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The future of Film & Television: High Spatial Resolution (4K/UHD), High Dynamic Range (HDR), Wide Color Gamut (WCG) and Higher Frame Rates (HFR)

Hochschule der Medien 2015

Stefan Grandinetti, Jan Froehlich

Outline of the Talk

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- UHD, Technical Aspects:
  - Higher Resolution
  - High Dynamic Range
    - Motivation
    - Display technology
    - Encoding (EOTF)
    - Delivery
  - Wide Color Gamut
    - Motivation
    - Is it needed?

- The HdM-HDR-Project (Stefan)
- Creative Aspects of HDR & WCG (Stefan)

- **HDR & UHD Demo (in small groups)**
- **WCG Demo (all together again)**

- HFR: Technical and Creative Aspects (Stefan)

- **HFR Demo**

Motivation – Why Higher Resolution?

- Cinema:
  - 4K (4096x2160) was already specified in the DCI/SMPTE DC21 specs from the beginning.
  - Differences between 2K and 4K and even 8K resolution (for the first rows) can be perceived in typical cinema environments.
  - 4K Projectors available from 2011.

Motivation – Why Higher Resolution?

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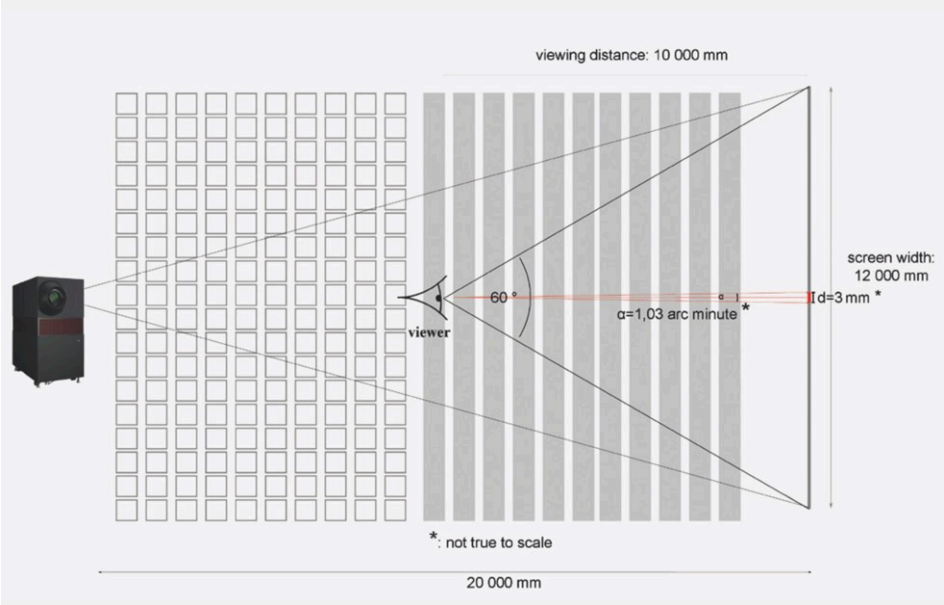
- Typical mid size cinema:



Hans Kiening, “4K+ Systems - Theory Basics for Motion Picture Imaging”, HPA 2009, Palm Springs

Motivation – Why Higher Resolution?

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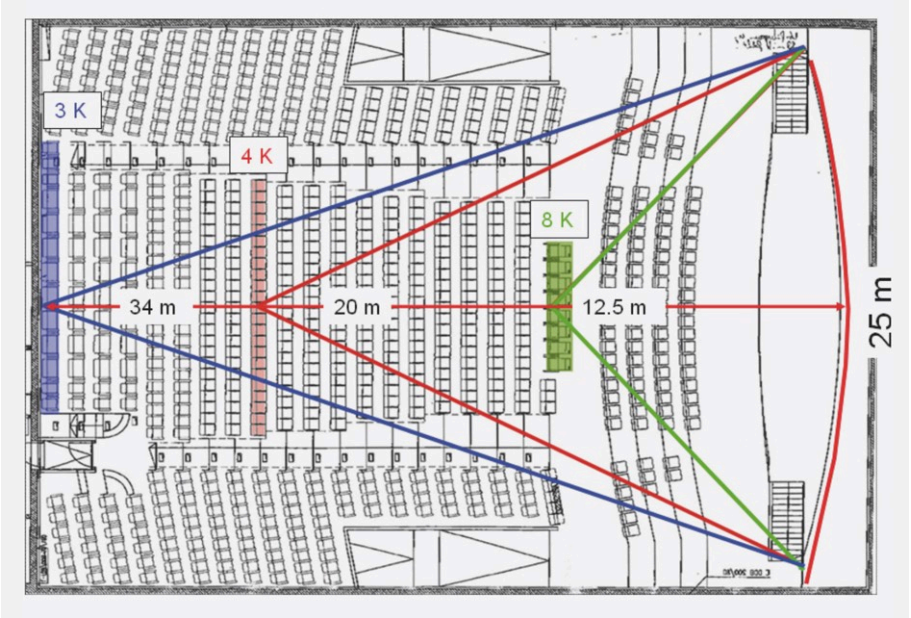
- Typical large size cinema:



Hans Kiening, “4K+ Systems - Theory Basics for Motion Picture Imaging”, HPA 2009, Palm Springs

Motivation – Why Higher Resolution?

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- Do the creatives like it?

"Big, big screens would make me happy," said *Tomorrowland* director **Brad Bird,** speaking Friday at Cine Gear Expo. "Movies are big, bright images that are shared [with an audience]—that's what makes cinema cinema. I think exhibitors should head back in the direction of spectacle."

He made these remarks during a panel and opening night screening of his sci-fi fantasy *Tomorrowland* in 4K, held in the Paramount Theater on the Paramount lot, where the equipment show is being held.

Hollywood Reporter, 5.6.2015

Motivation – Why Higher Resolution?

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- Do the creatives like it?

In visualizing the screenplay he co-wrote with Damon Lindelof, Bird insisted on an image that would hold up to 4K digital projection. "I was looking for something that would have a rich look," Bird says. "We figured 4K digital projectors would be the best way this movie would be exhibited.

The ASC, June 2015 (https://www.theasc.com/ac_magazine/June2015/Tomorrowland/page1.php)

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https://makeupcrazy1.files.wordpress.com/2013/06/evening-bronze-and-browns-video-tutorial-and-pics-0143.jpg

Motivation – Why Higher Resolution?

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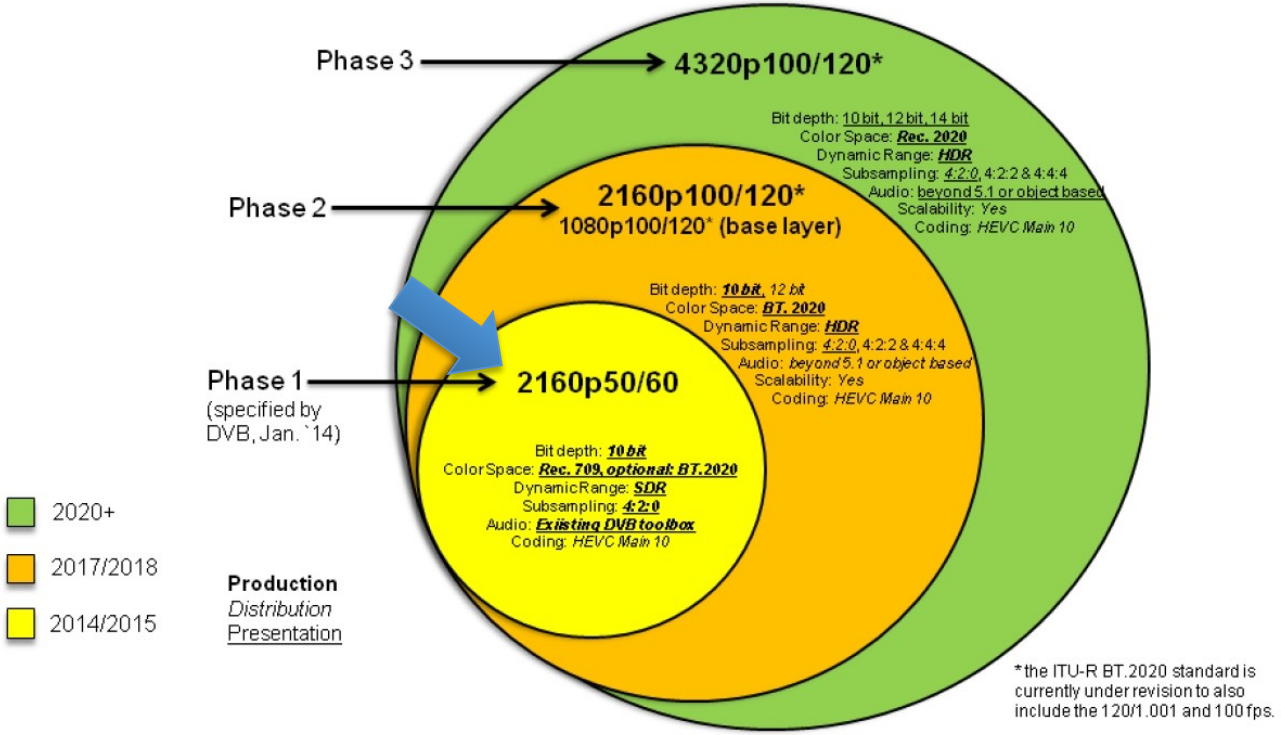
- TV:
  - Sceensize!
  - 12“ → 65“ (20qm livingroom → 600qm)
  - 4K SDR can be seen at 1.5PH

Standards?

- TV:
  - UHD-1
    - (3840x2160)
  - UHD-2
    - (7680x4320)



2014

Standards?

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- TV:
  - UHD-1
    - (3840x2160)
  - UHD-2
    - (7680x4320)

40

UHD Standard Roadmap

Planning & 5/20/2015

Category	UHD-1 Phase 1	UHD-1 Phase 2	UHD-2
Deployment	2015	2018	2020
Resolution	3840 x 2160	3840 x 2160	7680 x 4320
Frame Rate	P50, p60	P100, p120	P100, p120
Dynamic Range	HDR Prefer	HDR Mandatory	HDR Mandatory
Color Space	Rec.709	Rec.709 or Rec.2020	Rec.2020
Color Sampling	4:2:0	4:2:0	4:2:0, 4:2:2, 4:4:4
Bit Depth	10 bit	10, 12 bit	10, 12, 14 bit
Video Encoding	HEVC Main 10	HEVC Main 10	HEVC Main 10
Audio Format	5.1	Beyond 5.1	Objected Base
Audio Codec	Open	TBD	Next Generation Audio Codec
Viewing Angle	66°	66°	100°
Viewing Distance	1.5 times of the picture height	1.5 times of the picture height	0.75 times of the picture height

2015

Motivation – Why High Dynamic Range?

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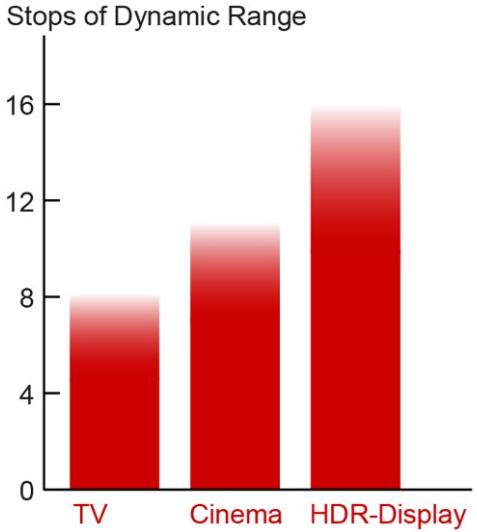
- Brightness and dynamic range of consumer displays will probably increase over the next years:
- 42” 700cd/m2 TVs available for $700, 300-500cd/m2 mainstream.



When It Comes to TVs, Forget 4K ... It’s the Brightness, Stupid

http://variety.com/2014/digital/columns/when-it-comes-to-tvs-forget-4k-its-the-brightness-stupid-1201055191/ (received 19.01.2014)

Do the creatives like it?

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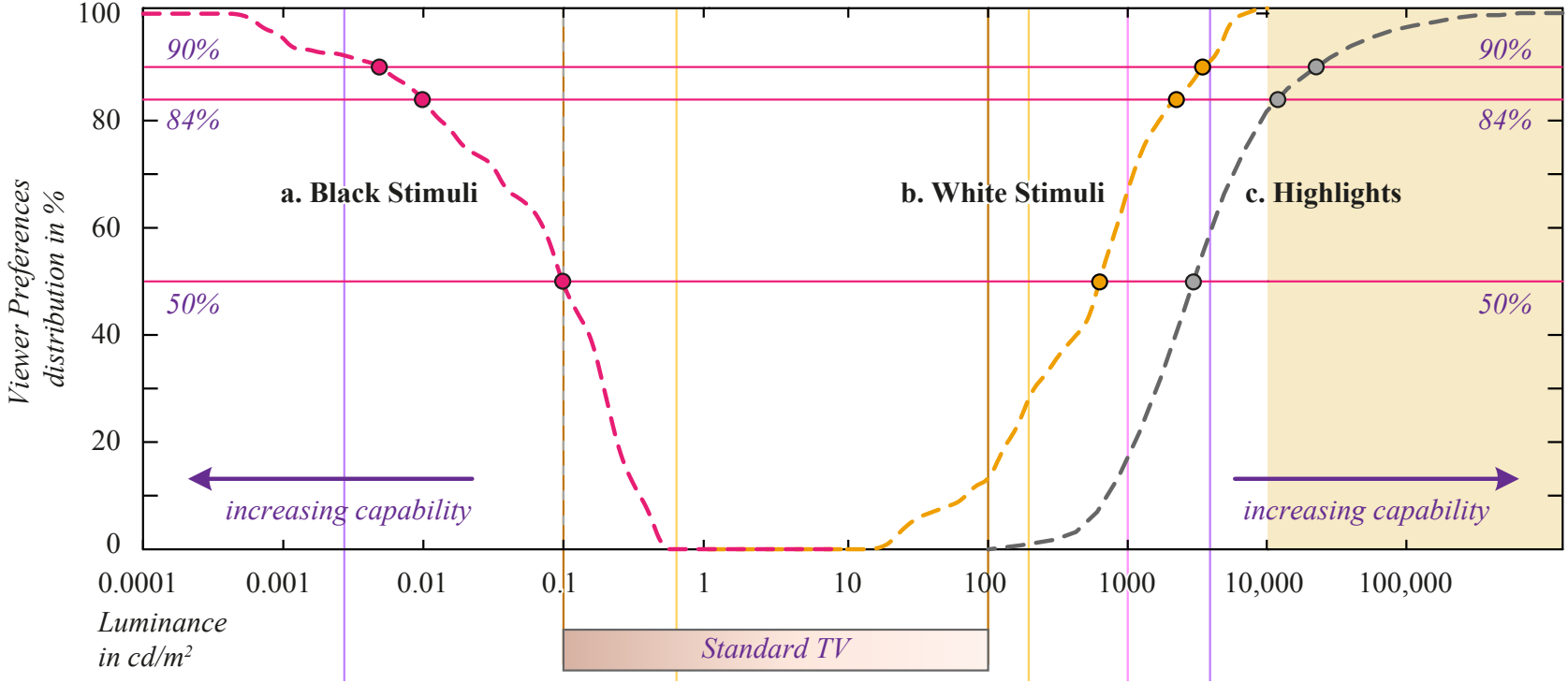
- IBC 2015 Keynote from Rick Sayre (Pixar) & Jeroen Schulte (ILM):
  - Talking about Tomorrowland & Inside Out both creative teams loved HDR and WCG but did not like HFR.

On another panel (moderated by *The Hollywood Reporter*'s **Carolyn Giardina**), *Oblivion* director **Joe Kosinski** said he would like to make his next movie in 4K but at today's standard 24 frame per second frame rate. While he wasn't enthusiastic about high frame rates, he gave high marks to HDR. He has already been testing this with HDR-mastered footage from *Oblivion,* some of which has already been shown at various trade shows as part of demonstrations of Dolby's developing HDR format Dolby Vision.

Hollywood Reporter, 23.10.2014.

What do consumers want?



S. Daly, T. Kunkel, S. Farrell & Xing Sun: Viewer Preferences for Shadow, Diffuse, Specular, and Emissive Luminance Limits of High Dynamic Range Displays. SID Display Week 2013.

What is High Dynamic Range?

- Let’s first have a look at HDR display technology to better understand how to define HDR

High Dynamic Range Displays? Dual-Modulation

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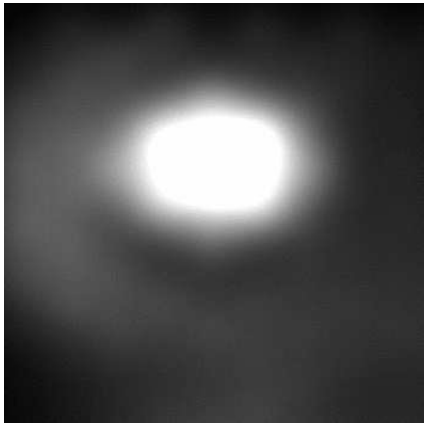
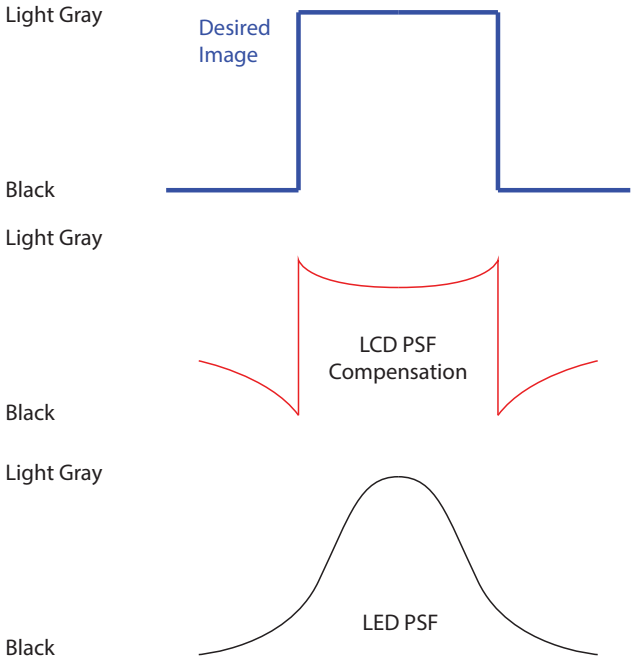
Backlight



LCD w/ PSF Compensation

Seetzen et al.: '**High dynamic range display systems**'. Proceedings of ACM SIGGRAPH 2004, Volume 23 Issue 3, August 2004, Pages 760-768



Simplified concept of LED/LCD dual modulation (Timo Kunkel, CIC 2015, Darmstadt)

Results

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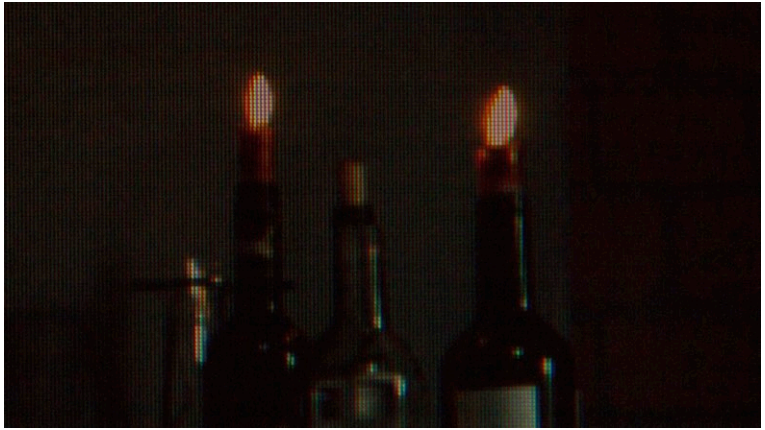
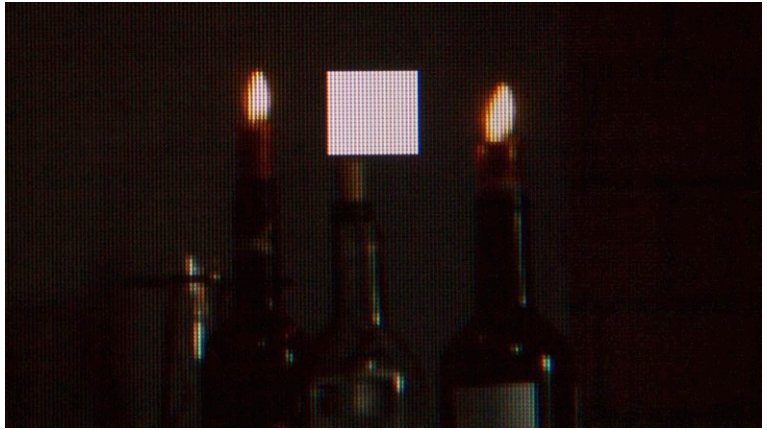
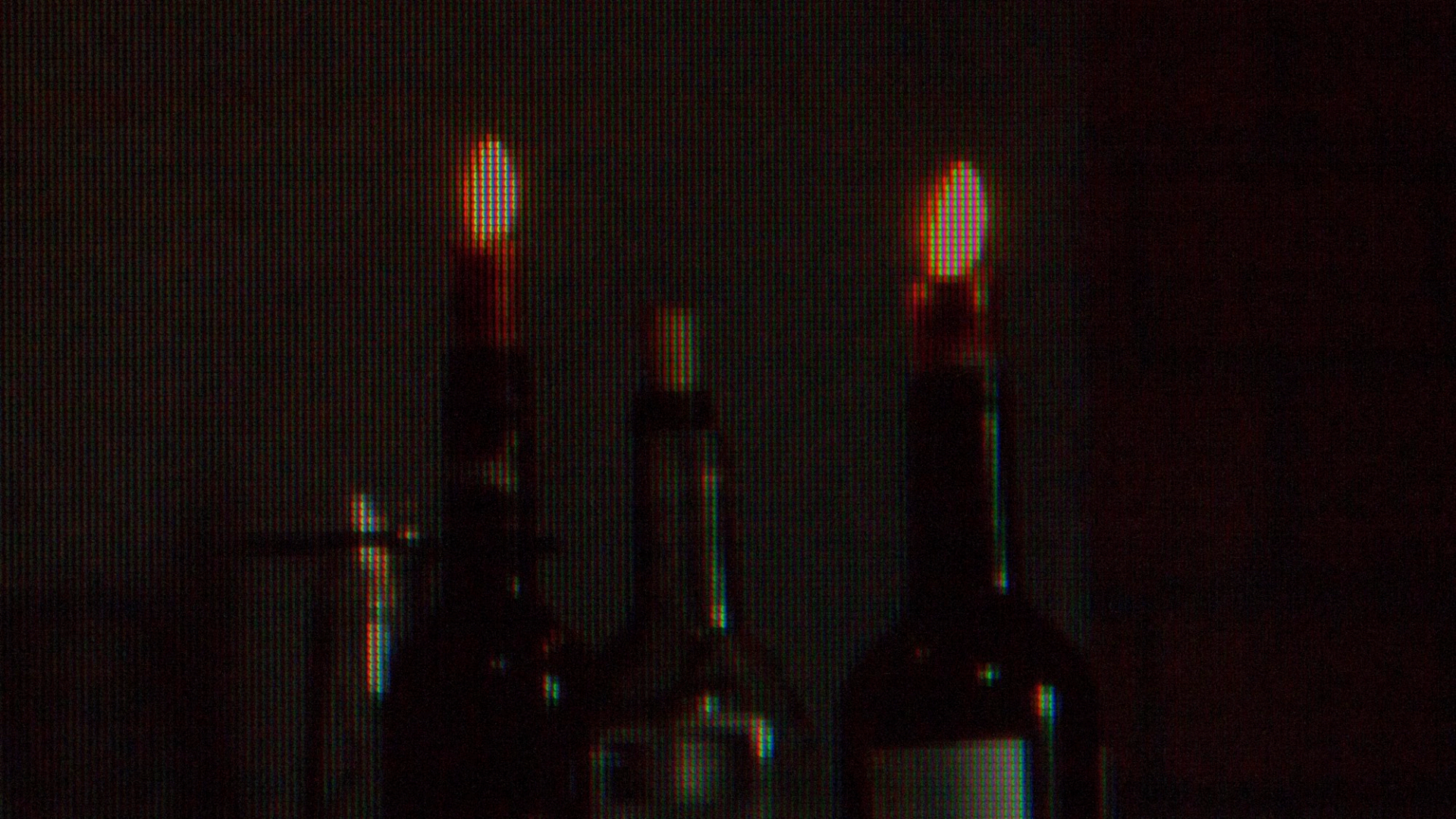
- Different display technologies show different weaknesses





Example: Deficiencies of variable backlight monitors



High Dynamic Range Displays? OLED

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Example:

- Sony 30" PVM-X300

- Promises high local contrast

What is High Dynamic Range?

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Blu-ray Format Extension Video Characteristics

Video Codec	HEVC[1]		AVC
Spatial Resolution	3840x2160	1920x1080	1920x1080
Picture Format Aspect Ratio	16:9		
Bit Depth – SDR	10		8[2]
Color Space Primaries	BT.2020[3] BT.709 (SDR only)		BT.709 (SDR only)
Color Sub sampling	4:2:0		
Frame Rates	23.976p, 24p, 25p[4], 50p[4], 59.94p, 60p		23.976p, 24p
Peak Video Bit rate[5]	100Mbps		40Mbps
Bit Depth - HDR	10		N/A
HDR EOTF	SMPTE ST 2084		
Static Metadata	SMPTE ST2086, MaxFALL (HDR only) [6], MaxCLL (HDR only) [6]		

http://www.blu-raydisc.com/en/Industry/Specifications/

What is High Dynamic Range?

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- Blu Ray – the devil is in the details:

(1) Main 10 High Tier Level 5.1. NOTE: in the mandatory part, HDR content is transmitted using a single layer codec with metadata in SEI messages.

(2) AVC 8-bit BT.709 SDR is allowed only for 1080/23.976p and 1080/24p frame rates and with a peak bit rate that is within existing BD specification

(3) BT.2020 uses the YCbCr non-constant luminance format

(4) Decoding 25Hz and 50Hz video is BD-ROM Player mandatory if a 50Hz TV system is used

(5) Peak Video Bitrate is constrained by the relevant ISO/IEC HRD conformance and by the MPEG-TS T-STD decoder buffer input rate

(6) See following slides for description of MaxFALL and MaxCLL metadata

NOTE:

BDA Authoring Guideline for HDR Content will be prepared to include the following recommendation text: "Maximum Frame Average Light Level" not to exceed 400nits. Over 1000 nits should be limited to specular highlights which are expected to be a small percentage of the picture area.

SD resolution and 3D (MVC) video are not included. HDR Video optional functions under study in BDA.

ST 2084 : High Dynamic Range Electro-Optical Transfer Function of Mastering Reference Displays (published as of September 2014)

ST 2086: Mastering Display Color Volume Metadata Supporting High Luminance and Wide Color Gamut Images (published as of November 2014)

http://www.blu-raydisc.com/en/Industry/Specifications/

BDA High Dynamic Range Components:

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- MaxFALL (Frame Average Max: BDA:400)
  - $\text{mean}_{\text{allPixels}}(\text{max}_{\text{eachPixel}}(r,g,b))$ | calculation in linear light domain

- MaxCLL
  - $\text{max}_{\text{allPixels}}(\text{max}_{\text{eachPixel}}(r,g,b))$

CEA Standard CEA-861.3 „HDR Static Metadata Extensions“
January 2015

- ST 2086
  - Mastering ***Color Volume*** data (Black, White, Red, Green, Blue)

- ST 2084 (EOTF – see next slides)

What is High Dynamic Range?

- Can not only be defined via the peak white over black ratio
  - OLED dynamic range would be infinity

- Metrics:
  - Peak white for L20 (L20 = 20% white, 80% black)
  - Full White
  - MaxFALL
  - Local contrast
  - Black in a dark, dim, bright environment. (Screen reflectance)
  - Black when some pixels are bright (straylight)

- Do we need something like LEQ or ITU-R 128 for HDR?

MaxCLL?

For MaxCLL interpretation, the unit is equivalent to cd/m2 when the brightest pixel in the entire video stream has the chromaticity of the white point of the encoding system used to represent the video stream. Since the value of MaxCLL is computed with a max() mathematical operator, it is possible that the true CIE Y Luminance value is less than the MaxCLL value. This situation may occur when there are very bright blue saturated pixels in the stream, which may dominate the max(R,G,B) calculation, but since the blue channel is an approximately 10% contributor to the true CIE Y Luminance, the true CIE Y Luminance value of the example blue pixel would be only approximately 10% of the MaxCLL value.

http://www.movielabs.com/md/md/v2.3/Common_Metadata_v2.3-diff-v2.2.pdf

MaxFALL?

For MaxFALL interpretation, the unit is equivalent to cd/m2 when the maximum frame average of the entire stream corresponds to a full-screen of pixels that has the chromaticity of the white point of the encoding system used to represent the video stream. The frame-average computation used to compute the MaxFALL value is performed only on the active image area of the image data. If the video stream is a "letterbox" format (e.g. where a 2.40:1 aspect ratio is put inside a 16:9 image container with black bars on the top and bottom of the image), the black bar areas are not part of the active image area and therefore are not included in the frame-average computation. This allows the MaxFALL value to remain an upper bound on the maximum frame-average light level even if image zooming or pan/scan is performed as a post-processing operation.

http://www.movielabs.com/md/md/v2.3/Common_Metadata_v2.3-diff-v2.2.pdf

The High Dynamic Range Challenge?
Not Acquisition or Mastering, but Distribution:

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Mastering Display:

- 0.005 – 4000cd/m2
- Dark environment

Tablet:

- 0.15 – 600cd/m2
- Bright environment

HDR-TV:

- 0.01 – 1000cd/m2
- Dark environment

What about Color Trims and HybridLogGamma‘s backwards compatibility promise?

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- Static global tone mapping approach?
  - We know since the mid 90s this doesn’t work
  - Science publications like Ward 1994
  - Kodak Cineon System Preview LUTs for conversion between Print and TV
- Content and display adaptive automatic tonemapping?
  - We know since the mid 2000s this doesn’t work
  - Science publications like Reinhard 2002
  - Automatic tonemapping approaches in color grading software

How can we service devices with different capabilities in different viewing environments?

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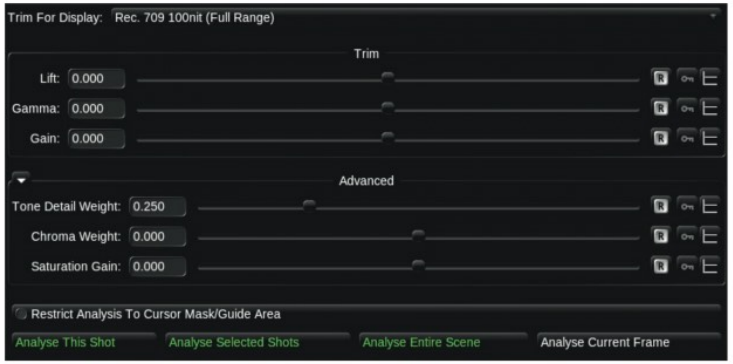
- Deliver color trims as metadata to account for non color appearance phenomena as:
  - Story-telling-issues (backlight)
  - Cultural issues (blueisch nights for TV, neutral dark nights for cinema)

http://www.journographica.com/wp-content/uploads/2011/05/backlight.jpg



Dolby Vision options in Baselight

How can a Metadata based workflow be used in live TV production?

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- Global settings?
  - Soccer example

How can a Metadata based workflow be used in live TV production?

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- CCU Operator (Has less work in HDR scenarios anyway)

Peter Centen (Grass Valley)
“4k-HDR-Imagers”, HPA 2015, Palm Springs

Motivation – Why Wide Color Gamut?

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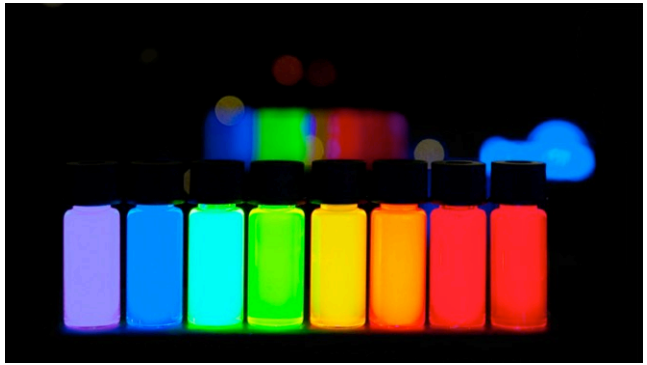
- Cinema:
  - The move from Xenon to laser illuminated projectors will give us Wide Color Gamut for free!

- TV:
  - Rec. 2020 is part of the UHD ecosystem and will enable Wide Color Gamut distribution.
  - LCD displays with quantum dots and OLED displays feature a gamut beyond Rec.709.

Christie Laser Illuminated Projection System



PlasmaChem Quantum Dots

Motivation – Why Wide Color Gamut?

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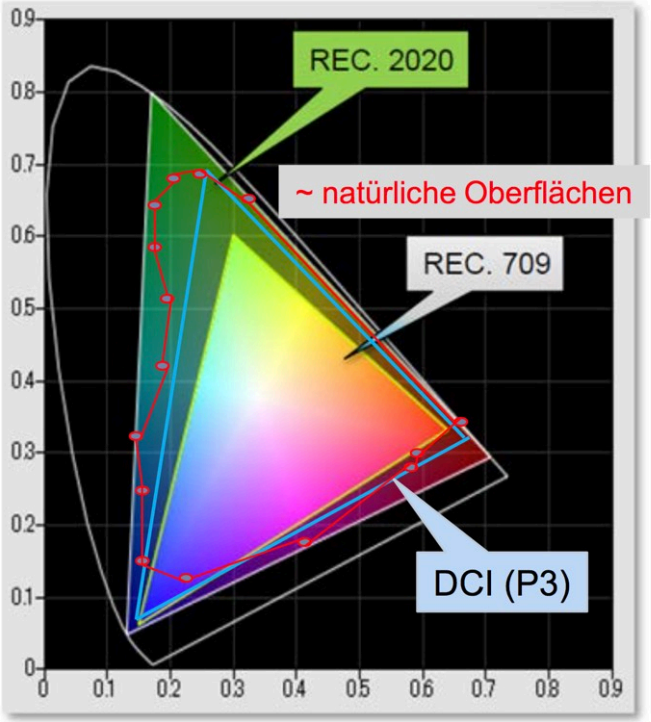
- Is Pointer's Gamut / are the optimal colors really a good reference for a TV colorspace?

- My personal opinion: No!
  TV & Cinema is about storytelling!

- For me the magic starts outside Pointer's gamut. (See the Demo)



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© IRT – R.Schäfer, D. Driesnack

What is Wide Color Gamut

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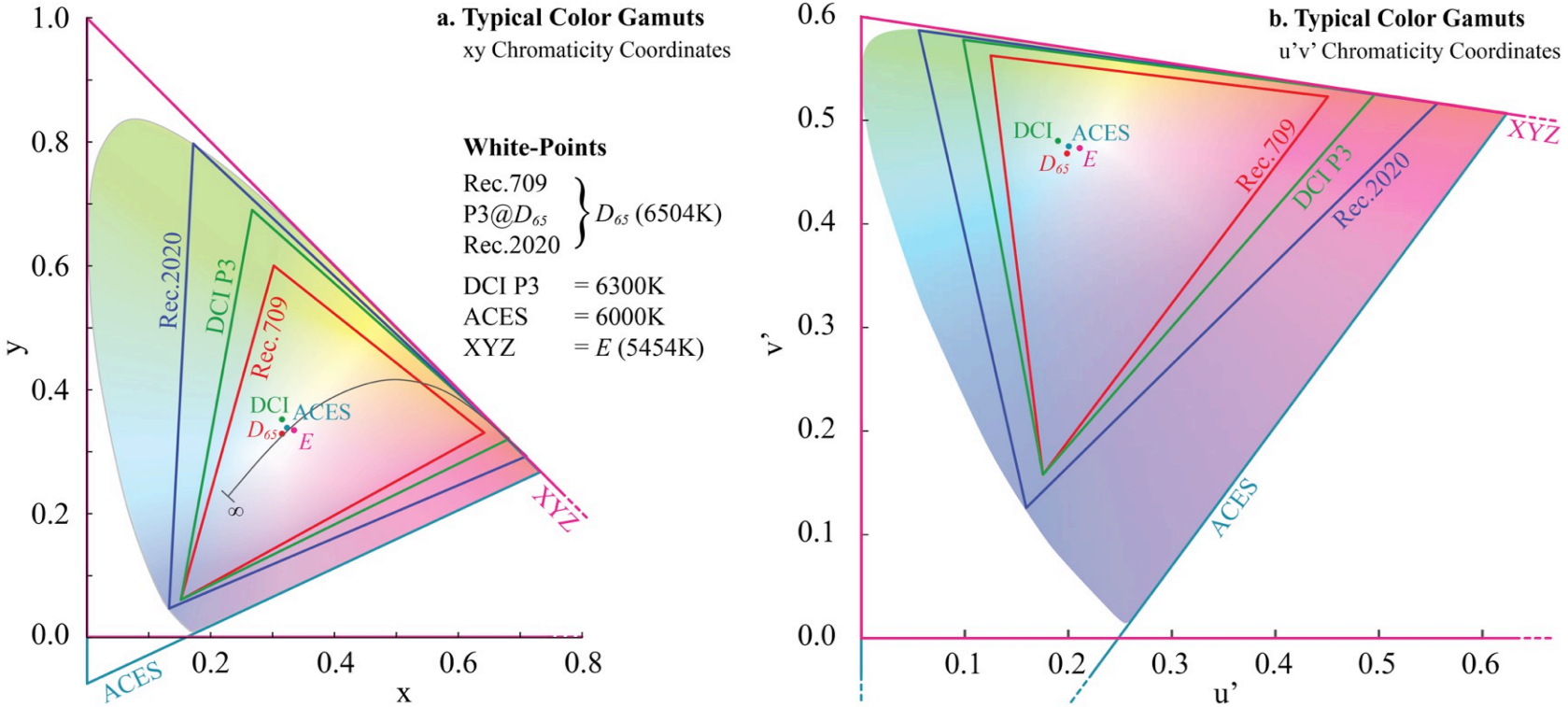

Timo Kunkel, Jan Froehlich, IBC 2014

Wide Color Gamut Challenge: Camera Characterization

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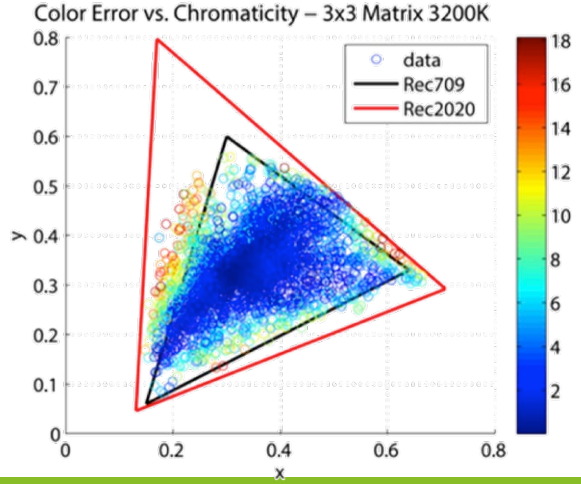
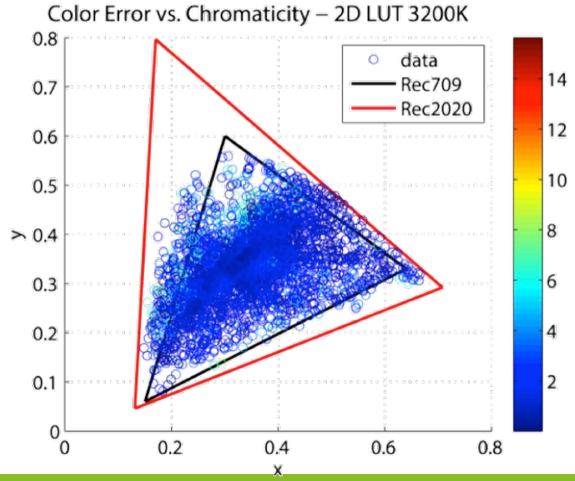
The good news: All current cameras are already wide gamut capable by design! It's just a matter of a different matrix.

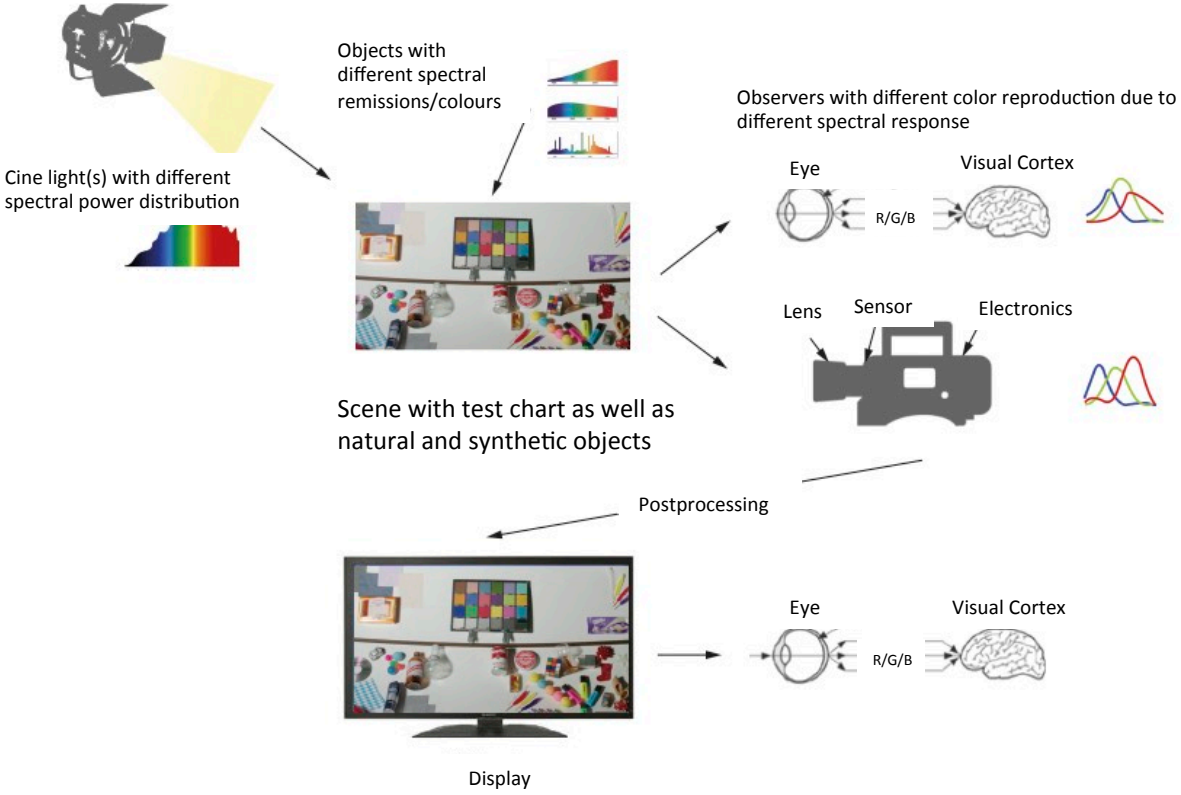
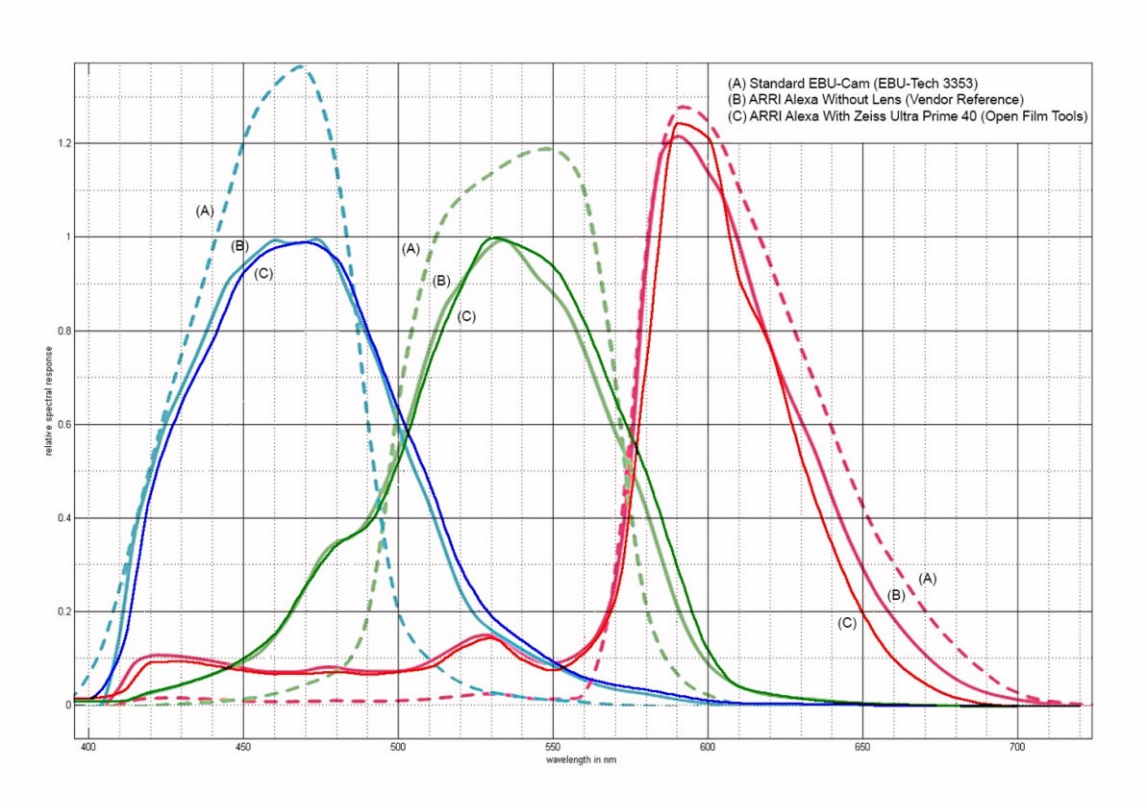
The bad news: 3x3 Matrices are not always sufficient for precise camera characterization. Better results can be obtained with 2D-LUTs:





Jon McElvain: „Cinematic Camera Emulation Using Two-Dimensional Color Transforms“ EI 2015

Open Film Tools Project @ HdM-Stuttgart



First Results – Spectral Response for Arri Alexa