Achieving Rec 2020: How Close is Close Enough

SID MidWest Chapter Meeting

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3M

Display Trend – Improved Visual Experience through Color

Large & Thin

85”+ Diagonal

Entitlement
Thinness

High Resolution

Retina

4K & 8K Resolution

Latest - High Color

Broadcast
Standards

OLED

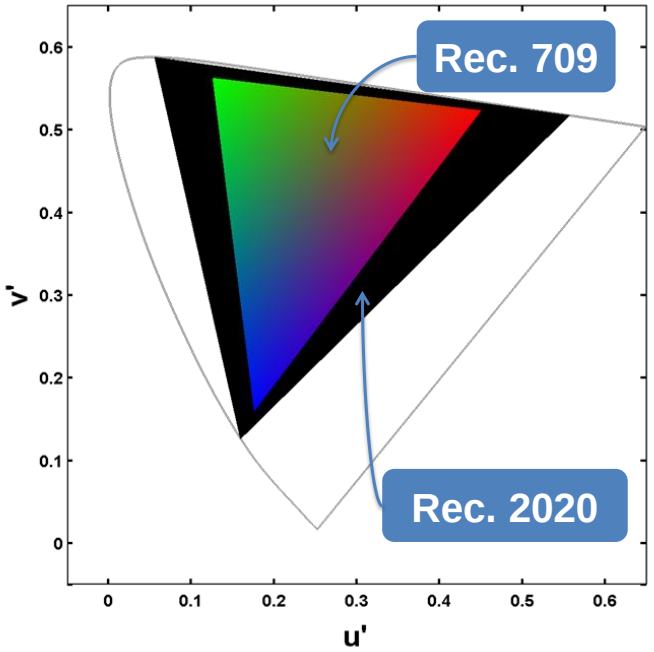
Quantum
Dots

CES 2015

- Expanded color performance offered in TVs now
  - *Content is also becoming available*
- Mobile devices will follow

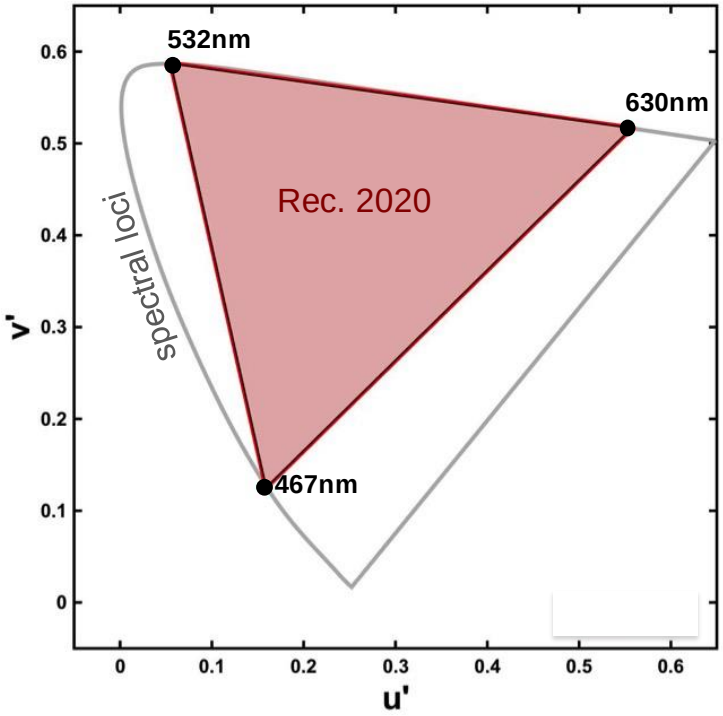
New Expanded Color Standard (Rec. 2020)

- ITU-R Recommendation BT.2020-1 (shorthand Rec. 2020)
  - *Published by the International Telecommunication Union (ITU) in June 2014*
- Establishes broadcast standards for Ultra High Definition (UHD) TV and therefore is applicable all consumer display devices
- Also adopted by other media systems such as the next generation Ultra HD Blu-ray™
- Requires a significantly larger color gamut than current broadcast standards (i.e., Rec. 709)

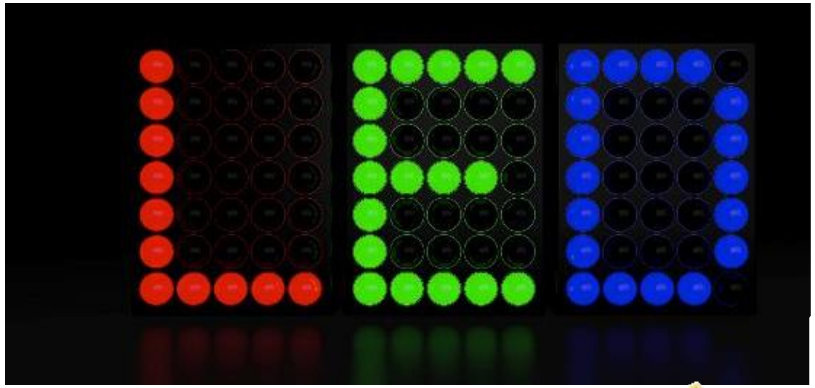


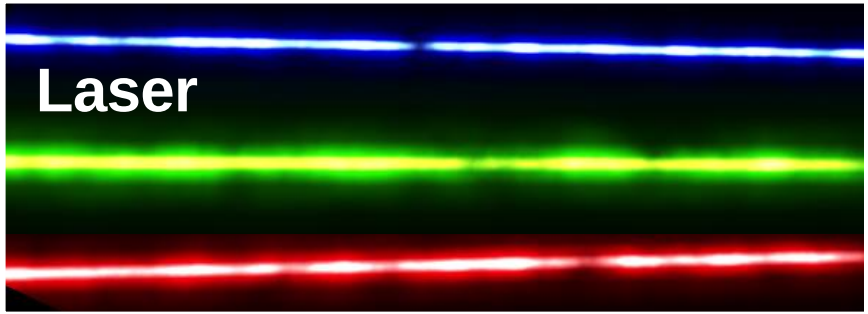
New Expanded Color Standard (Rec. 2020)

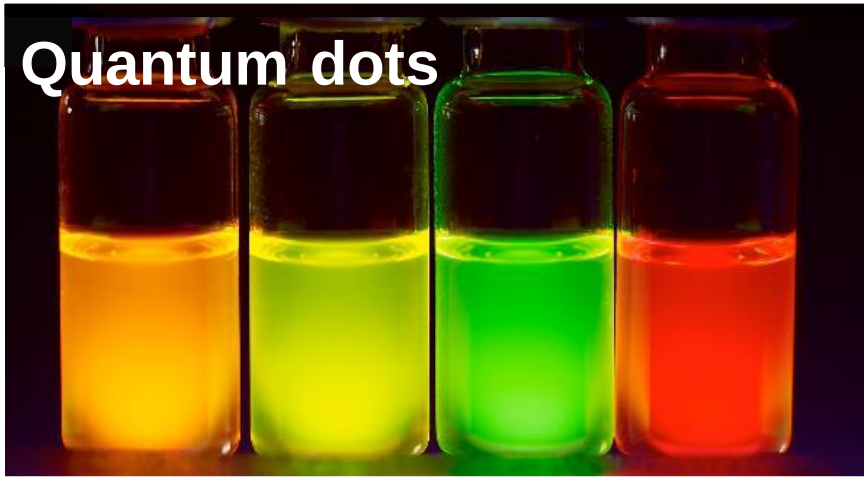
- *Benefit:* Rec. 2020 covers >99% of standard reference surface reflectance color gamut (ISO 12640-3:2007)
  - *i.e., most natural colors*
- Why would one would want a large color gamut?
  - *More beautiful and informative images*
  - *More accurate color*
    - *ecommerce*
    - *Content development*
  - *Better color accuracy in all viewing spaces*
  - *More attention*
  - *More favorable consumer evaluation*



Technologies for Wide Color Gamut

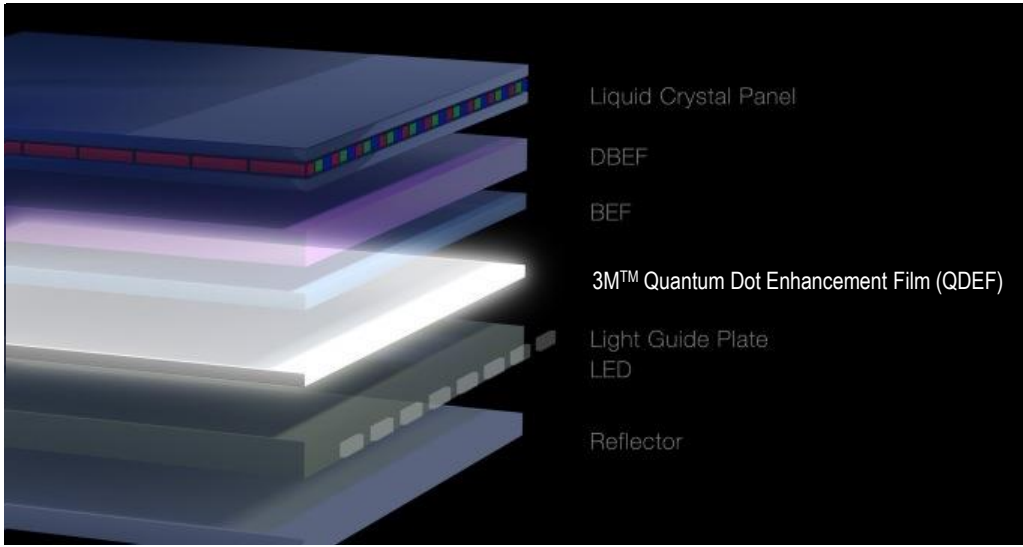






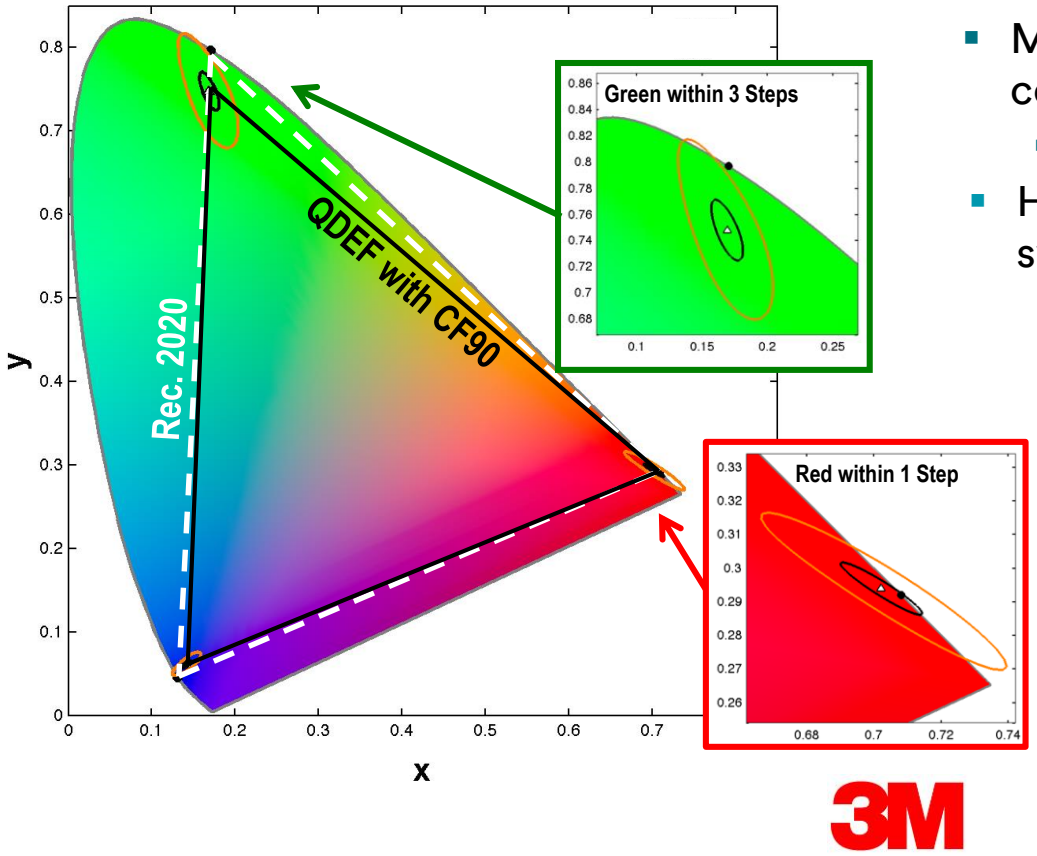
LCD Architecture and Quantum Dots

- Most energy efficient way to achieve high color performance in LCDs
- Utilizes existing LCD architecture
- Able to achieve very high color gamuts
  - *Narrow FWHMs and tunable peak wavelengths*
  - ***Can come very close to Rec. 2020 with current LCD systems***



Quantum Dots easily integrate into an LCD System

Rec. 2020 Within Perceptual Reach with Quantum Dots



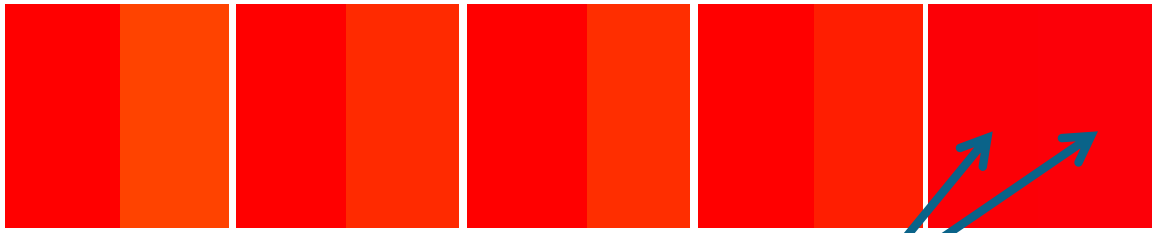
- Modeling/measurements show >90% coverage
  - *QD enabled commercially available display*
- Higher coverage achievable through system optimization

How close is close enough?

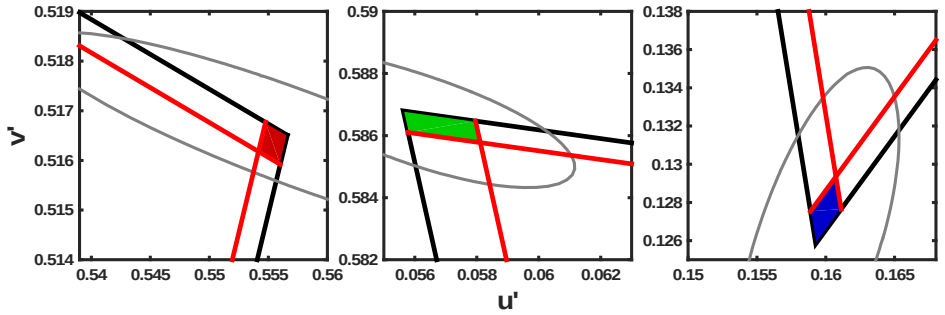
Or

How is a display qualified as Rec. 2020 compliant?

Previous Work: No Missing Colors



physically different but perceptually undetected most of the time



- Discrimination well predicted by CIE 2000 color difference formula (ΔE_{2000})
- *Too stringent a requirement for most consumer electronics applications*

SID Symposium Digest, 46(1) pp. 223–226, June 2015

Latest Study: Color Difference in Photographic Images

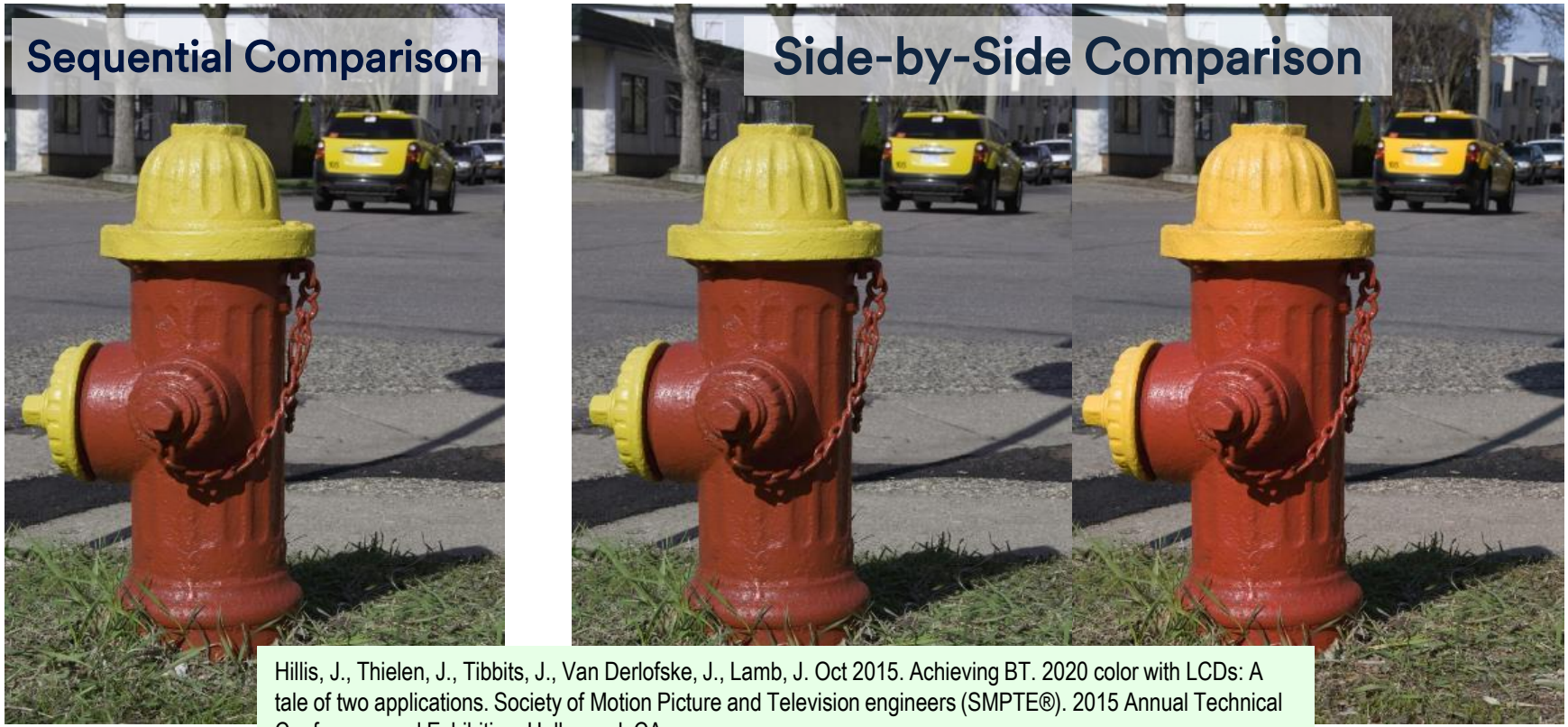
- When do mislocalized primaries noticeably affect color of photographic images?
  1. *For professionals grading content*
  2. *For consumers comparing displays side-by-side*

Professional

Consumer

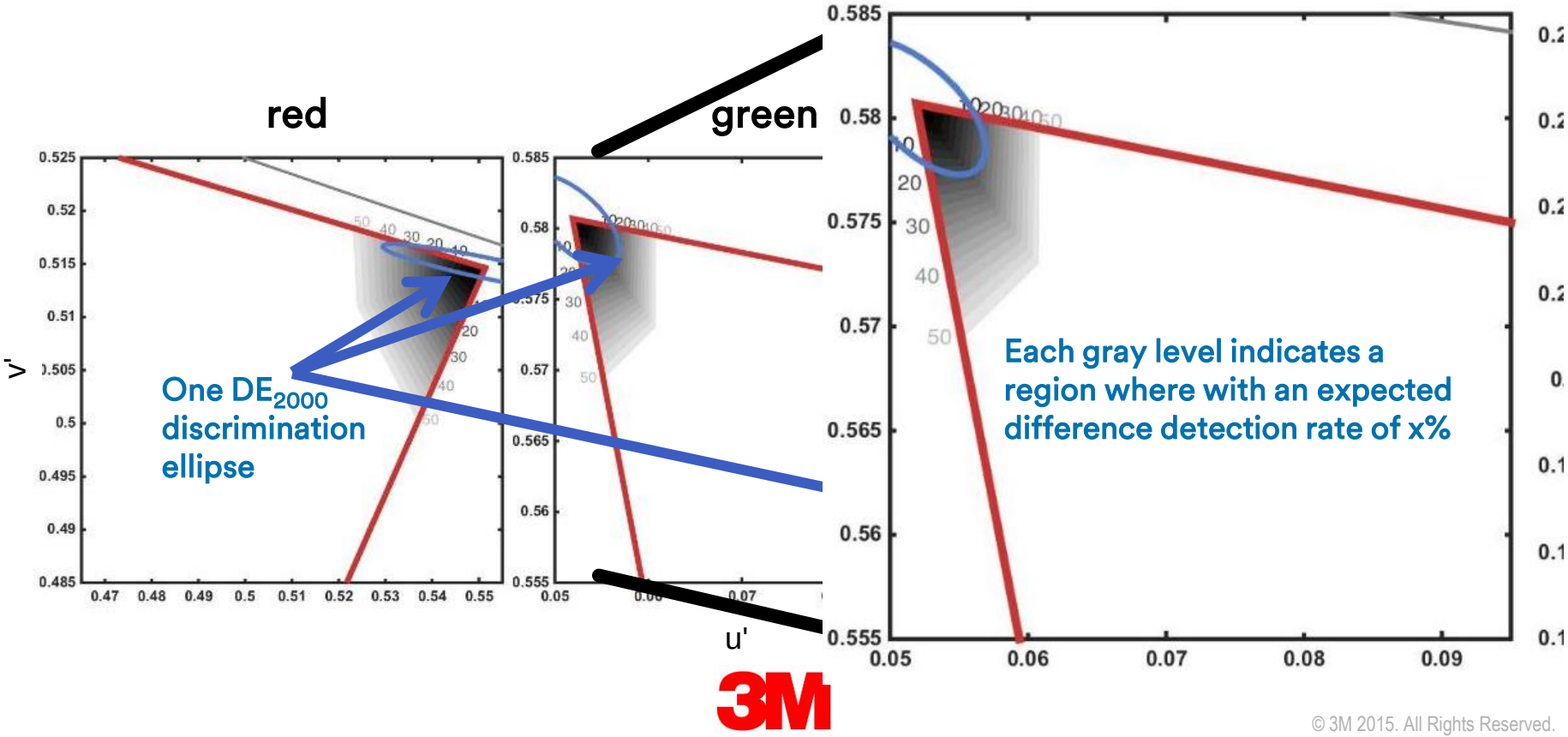
Sequential Comparison

Side-by-Side Comparison

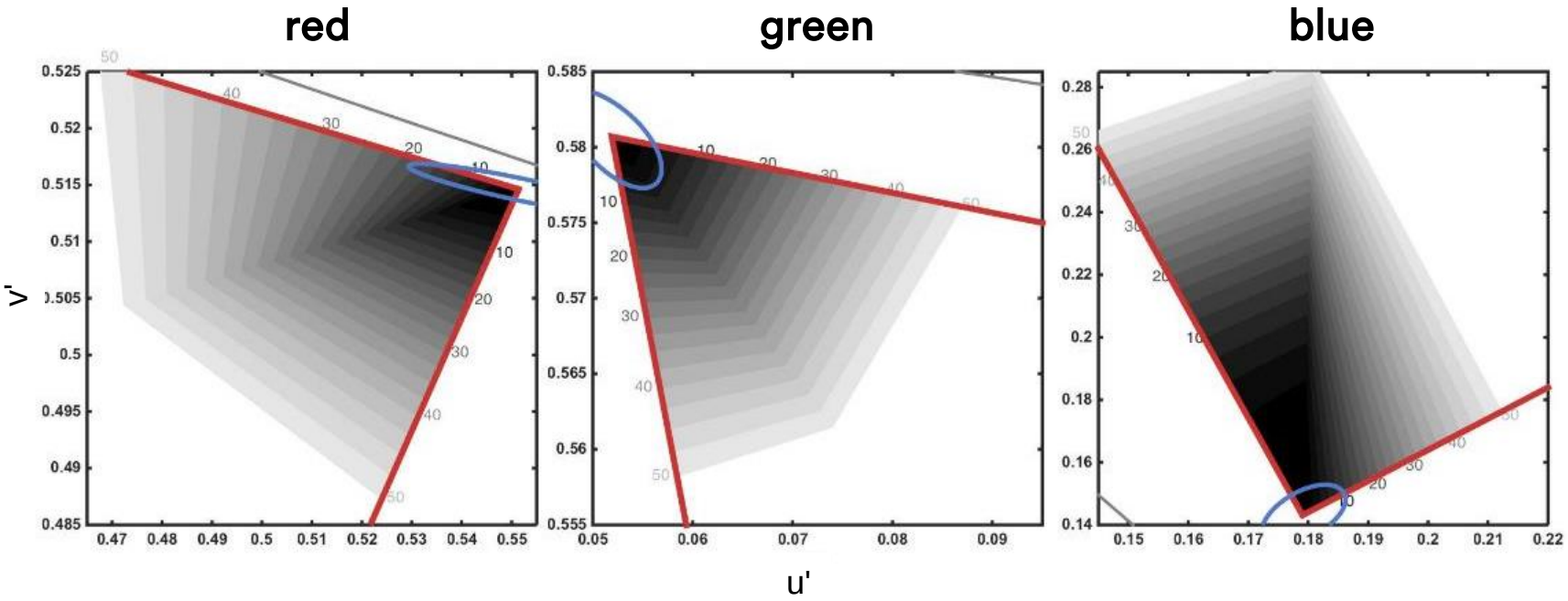


Hillis, J., Thielen, J., Tibbits, J., Van Derlofske, J., Lamb, J. Oct 2015. Achieving BT. 2020 color with LCDs: A tale of two applications. Society of Motion Picture and Television engineers (SMPTE®). 2015 Annual Technical Conference and Exhibition. Hollywood, CA

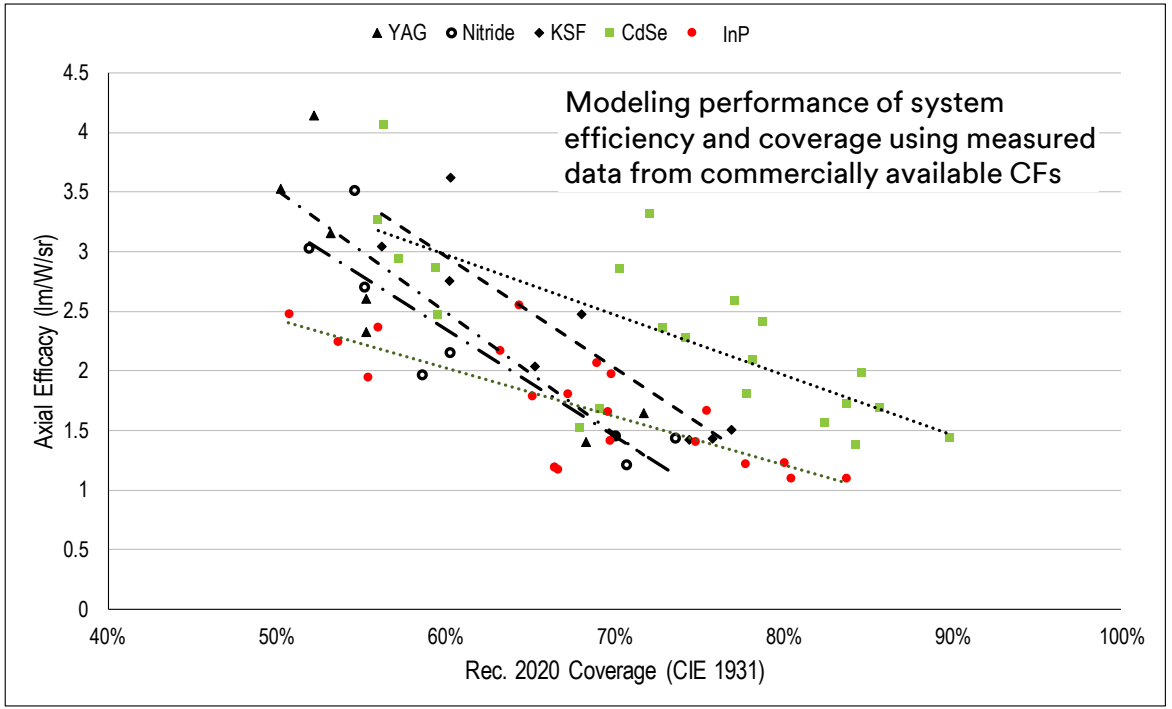
Difference Detection Rate Contours: Sequential task



Difference Detection Rate Contours: Side-by-Side Task



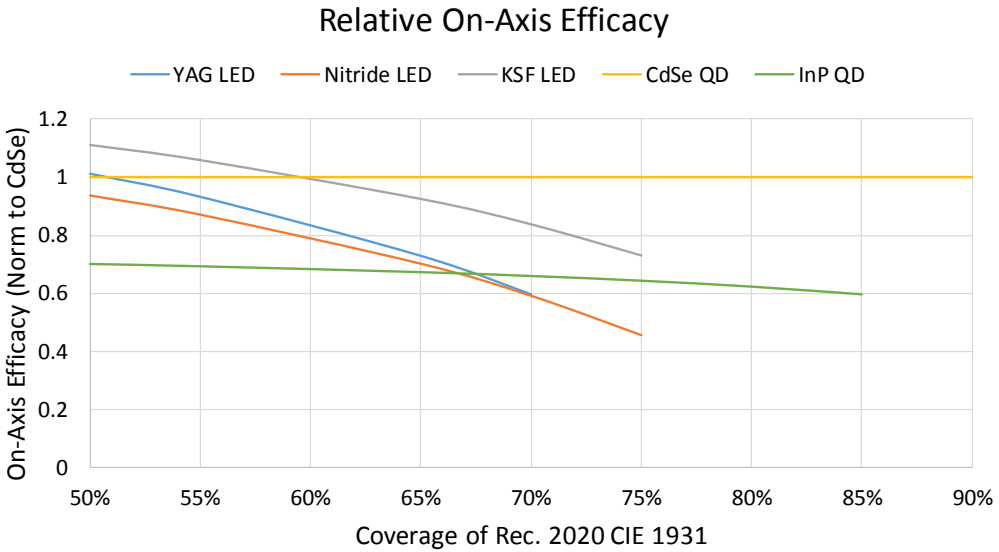
Achieving Rec. 2020 Color



- A study was performed to determine device efficiency as a function Rec. 2020 coverage for various high color gamut source technologies
  - *System parameters used (i.e., source spectrum, source efficiency, color filter transmission) were measured from commercially available devices*

Thielen, J., Hillis, J., Tibbits, J., Van Derlofske, J., Lemmon, A., Lamb, J., Benoit, G. 2015. *ITU-R BT.2020 Color in LCDs with Todays Technology: A Comparative Analysis.* The 22rd International Display Workshop (IDW). Japan.

Achieving Rec. 2020 Color

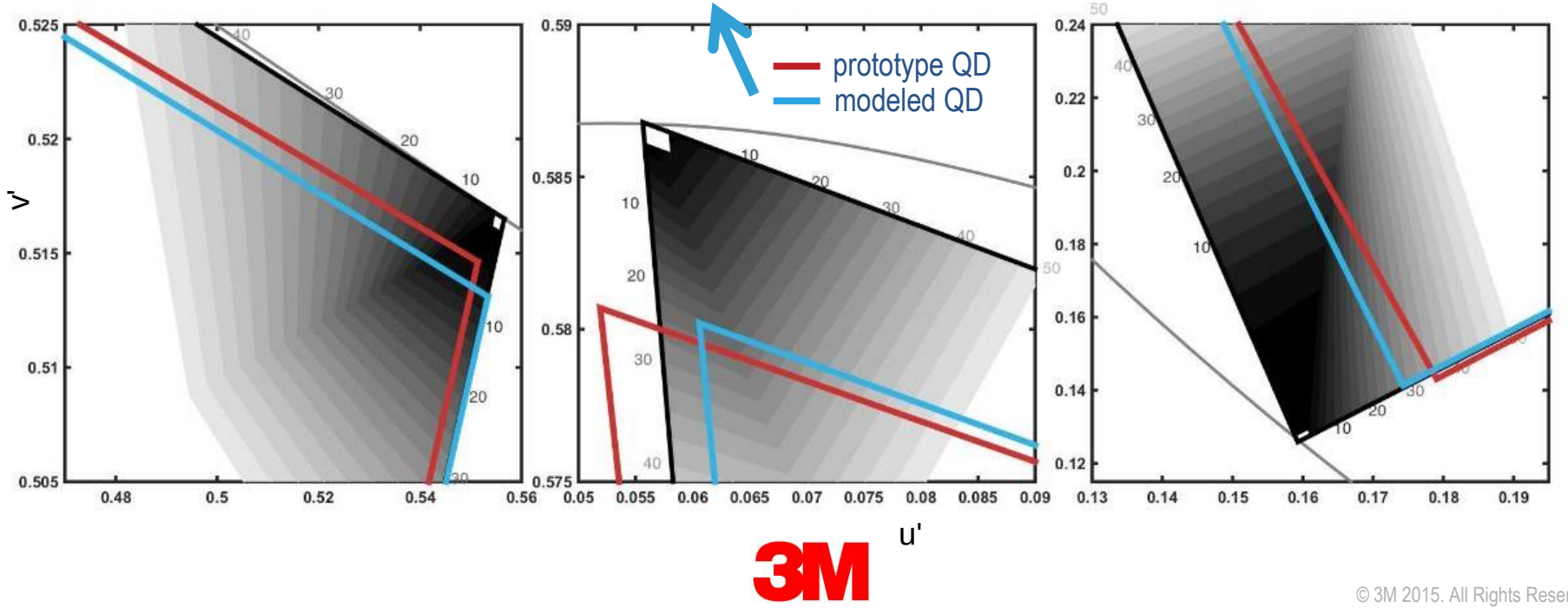


- CdSe based QDs are currently the only practical and efficient way to perceptually achieve Rec. 2020 color gamut coverage within a reasonable tolerance

	YAG LED	Nitride LED	KSF LED	InP QD	CdSe QD
Relative on-Axis Efficacy at 72% Rec. 2020	53%	54%	80%	65%	100%
Relative on-Axis Efficacy at 83% Rec. 2020	N/A	N/A	N/A	61%	100%

Continuous Qualification Metric

There is a *47%* chance that a randomly selected person would detect a color difference between a randomly selected image shown on perfect Rec. 2020 and the modeled QD display.



Summary

- Because truly monochromatic light sources do not exist, compliance with the Rec. 2020 color specification must allow for tolerances on the RGB primaries
- Guidelines for achieving Rec. 2020 color compliance must be developed in order to spur adoption of improved color performance
  - *Should depend on the intended display application (e.g. consumer vs. professional)*
- Methods demonstrated here provide a foundation for the development of a perceptually meaningful guidelines for Rec. 2020 compliance
- QD enhancement of *existing* LCDs without any color management achieves a high level of compliance for consumer applications

Questions

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