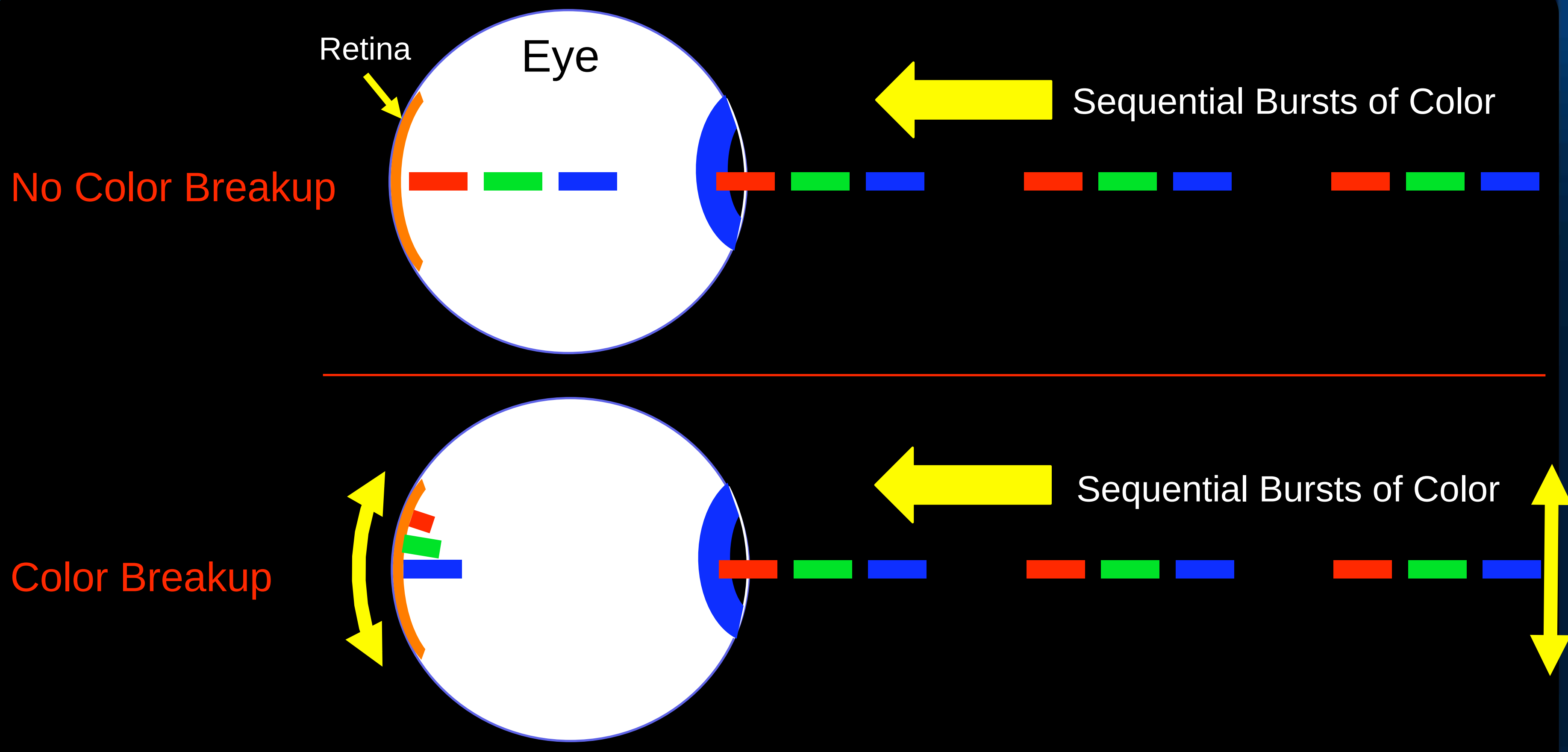
Video Frames

Primary Color Sub-Frames

Binary Weighted Grayscale Bit Planes



Color Breakup



- If either the eye or the observed object move too quickly, the bursts of color can hit different parts of the retina causing color breakup.

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Color Breakup Mitigation – Speed

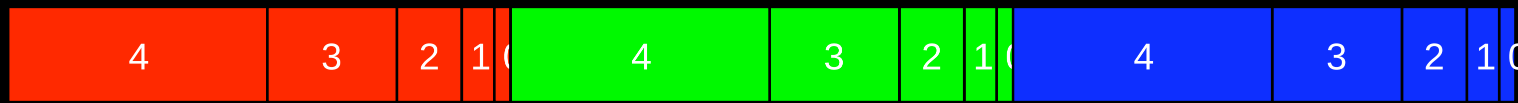
- If color bursts reach the eye within 4ms, it has been shown that color breakup is eliminated.

- TMOS Pixel speed
  - <2μs response time (1,000x faster than LCD)

- TMOS Video frame rates
  - >150 fps (FSC Field Rate is >3600/sec)

Color Breakup Mitigation – Non-contiguous Primary Colors

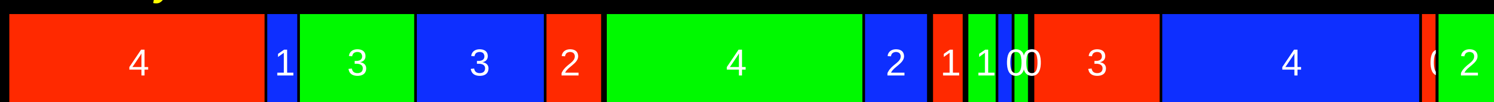
Traditional Field Sequential Color with Binary weighted Pulse Width Modulation



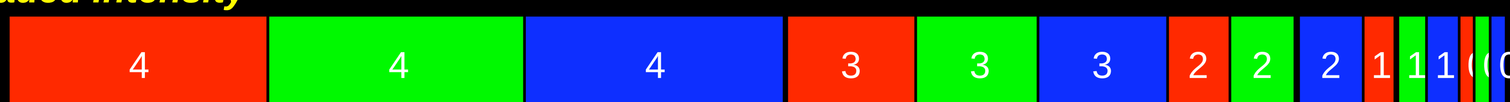
- TMOS not restricted to contiguous primary color sub-frames
- Bit Rearrangement -- R-G-B bits can occur in any order
  - The Red light need not be emitted from the display in a single contiguous time segment within a frame

Two Variations of Bit rearrangement

Averaged Intensity

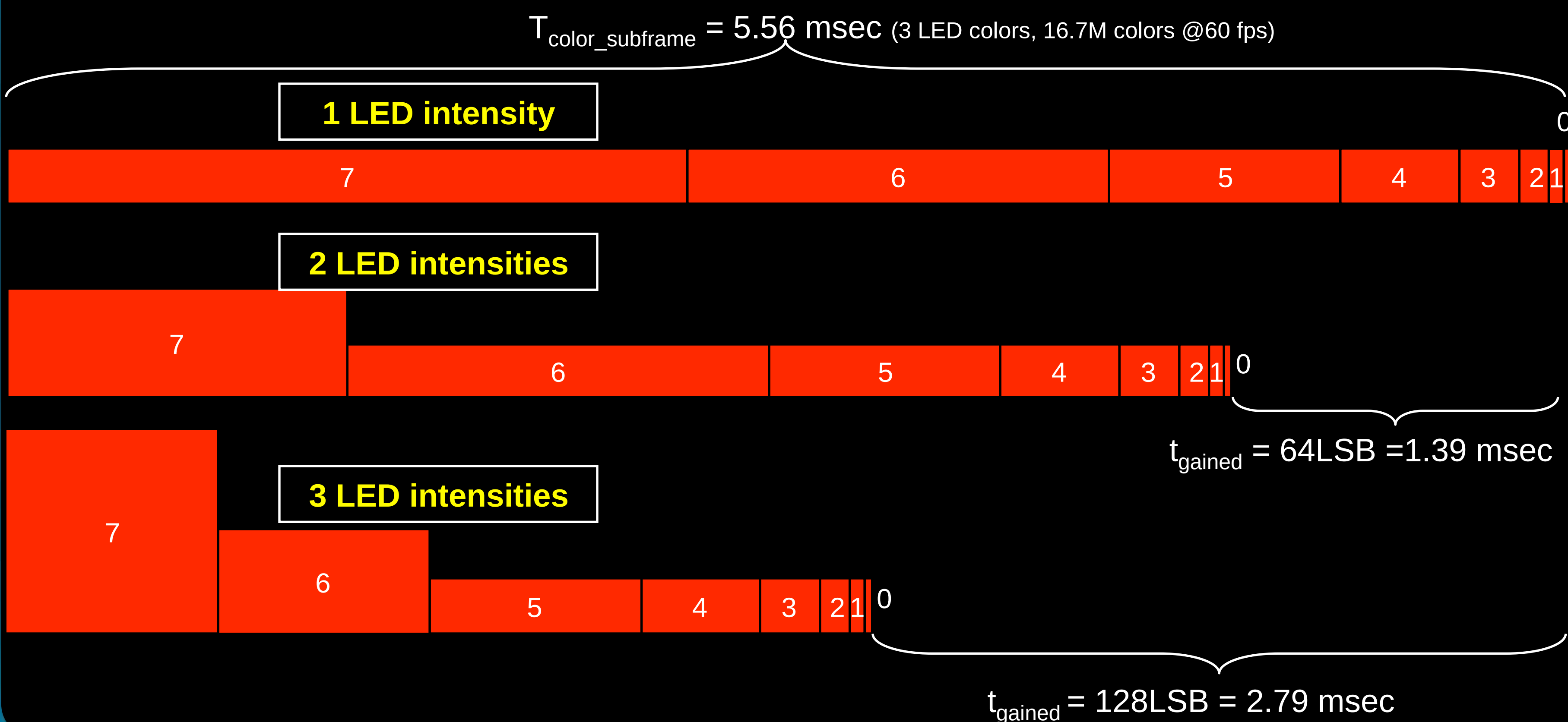


Front Loaded Intensity



Color Breakup Mitigation – Intensity Modulation to Shorten Overall Frame Time

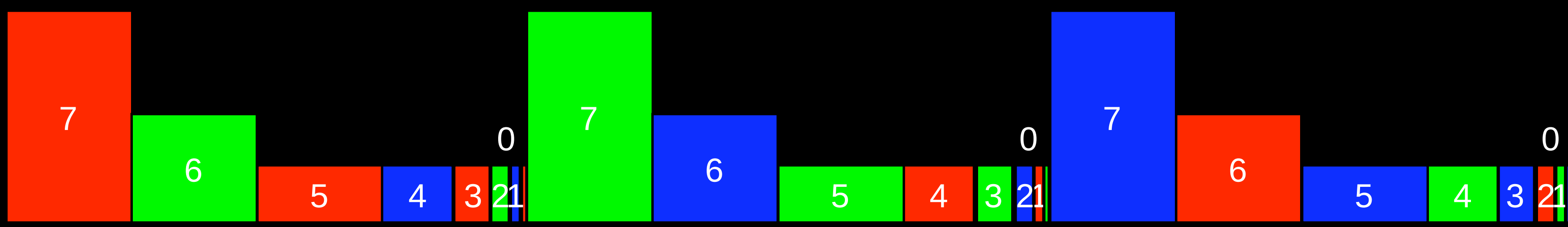
- As number of different LED intensities increase, the time required for each color subframe decreases



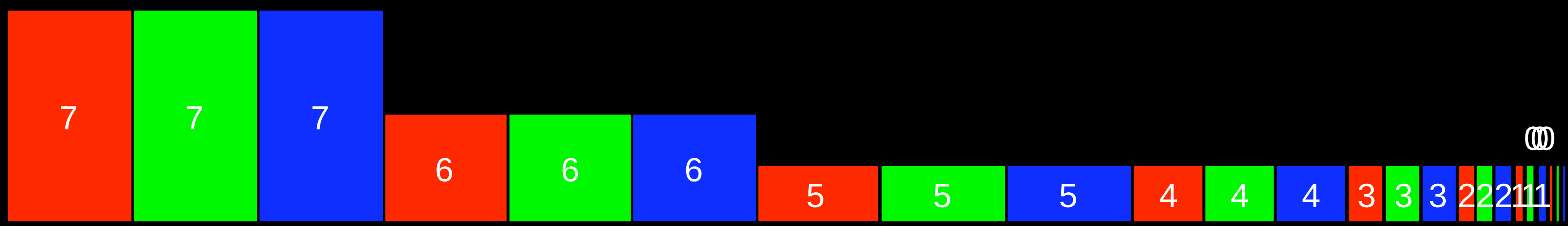
Color Breakup Mitigation –
Non-contiguous Primaries with LED Intensity Modulation

Three LED intensities

Averaged Intensity

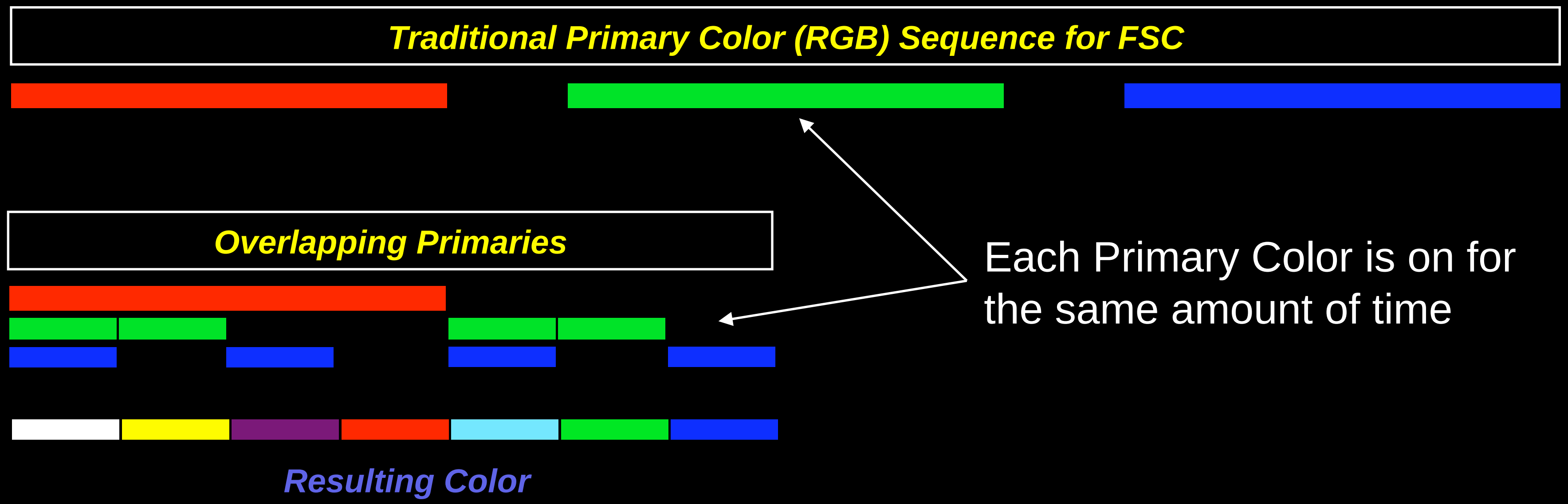


Front Loaded Intensity



Color Breakup Mitigation –
FSC Compression to Shorten Overall Frame Time

- Overlapping Primaries can shorten the overall frame time
  - Amount of savings depends on program content
- We have demonstrated savings of over 50% with video content



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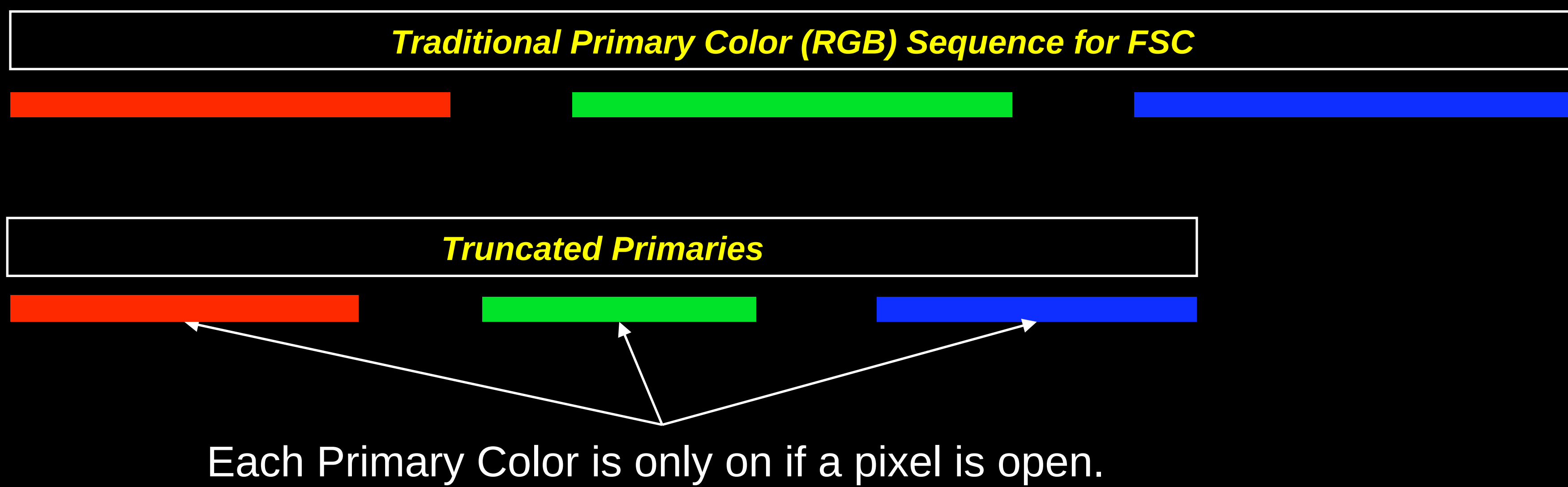
Color Breakup Mitigation – Primary Truncation to Shorten Overall Frame Time

- Turning off the light source when no pixels are open can shorten the overall frame time
  - Amount of savings depends on program content



Conclusion

Questions?

Thank you.