IMID 2024

Advances in Assessing and Certifying Display Picture Quality

Dale Stolitzka
Samsung Display America Lab, San Jose, CA

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Time travel back to 2013

"…key takeaway…UHD is about far more than '4K'—more pixels

"Other elements being considered for UHD formats include greater digital video bit depth, improved color subsampling—'better pixels'—and higher frame rates—'faster pixels'"

NAB TV TechCheck, "SMPTE Symposium Brings Ultra HD Into Sharper Focus", *NAB Labs*. 11/04/2013.

More pixels, faster pixels and better pixels = UHD/HDR

Return to the present day – a few scorecard examples [1]

Are there more pixels in a display after ten years … on average, yes

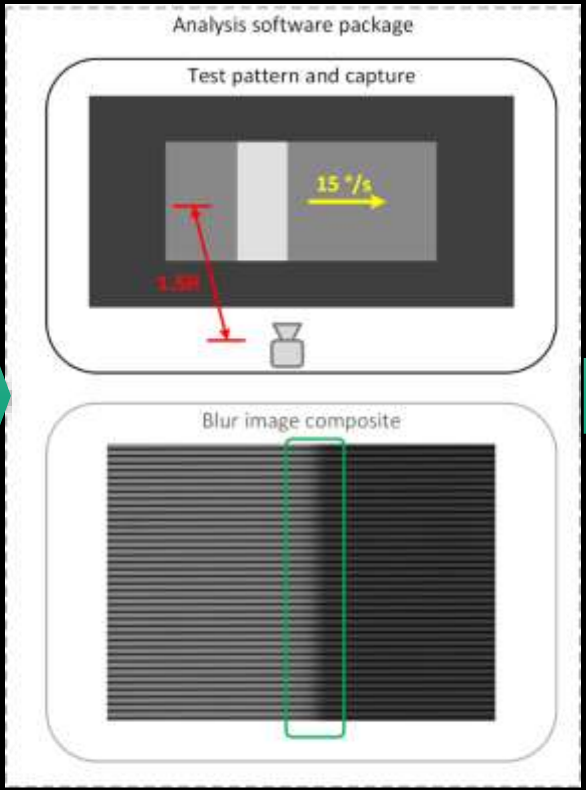
Are pixels getting faster and better after ten years … yes

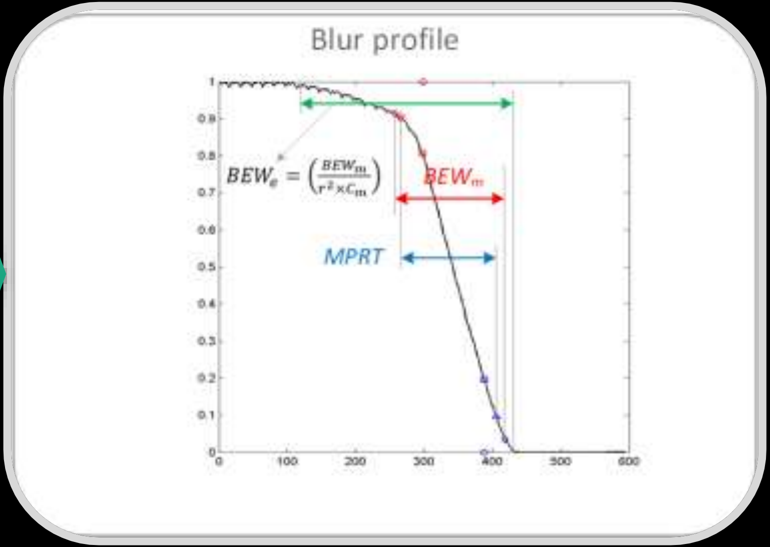
	Feature	TVs	Monitors	Notebooks	Mobiles
More pixels	Megapixels	33.2	33.2	8.3	6.3 ~ 8.3 [2]
	Density [Kpix/in^2]	18	76	110	410 ~ 640 [2]
Faster pixels	Frame rate [Hz]	144	500	480	144
	CMR [3]	n/a	13,000	9,000	n/a
Better pixels	Best bit depth (panel drive)	10	8 (+ 2) ~ 10	8 + 2	8 ~ 10
	DCI-P3 coverage	> 100%	100%	100%	100%

1. Several web sources, including gsmarena.com, RTINGS.com and e-commerce sites
2. True 4K phone (released in 2018)
3. Clear Motion Ratio, presented in E29-3

Faster pixels – ClearMR™ VESA compliance program

CMR is the metric = Clear Motion Ratio





Display motion → Capture motion / extract edge-blur → Analysis

VESA CERTIFIED ClearMR – Seeing is believing

Simulated results on a 2560 x 1440 display
Blender-created image by York University licensed under a CC BY 4.0 deed.

3 Color modeling the H-K Effect

Claude Monet, *Impression Sunrise*. Concept from Margaret Livingstone.

Failure of luminance to predict perceived colors

Claude Monet, *Impression Sunrise*. Concept from Margaret Livingstone.

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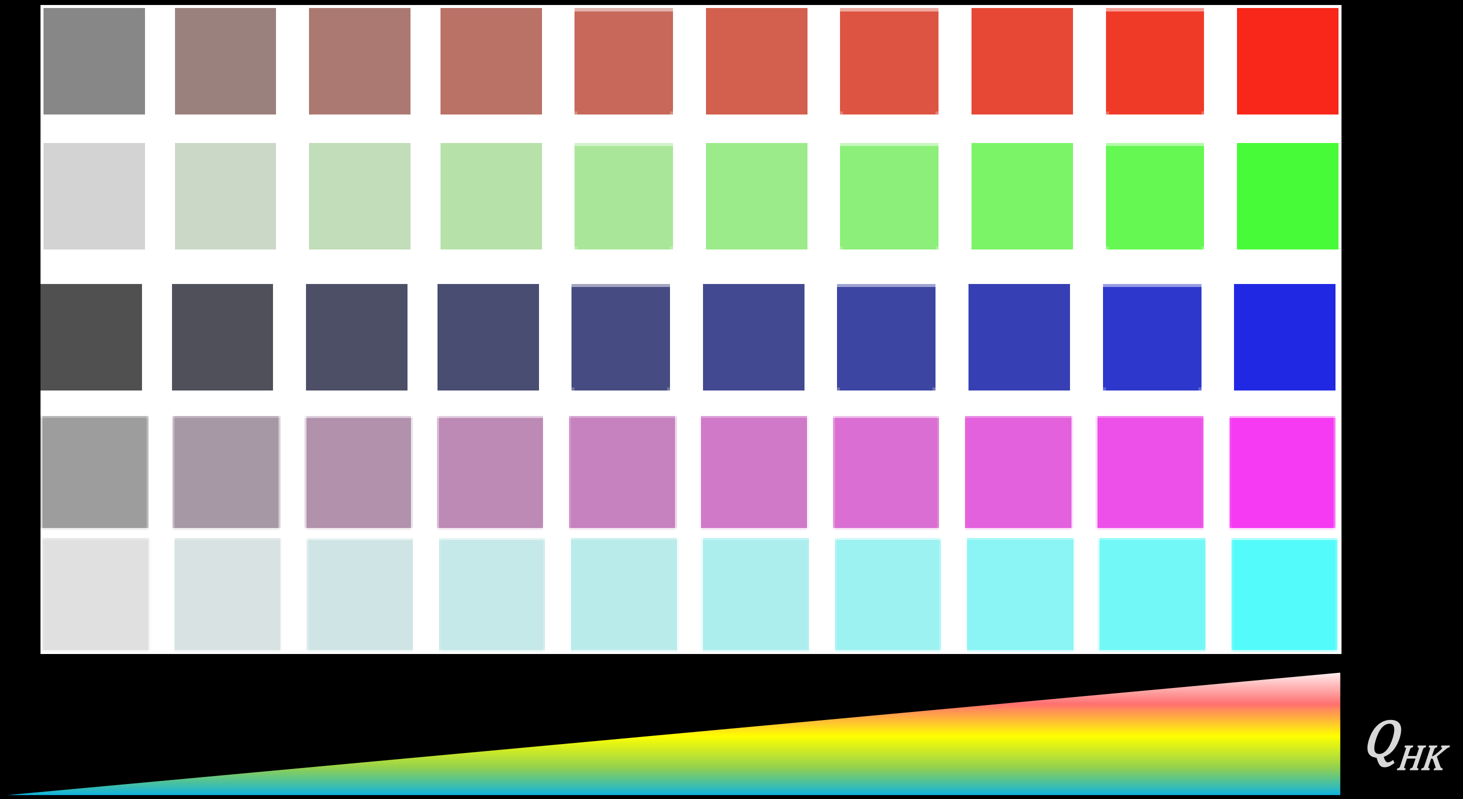
Helmholtz-Kohlrausch Effect

At constant luminance, perceived brightness increases with increasing colorfulness or saturation

- **Well reported**
- **No accepted model until XCR (Experienced Color Range), 2023**

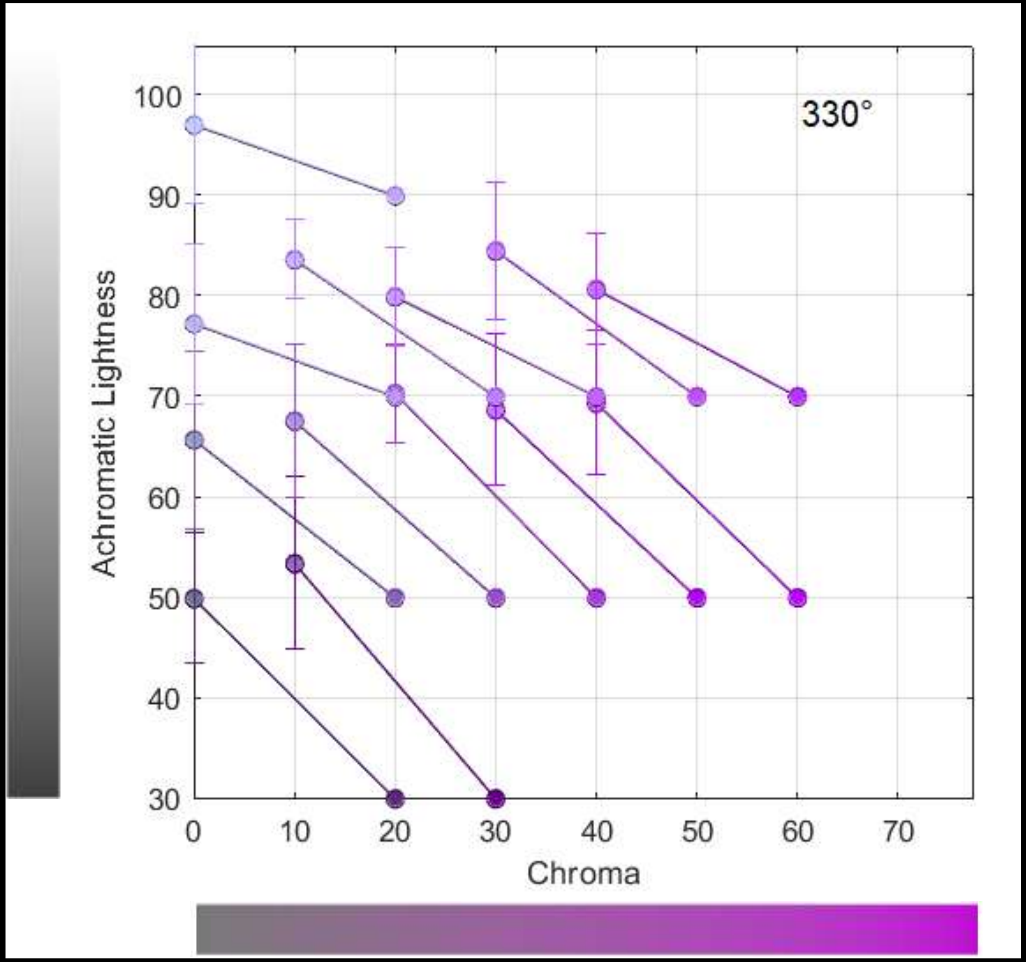


Decoding the results for one hue

- Lines connect pairs of stimuli that were matched in brightness by observers (spacing by ΔChroma = 20)
- H-K Effect:

  Higher chroma, lower luminance stimuli are equally bright to **lower chroma, higher luminance** stimuli.

- **H-K strength ∝ negative slope of loci**



Data testing included 3 studies across 171 stimuli viewed by 50 observers

CIECAM16-based model

Trends represented by a differential equation:

$$\frac{dJ}{dC} = \frac{-a}{J-b}$$

J: Achromatic lightness
C: Chroma

Proposed CIECAM16 Model [1,2]

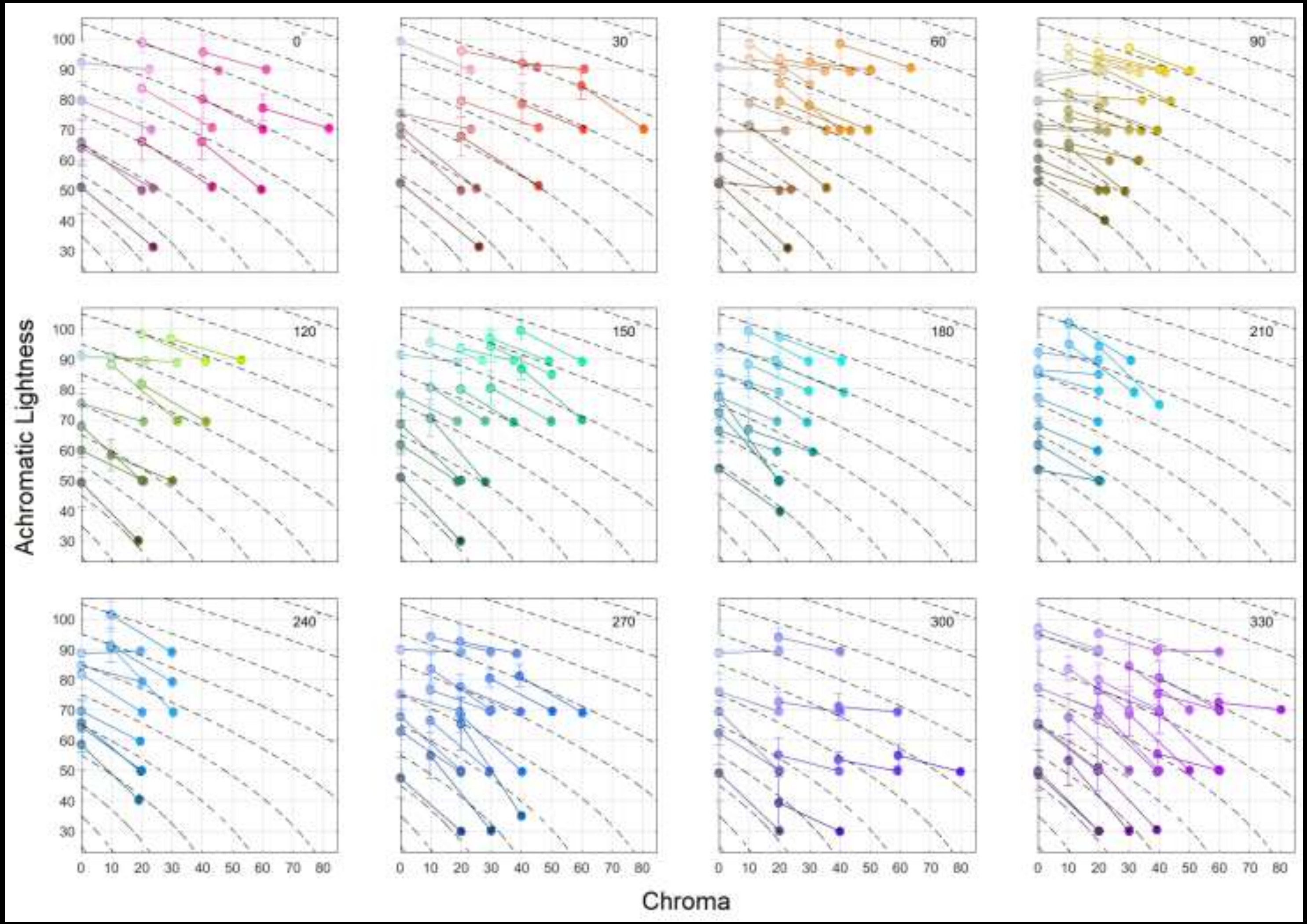
$$J_{HK} = \sqrt{J^2 + 66C}$$

J_{HK}: Perceived lightness

CIECAM16-mod conversion from lightness to brightness [3]:

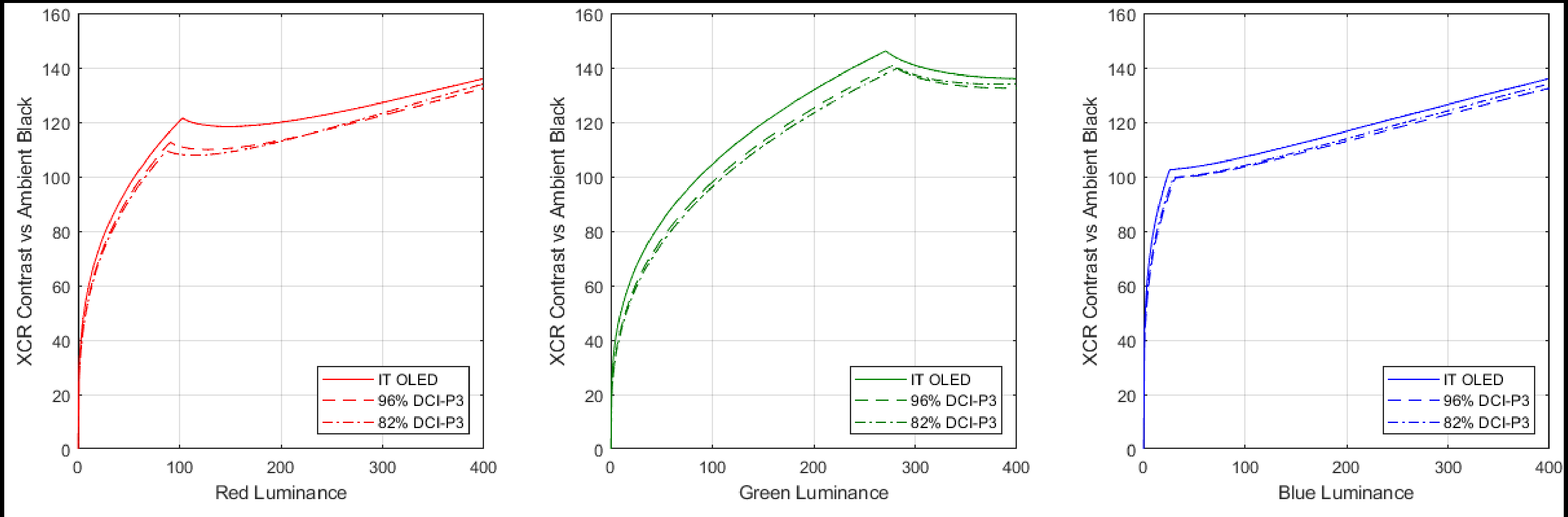
$$Q_{HK} = \frac{2A_w}{c} \cdot \frac{J_{HK}}{100}$$

Q_{HK}: Perceived brightness
A_w: Brightness of white
c: Viewing conditions



1. Hellwig and Stolitzka, “An Advanced Color Model for Evaluating New Display Technologies, *Info. Disp., 39, #3 , pp 11-15* (May/June 2023).
2. Hellwig, Stolitzka and Fairchild, “The brightness of chromatic stimuli’, *Color Res. Appl., **49**, #1, pp 113-123* (January 2024).
3. Hellwig, Stolitzka and Fairchild, “Improvements to CIECAM16 and Future Directions”, *Proceedings of the 30th Session of the CIE* (Dec 2023).

Example of applying the XCR model



Improvement still visible in presence of ambient light & reflections
XCR in 100 lux ambient light plus facial reflection light onto a notebook PC

* CIECAM16* as modified by Hellwig, et. al.

VESA – build consumer confidence in logoed products

VESA CERTIFIED DisplayHDR

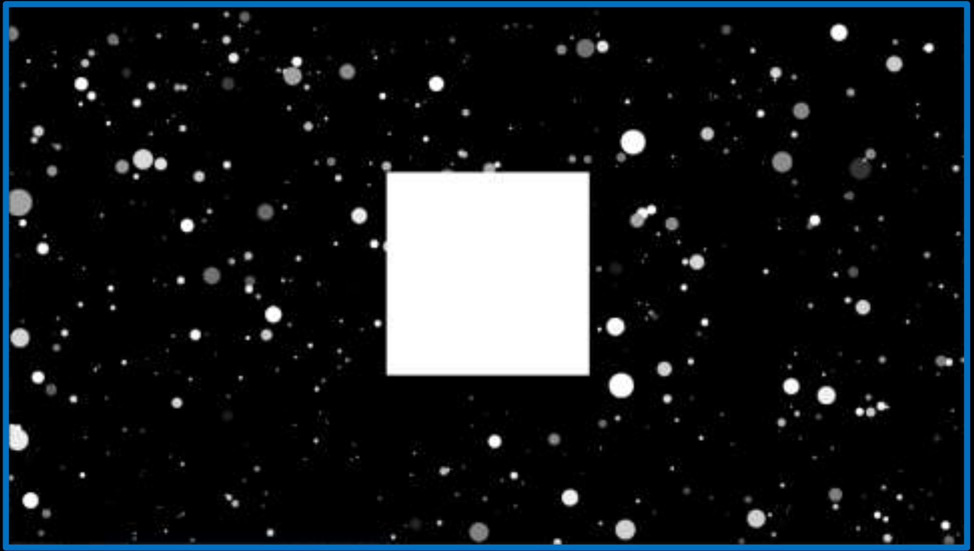
DisplayHDR v1.2 Improvements, 8 years in the making (2024/05)

Refined, reinforced tests	***New tests***
Background for luminance testing	Static contrast
Increased color gamut	**HDR Color accuracy**
Bit depth increased for entry HDR	HDR vs SDR black level
White point PQ accuracy upgrade	Black crush
	Subtitle flicker

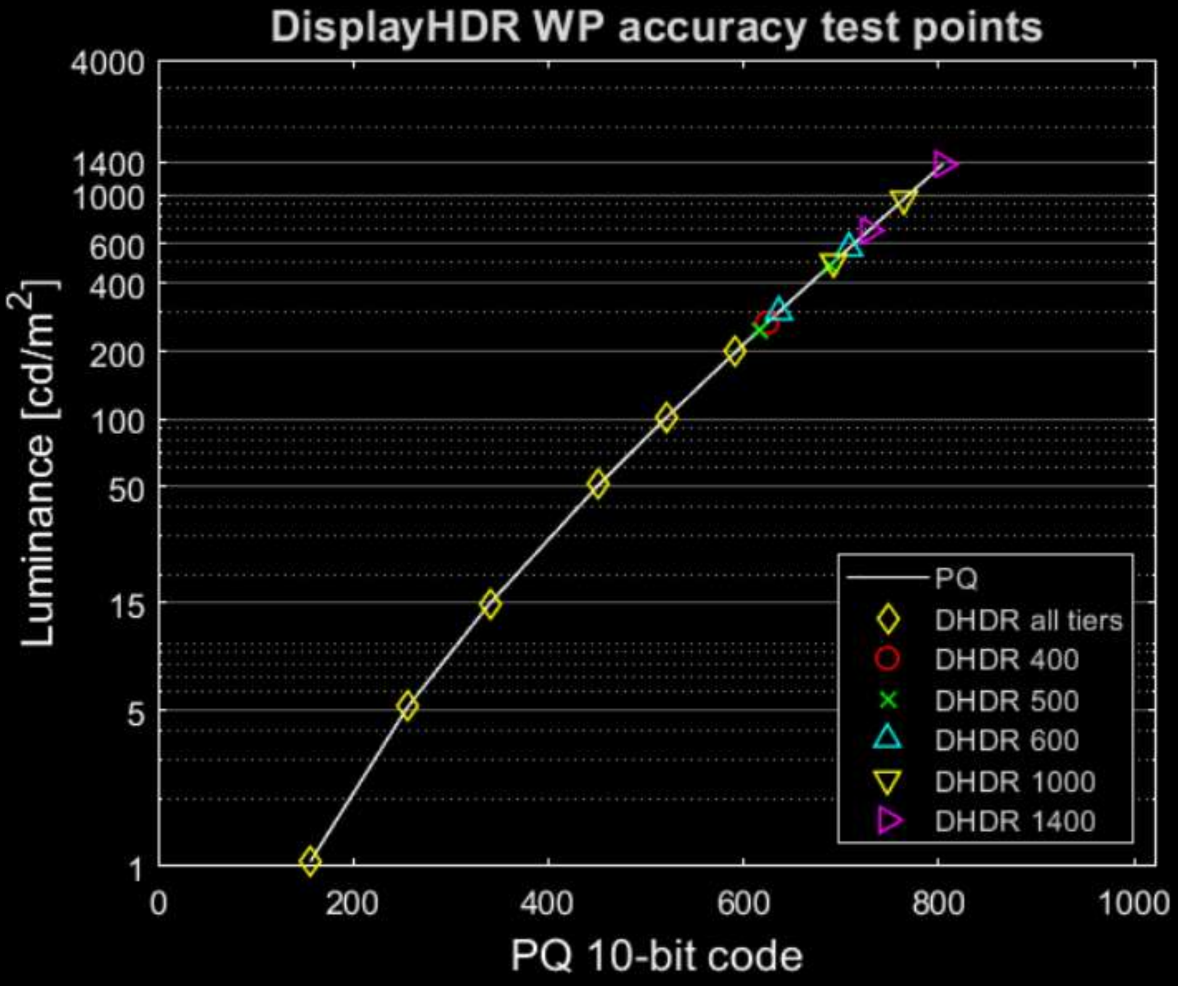
White point accuracy testing

PQ curve / WP	Test limit
1 to 5 cd/m^2	$\Delta E_{ITP} \leq 20$
> 5 to 15 cd/m^2	$\Delta E_{ITP} \leq 15$
> 15 cd/m^2	$\Delta E_{ITP} \leq 10$

ΔE_{ITP} defined in Rec. ITU-R BT.2124-0 (2019/01)

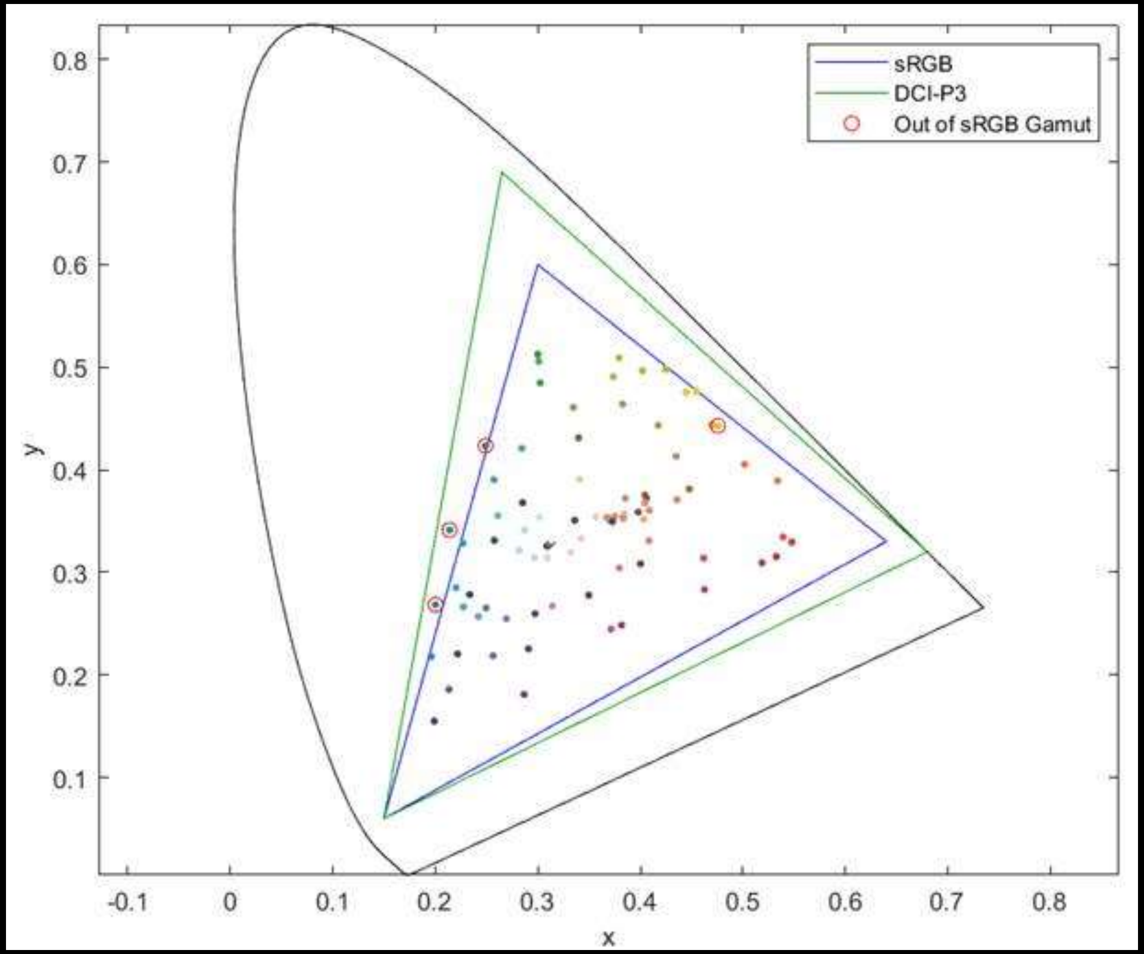


10% $APL_{Luminance}$

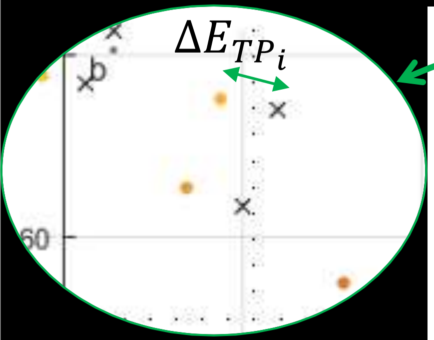


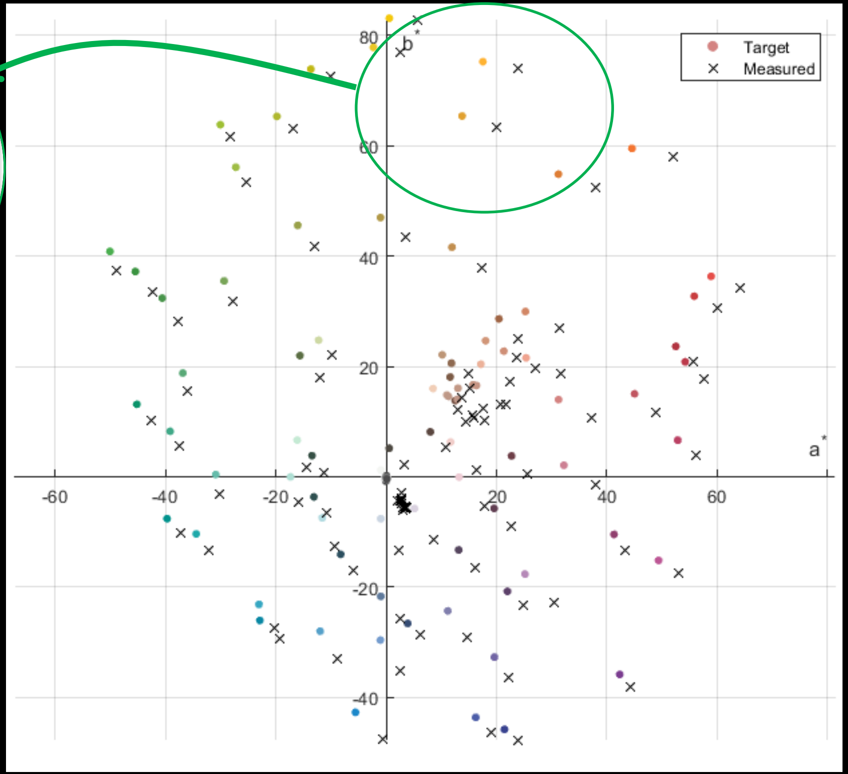
Out of box color accuracy – not using traditional metrics

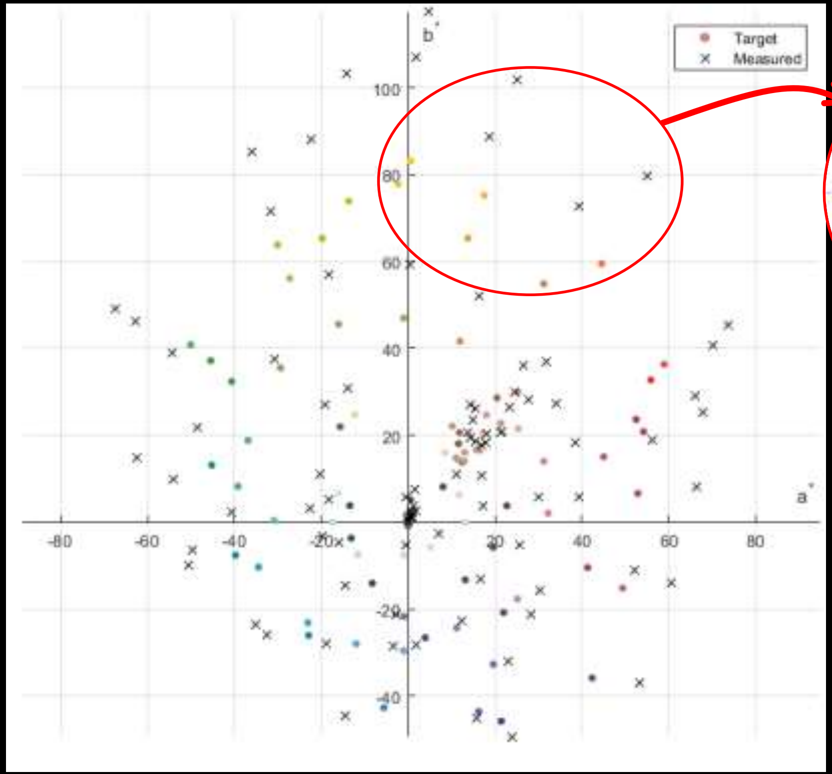
PQ curve / WP	Test limit ($\Delta I = 0$)
Tiers 400, 500, 600	$\Delta E_{TP} \leq 8$
Tiers 1000, 1400	$\Delta E_{TP} \leq 6$

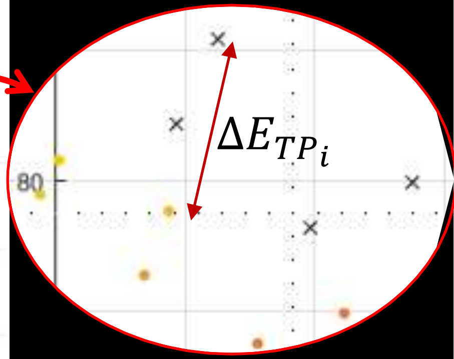


Color accuracy test example (DisplayHDR 600)









$\overline{\Delta E_{TP}}$	6.0 (pass ≤ 8)	11.2 (fail)
$\overline{\Delta E_{00}}$	3.8	4.7
Three tests with white patch luminance at 50, 100 and 50% of tier [cd/m^2]		

Conclusions

- HDR is here more pixels, faster pixels, better pixels every year
- Faster pixels more than frame rate – need obj. criteria, → ClearMR
- Better pixels means better color, use HDR-ready criteria
- Consumer confusion abounds—HDR is more than just luminance –

  VESA display confidence: DisplayHDR™, ClearMR™, Adaptive-Sync™

Thank you

Dale Stolitzka, San Jose, CA USA

d.stolitzka@samsung.com