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

- 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?

- Typical mid size cinema:

Hans Kiening, “4K+ Systems - Theory Basics for Motion Picture Imaging”, HPA 2009, Palm Springs
Motivation – Why Higher Resolution?

- Typical large size cinema:

Hans Kiening, “4K+ Systems - Theory Basics for Motion Picture Imaging”, HPA 2009, Palm Springs
Motivation – Why Higher Resolution?

- 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?

- 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.”

Motivation – Why Higher Resolution?

Motivation – Why Higher Resolution?

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

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

- **TV:**
  - UHD-1
    - (3840x2160)
  - UHD-2
    - (7680x4320)
Motivation – Why High Dynamic Range?

- 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.

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

Do the creatives like it?

- 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.

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

Backlight

LCD w/ PSF Compensation


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

- Different display technologies show different weaknesses

Example: Deficiencies of variable backlight monitors
Results – Evaluation of HDR Displays:

- Example: Deficiencies of variable backlight monitors

FOTOS DOLBY KERZEN
Results – Evaluation of HDR Displays:

- Example: Deficiencies of variable backlight monitors

FOTOS DOLBY KERZEN
High Dynamic Range Displays?
OLED

Example:
- Sony 30" PVM-X300
- Promises high local contrast
### What is High Dynamic Range?

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What is High Dynamic Range?

- 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 400 nits. 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)

BDA High Dynamic Range Components:

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

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

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

- **ST 2084** (EOTF – see next slides)

CEA Standard CEA-861.3 „HDR Static Metadata Extensions“
January 2015
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 \((L20 = 20\% \text{ white, } 80\% \text{ black})\)
  - 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:

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?

- 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?

- 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)

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

- Global settings?
  - Soccer example
How can a Metadata based workflow be used in live TV production?

- CCU Operator (Has less work in HDR scenarios anyway)
Motivation – Why Wide Color Gamut?

- 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.
Motivation – Why Wide Color Gamut?

- 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)
What is Wide Color Gamut

a. Typical Color Gamuts
xy Chromaticity Coordinates

White-Points
Rec.709
P3@D_65
Rec.2020 \{ D_65 (6504K) \\
DCI P3 = 6300K
ACES = 6000K
XYZ = E (5454K)

b. Typical Color Gamuts
u'v' Chromaticity Coordinates

Timo Kunkel, Jan Froehlich, IBC 2014
**Wide Color Gamut Challenge: Camera Characterization**

*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:

Open Film Tools Project @ HdM-Stuttgart

Scene with test chart as well as natural and synthetic objects

Cine light(s) with different spectral power distribution

Objects with different spectral remissions/colours

Observers with different color reproduction due to different spectral response

Eye

Visual Cortex

Eye

Visual Cortex

Lens

Sensor

Electronics

Postprocessing

Display
First Results – Spectral Response for Arri Alexa