An Overview of the Hybrid Log-Gamma HDR System

MediaNet Flanders and the Dutch Guild of Multimedia Engineers

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BBC | Research & Development

What to Expect

- Motivation for Hybrid Log-Gamma (HLG)
- Fundamentals of HDR
- Compare ITU-R PQ & HLG solutions
- HLG HDR in Production
- HLG HDR in Distribution
- HLG HDR in the Home
- Summary

Motivation for developing HLG

HLG Enables Easy Migration to HDR TV Production & Distribution

Jointly developed by BBC and NHK, included in ITU-R Recommendation BT.2100

- Specifically developed for Television
- Delivers high quality HDR pictures
  - Delivery to diverse displays
- In Production
  - Requires no metadata
  - Compatible with existing 10-bit infrastructure, codecs and equipment
  - Provides compatible picture on SDR screens
  - Migration only requires HDR cameras, and HDR displays in critical monitoring areas
- In Distribution
  - Supported by HEVC and HDMI 2.0b (via software upgrade)
  - Specified (alongside PQ) by DVB, ARIB and YouTube
  - Delivers a compatible image to SDR DVB UHD Phase-1 (BT.2020 colour) receivers & displays

Metadata Free Operation Key to Unlocking Benefits

- Allows use of conventional circuits, routers, switchers and codecs
- Enables simple reliable and consistent production
- Delivers consistent results on consumer screens and devices
- Places no constraints on operational practices
  - Even simple metadata prevents, mixes, DVE and complicates graphics

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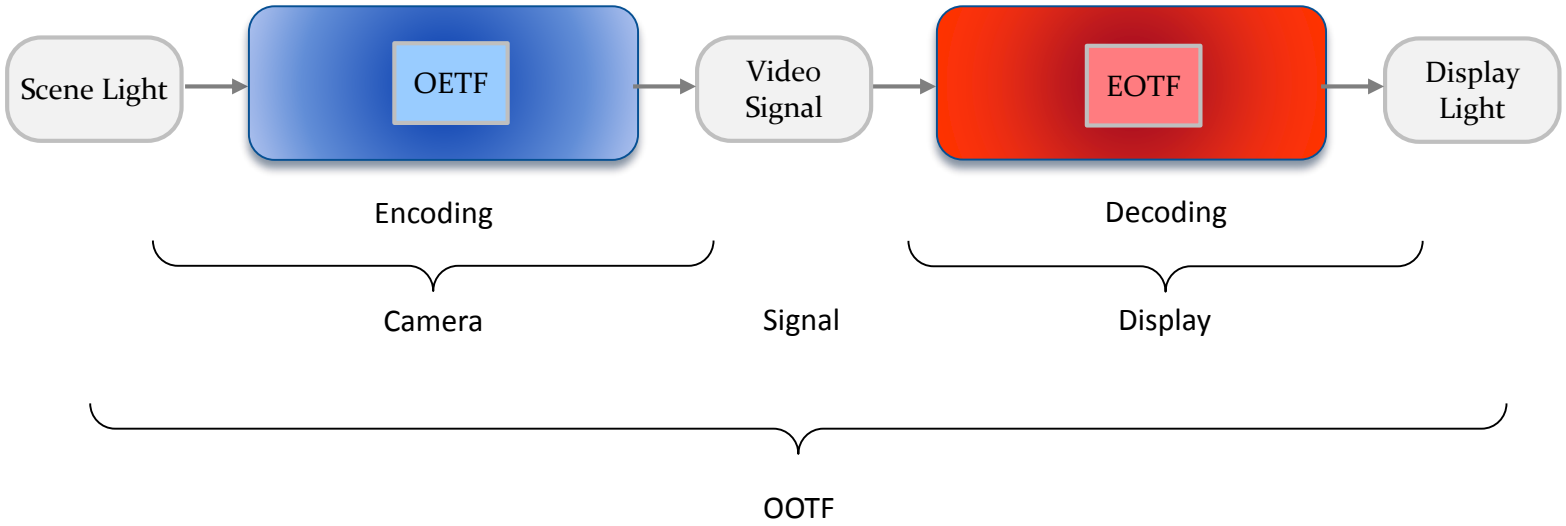
- Same issues apply in consumer equipment

Just like existing TV systems, HLG based on Relative Brightness

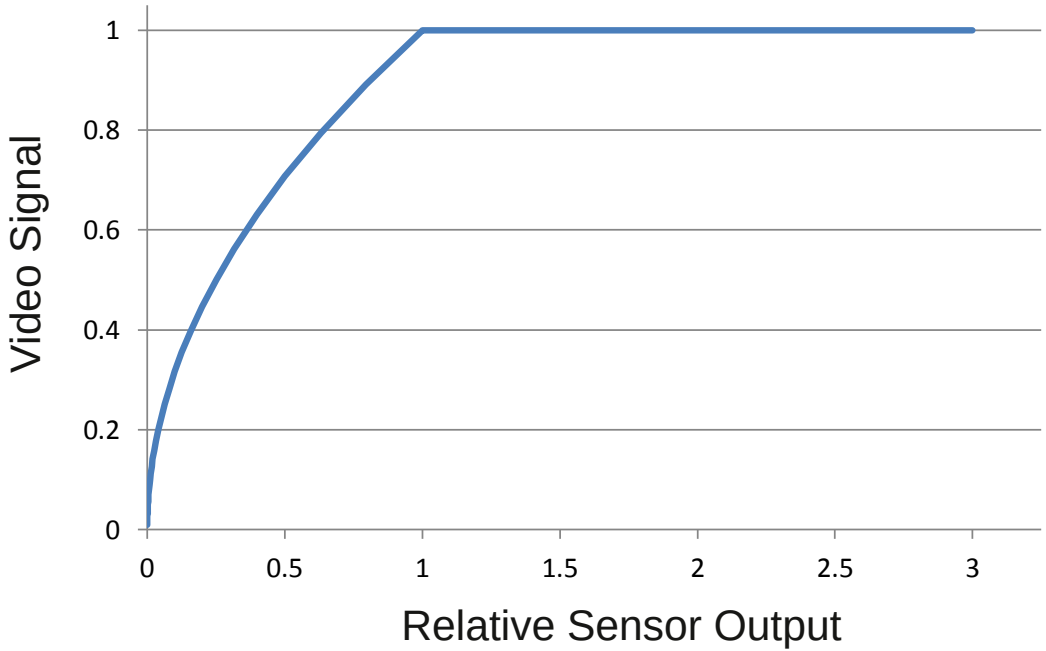
- Signal independent of the display
  - Utilises entire code range regardless of mastering monitor
  - Preserves the value of the archive as consumer displays get brighter
- Engineers and Craft staff read waveform monitors in the conventional way
- By design, entire image gets brighter as display brightness increases
  - Allows HDR viewing in brighter environments whilst maintain the creative intent
  - Allows consistent signals across a wide range of production environments and displays

HDR Fundamentals

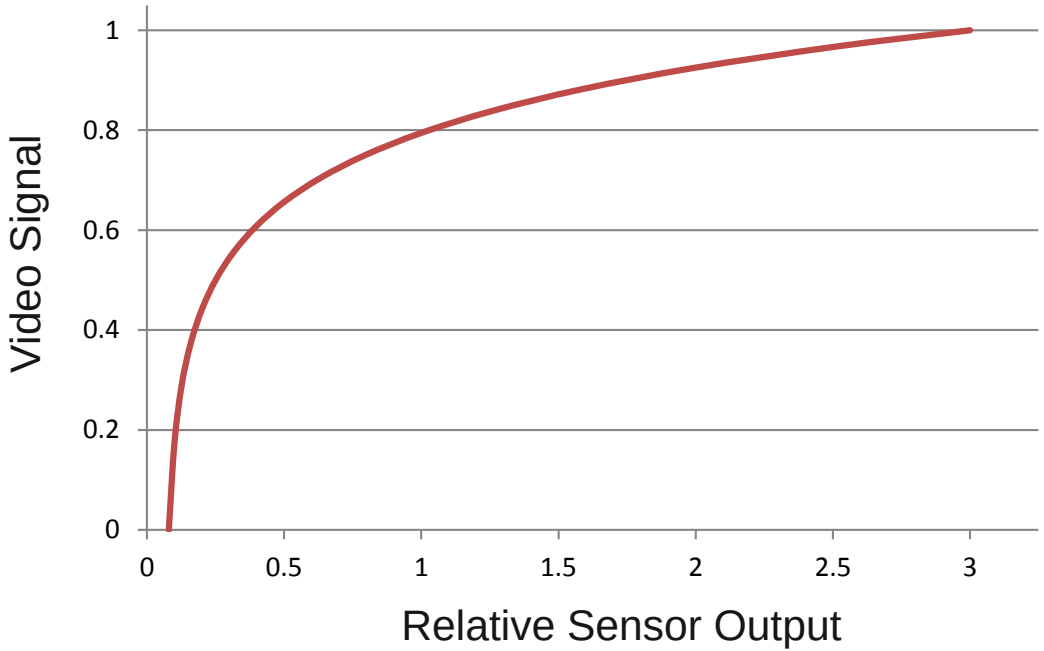
End-to-End Television Signal Chain



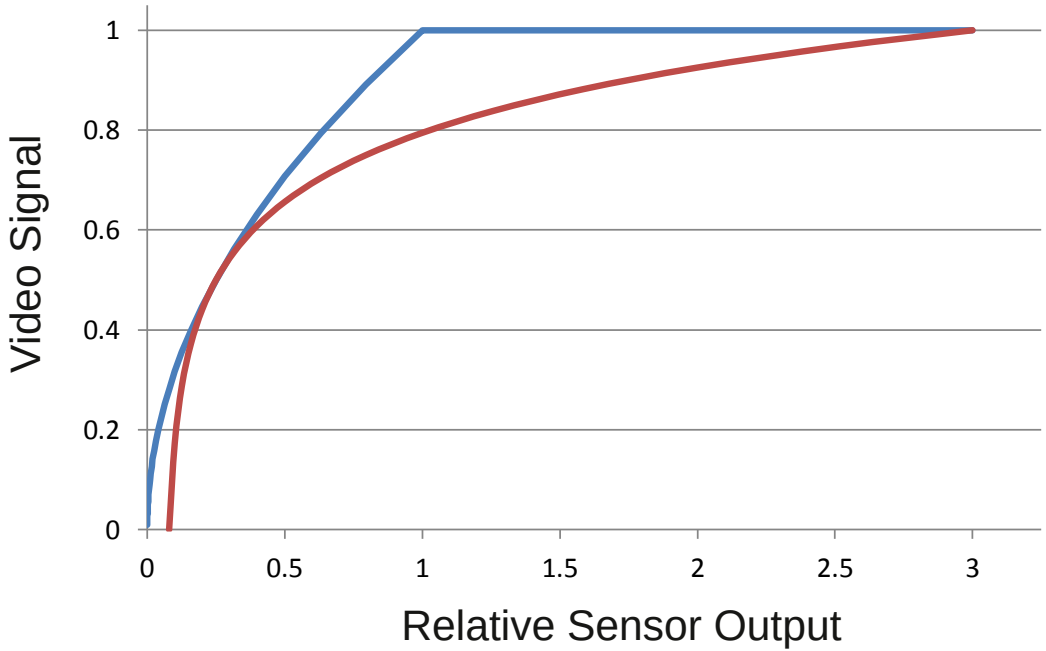
Conventional SDR Camera Curve



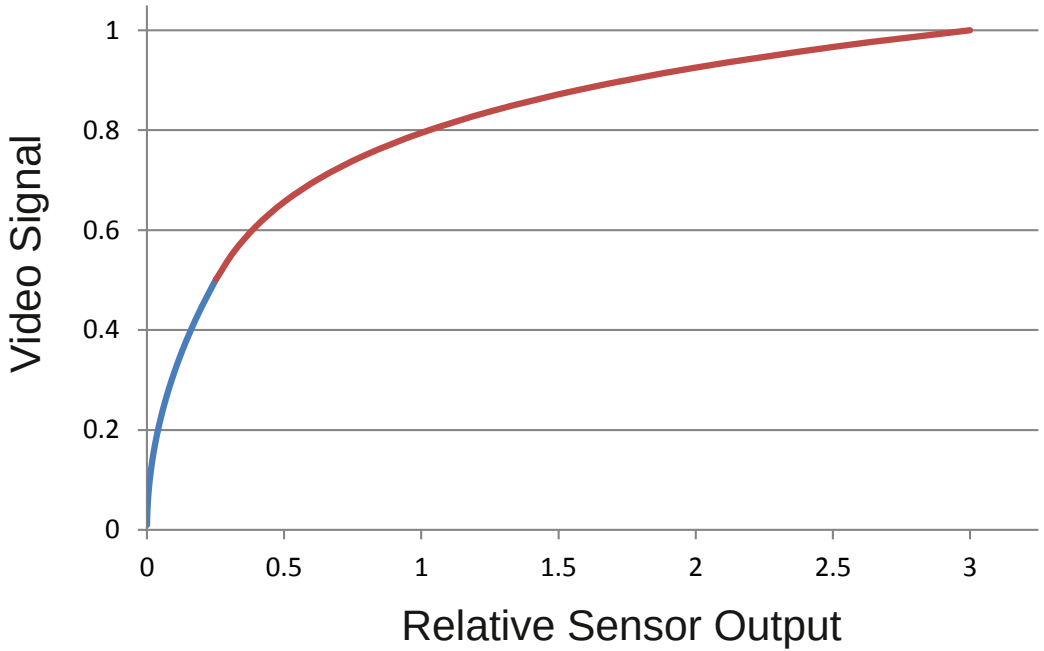
Camera Log Curve



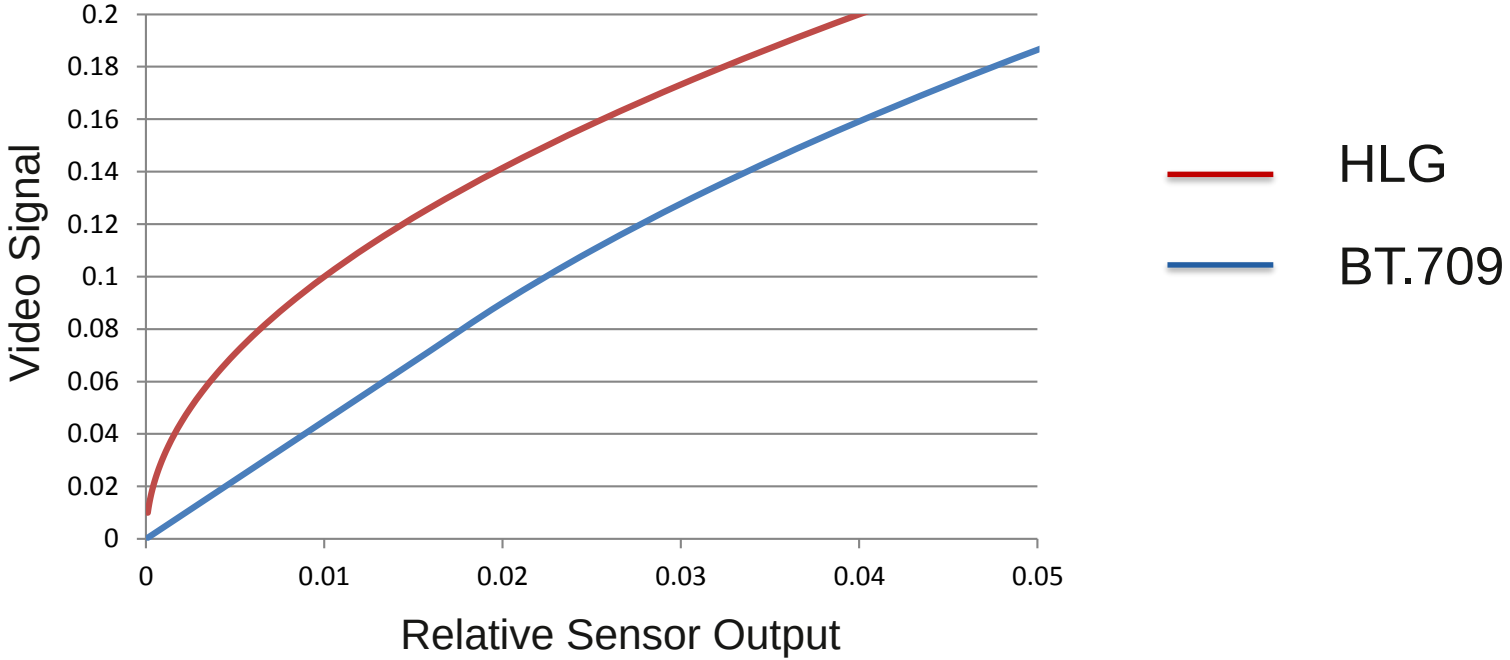
Best of Both


Video Signal
1
0.8
0.6
0.4
0.2
0
0
0.5
1
1.5
2
2.5
3
Relative Sensor Output

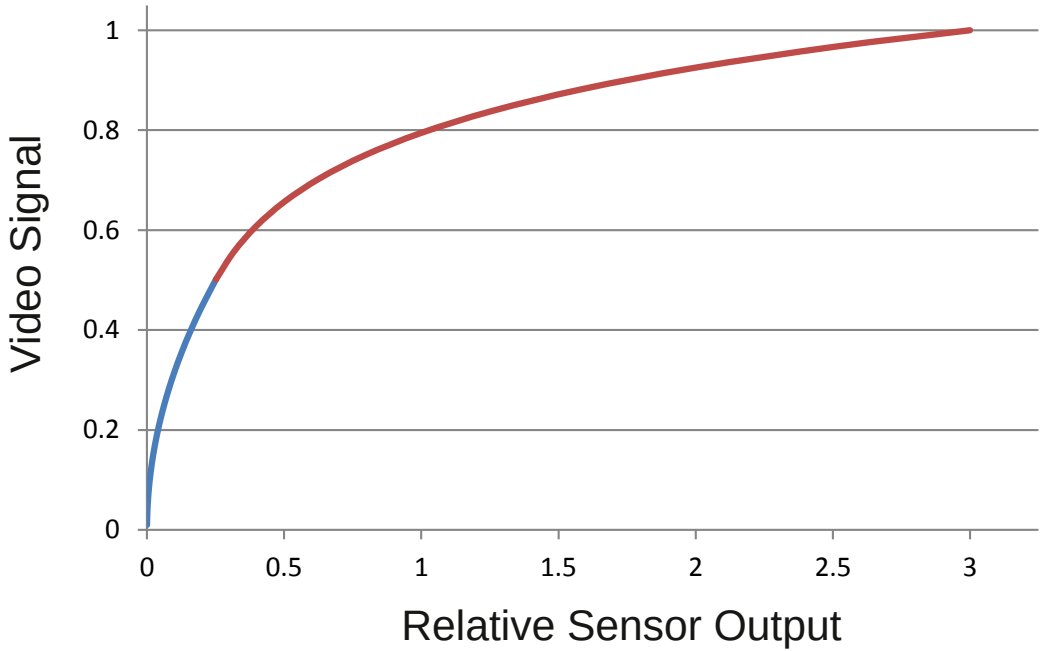
HLG HDR Camera Curve



Additional Dynamic Range in Blacks



HLG Camera Curve Similar to SDR Camera Curve With a "Knee"



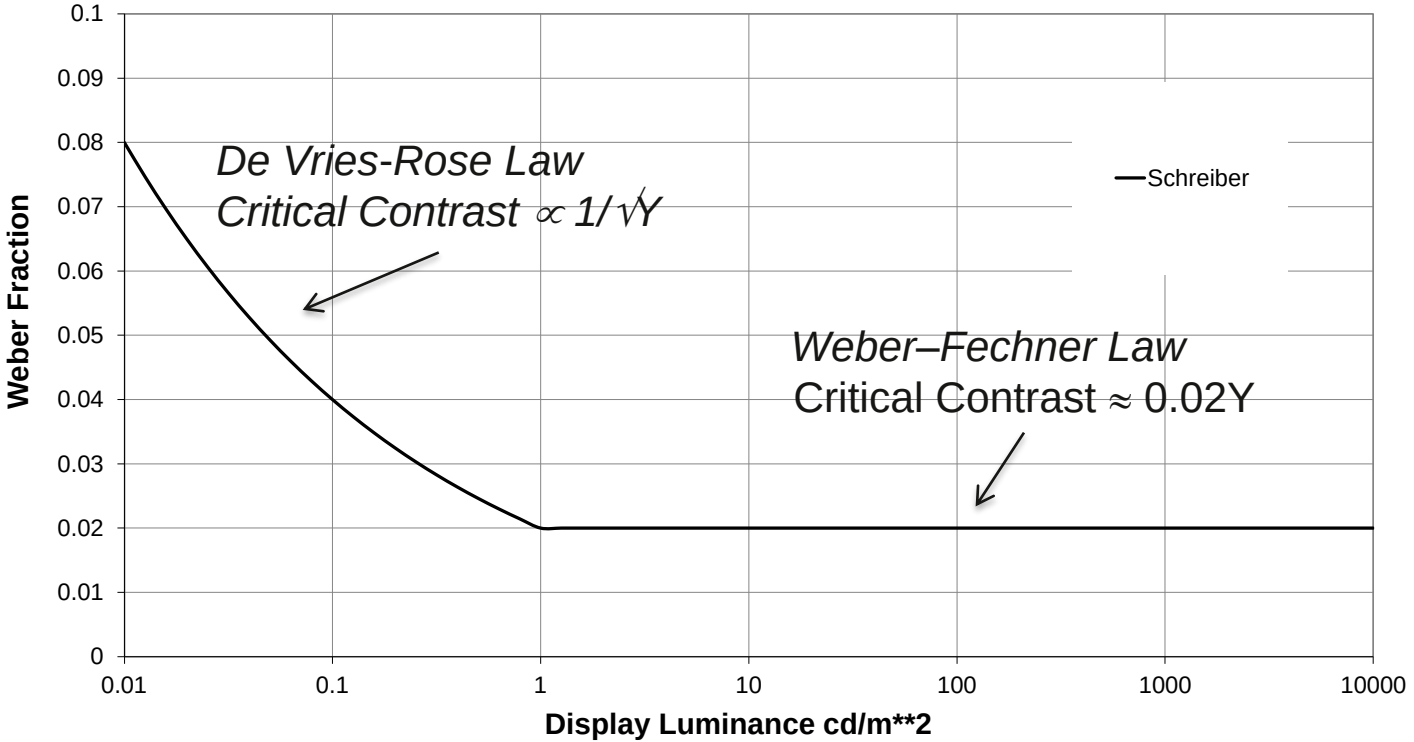
Banding

Image Quantisation

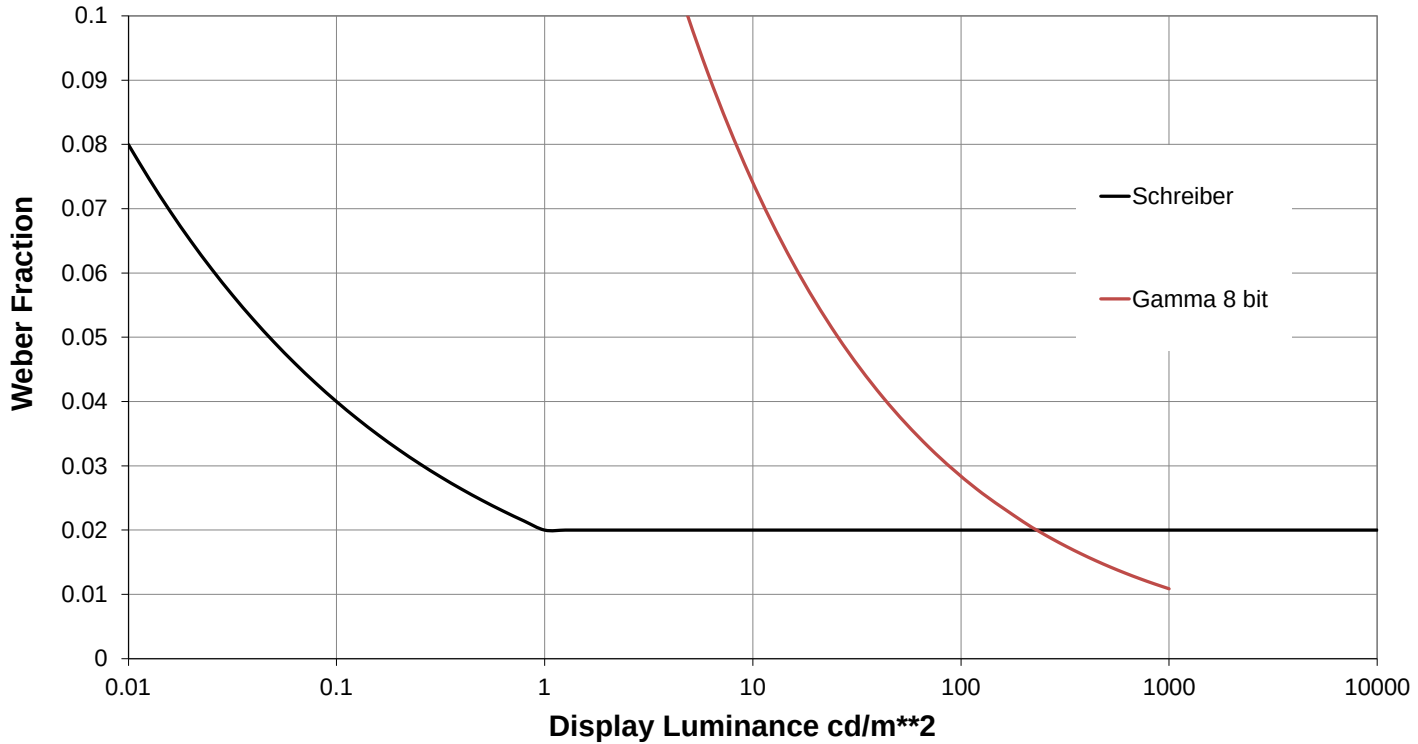
Original

Extreme Banding

Quantization Effects (Banding): The Schreiber Threshold



Quantization Effects (Banding): Gamma Curve



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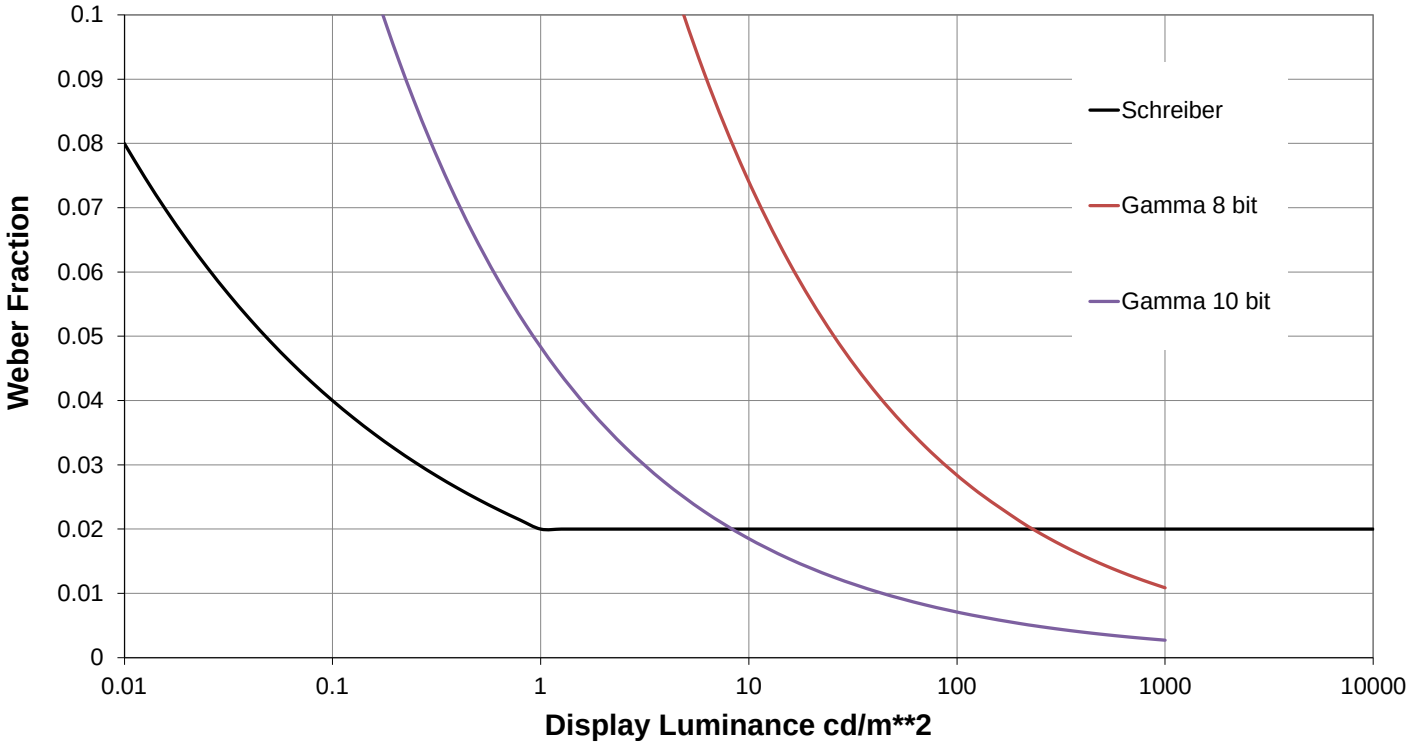
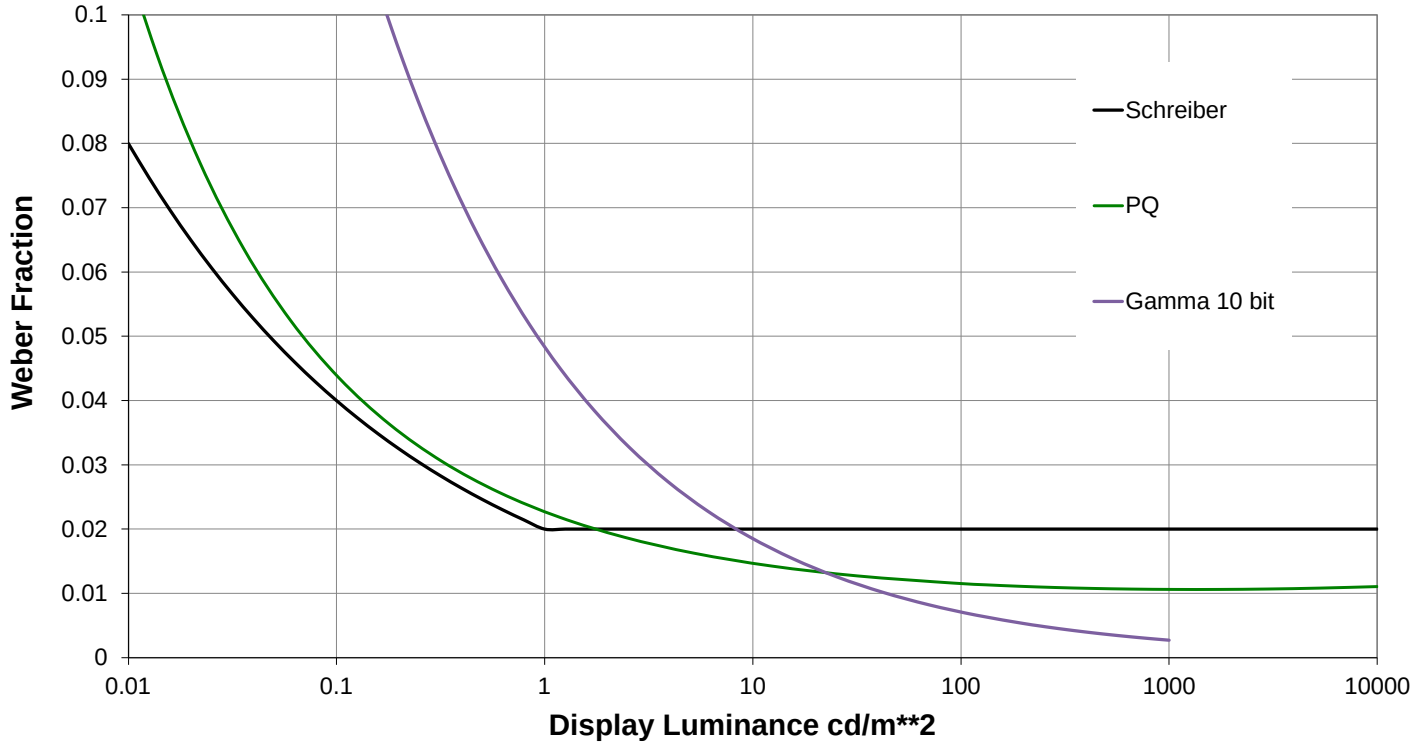
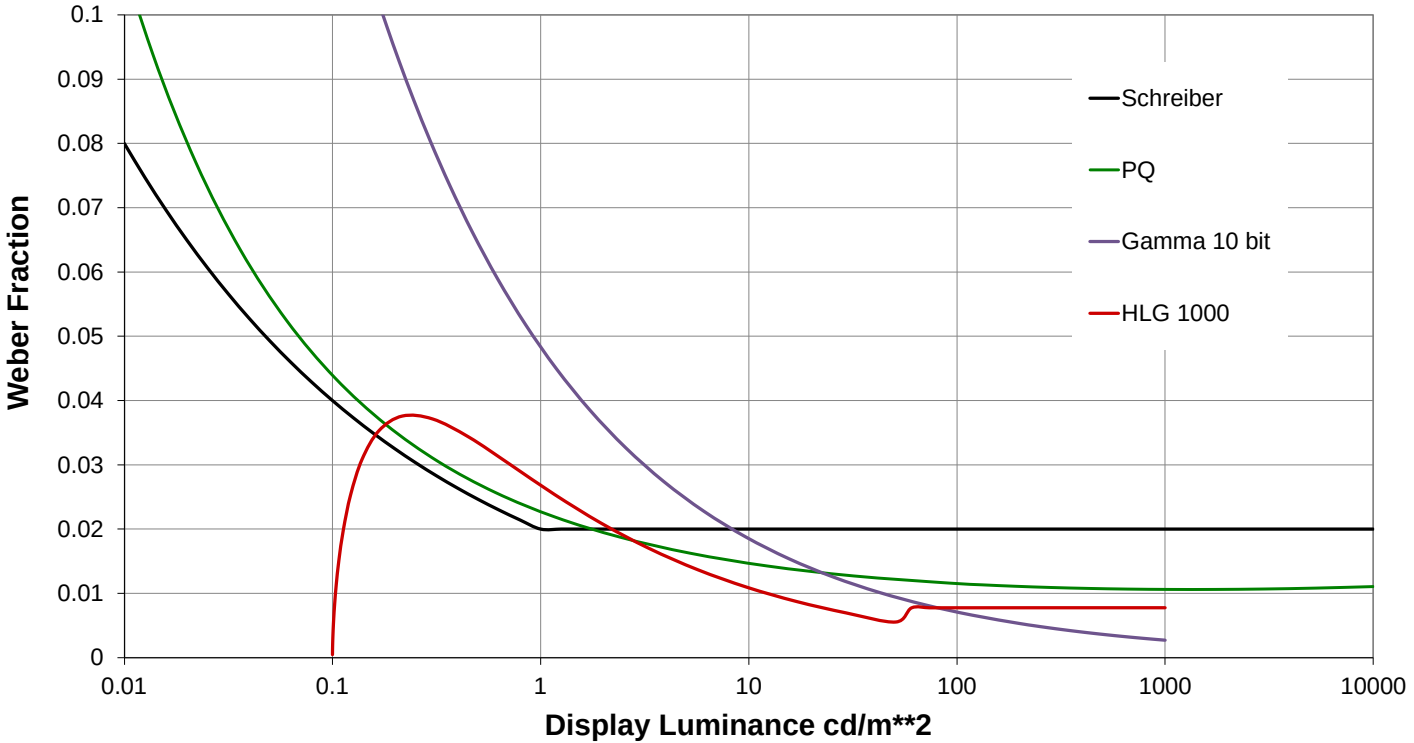


Quantization Effects (Banding): PQ



Quantization Effects (Banding): HLG



Psychovisual Adaptation

Image plus surround

Image in dark surround

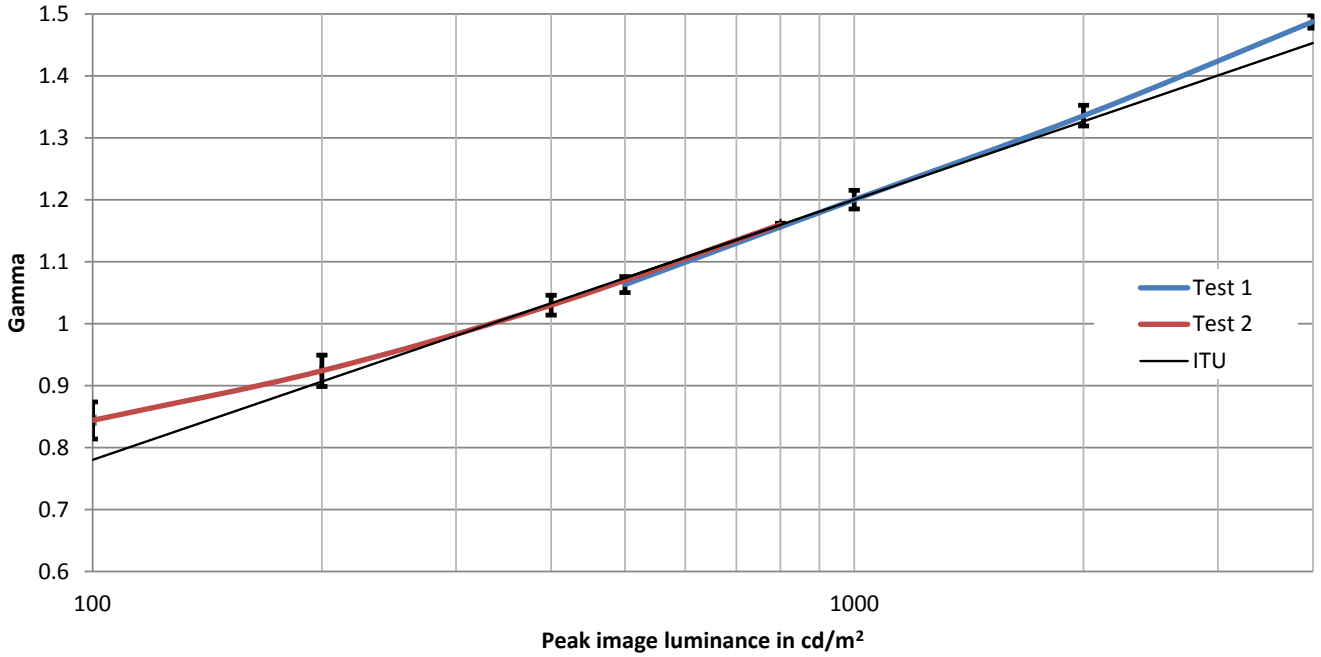
“Rendering Intent” (Display Gamma)

Gamma too low

Gamma correct

Gamma too high

Variation of Gamma for Perceptual Match



Artistic ("Creative") Intent

- Brighter environments need brighter pictures
- Different environments need different display gamma.
- Preserving luminance does NOT maintain creative intent

- The HLG signal, representing the camera output, remains constant.
  - HLG displays adapt to preserve artistic intent (defined in BT2100).
- The PQ signal represents the image specifically for a reference display
  - Dim environment
  - Adaption for other brightness and environments not specified

Compare ITU-R PQ & HLG solutions

Just like conventional TV, HLG is "Scene-Referred"

- Like BT.601, BT.709, Slog3, PanaLog etc., the HLG signal describes the **relative** light in the scene
- It is specified by the OETF (opto-electronic transfer function), the camera characteristic

PQ is "display-referred"

- Like the digital cinema standards, the signal describes the **absolute** light output from the mastering display
- The signal is specified by the display EOTF

PQ Represents Absolute Brightness

600 cd/m² "shading"
e.g. OB truck

1000 cd/m² "shading"
e.g. studio gallery

2000 cd/m² "grade"

e.g. Code Values 81 - 674

e.g. Code Values 81 - 723

e.g. Code Values 74 - 789

Display Re-Mapping

Display Re-Mapping

Display Re-Mapping

Display Re-mapping

e.g. 400 cd/m² home theatre

e.g. Code Values 74 – 636

e.g. 1000 cd/m² evening viewing

e.g. Code Values 81 - 728

e.g. 2000 cd/m² daytime viewing

e.g. Code Values 119 - 789

e.g. 4000 cd/m² signage display

e.g. Code Values 158 - 940

- The signal varies with mastering display.
- Display re-mapping often required.

HLG Represents Relative Brightness

600 cd/m² “shading”
e.g. OB truck

1000 cd/m² “shading”
e.g. studio gallery

2000 cd/m² “grade”

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Code Values 64 - 940

e.g. 2000 cd/m² daytime viewing

Code Values 64 - 940

e.g. 4000 cd/m² signage display

Code Values 64 - 940

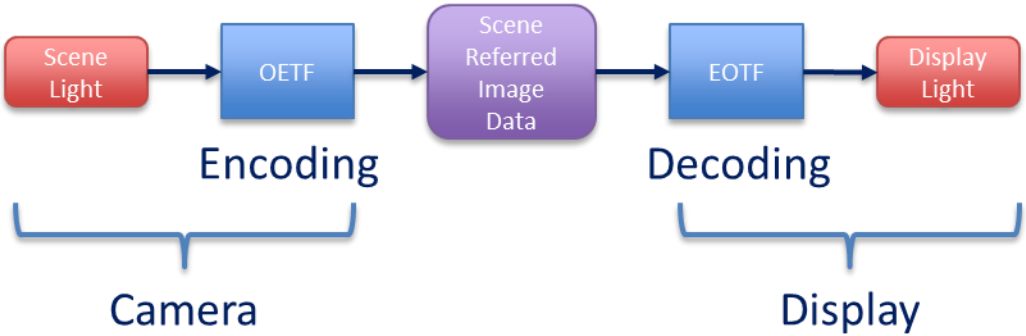
- The signal constant with mastering display.
- Display adaptation inherent part of HLG EOTF

PQ and HLG work differently

- HLG
  - Image brightness changes with display brightness
  - Dynamic range of highlights **constant**
  - **Brighter displays for brighter environments**

- PQ
  - Image brightness constant with display brightness
  - Dynamic range of highlights **increases** with display brightness
  - **Brighter displays for more highlights**

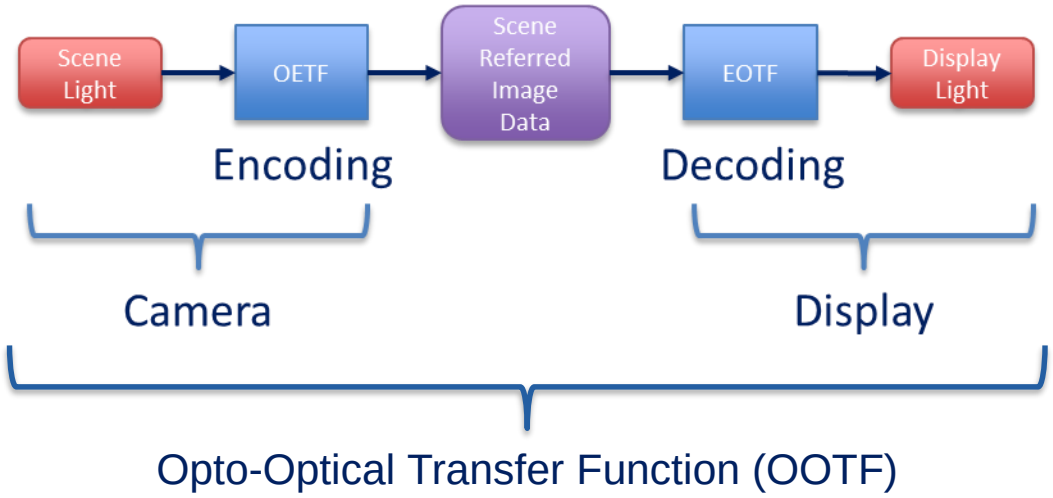
End-to-End Television Signal Chain



OETF: opto-electronic transfer function

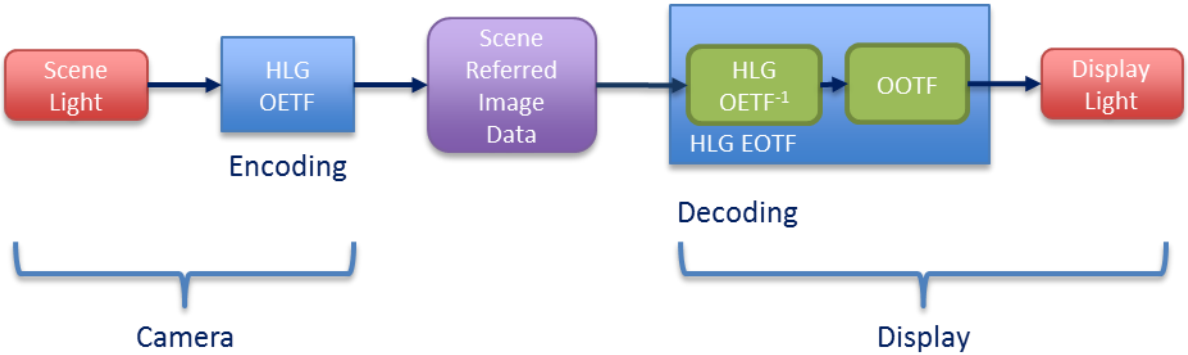
EOTF: electro-optical transfer function

Overall Transfer Function (OOTF) Non-Linear



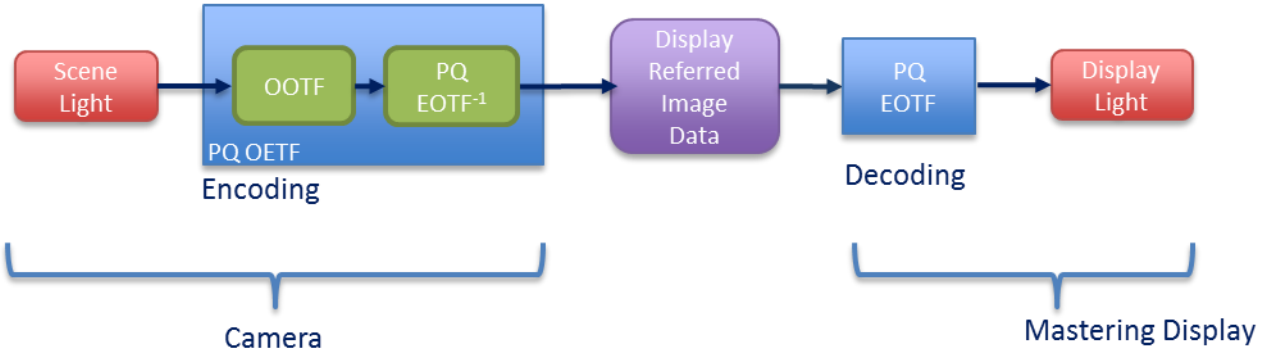
- OOTF varies according to viewing environment and brightness of the display
- Traditionally a "gamma" law OOTF

For “Scene Referred” Systems OOTF is Part of the Display



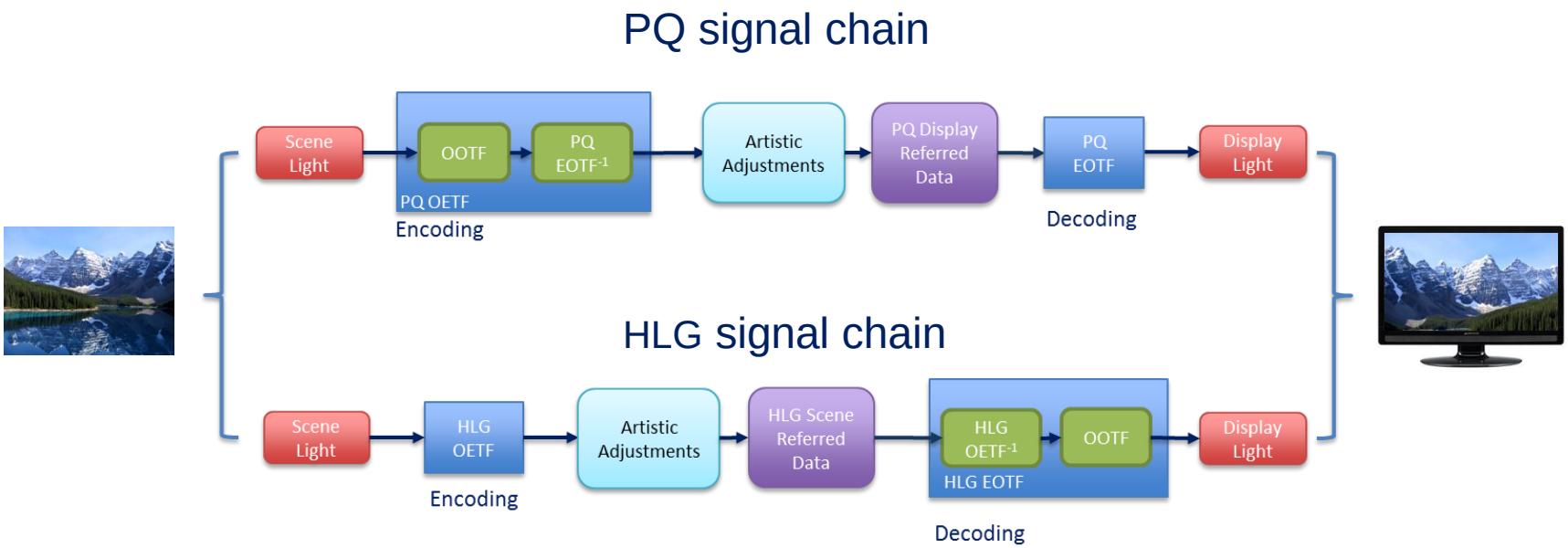
Hybrid Log-Gamma End-to-End Chain

For "Display Referred" PQ Systems OOTF is Part of the Camera

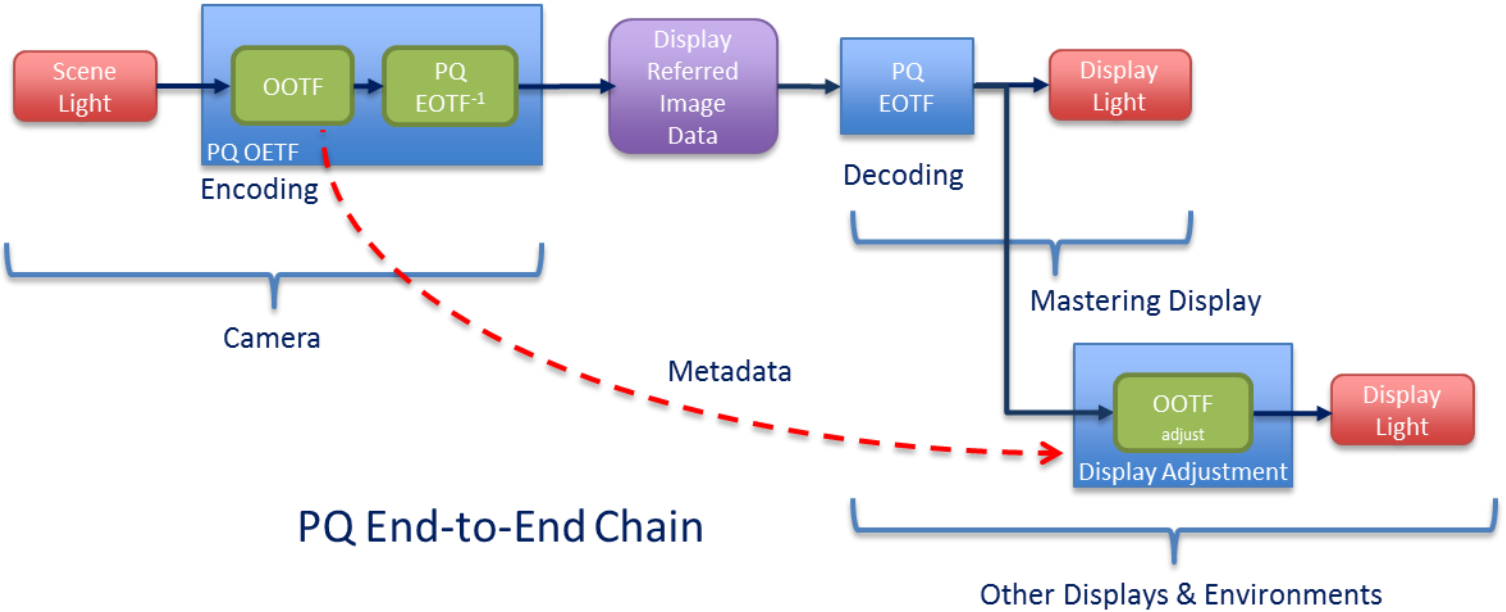


PQ End-to-End Chain

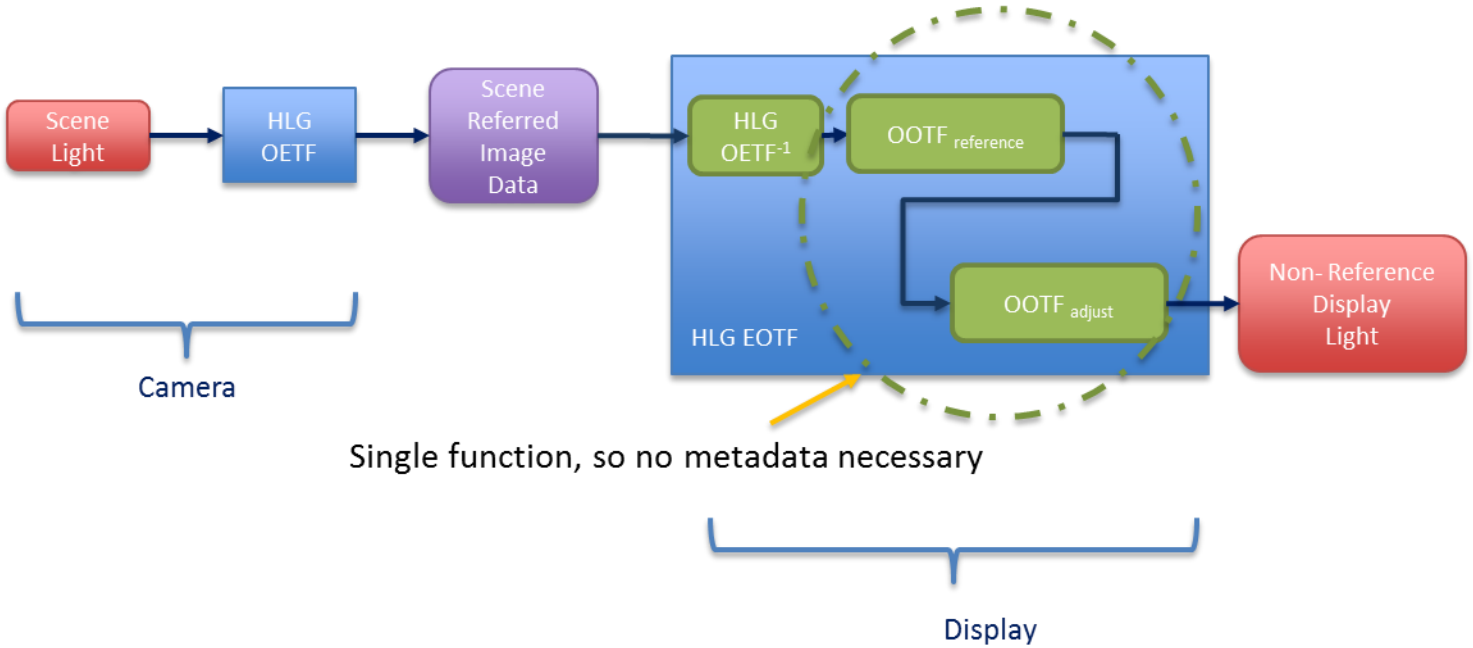
End-to-End Both HDR Systems Identical in Production Environment



BBC Believes PQ Display Rendering for Other Environments Requires Metadata for Optimal Presentation



Display Adjustments For HLG Needs No Metadata



HLG HDR in Production

HLG in TV Post-Production (other equipment available)

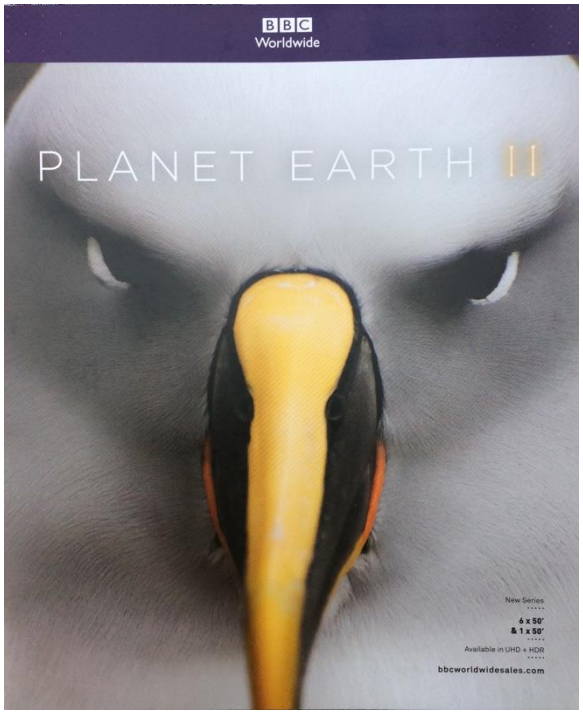
HLG "aware" grading software

- SAM Quantel Rio
- DaVinci Resolve
- SGO Mistika
- Filmlight Baselight
- Digital Vision Nucoda
- Colorfront

HLG displays

- Sony BVM-X300
- Canon DP-V2410, DP-V3010, DP-V2420
- Dolby PRM-4200/4220 (internal 3D-LUT for HLG)
- SIM2 (external converter)

Landmark TV Productions already Produced in HLG



- BBC's Planet Earth II
  - UHD HLG HDR
  - Baselight grade
  - Dolby PRM4220 (with internal HLG LUT) monitor
- Around 20 programmes for Sky Perfect Japan

HDR Cameras

- Live HLG
  - Grass Valley LDX-86
  - Sony HDC-4300
  - Panasonic AK-UC3000
  - Ikegami UHK-430, SHK-810

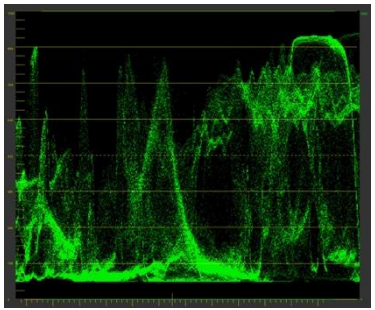
- Non-live, “Raw”
  - Sony (using sLog3)
  - Canon
  - Arri
  - Red
  - Panasonic
  - Many others ……

Setting the Signal Level

Camera

Zebra Stripes

Production or Grading Suite



Waveform Monitor

Setting the Signal Level

- Diffuse white
  - The brightness of ideal "matte" or diffusely reflecting surface
  - Ill defined – varies with lighting
  - Not all scenes have diffuse white

- About 90% signal level for conventional SDR TV

"Diffuse White" in HLG

- Fixed signal level
  - referred to as "reference level for graphics"
- 75% signal level (75 "IRE") proposed
- Good "compatible picture"
- ***Defines the number of stops for highlights***

"Diffuse White" in HLG

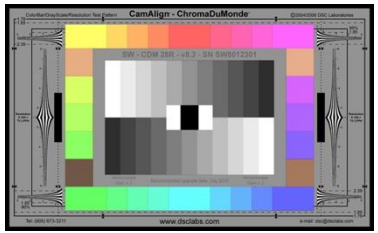
- Defined by the camera setup
  - e.g. 18% grey card or reflectance chart
- Varies with display brightness
  - 400 cd/m^2, 75 % = 102 cd/m^2
  - 1000 cd/m^2, 75 % = 203 cd/m^2
  - 2000 cd/m^2, 75 % = 344 cd/m^2
  - 4000 cd/m^2, 75 % = 581 cd/m^2
- About 2.5 stops allocated for highlights and speculars
  - Subject to artistic choice

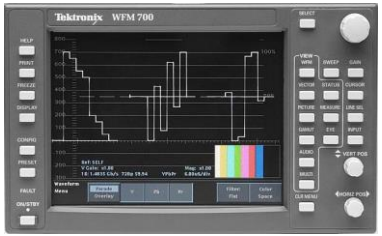
Levels for 1000 cd/m^2

Reflectance	Nominal Reference	
	% HLG	cd/m^2
18% Grey Card	38%	26
90% Reflectance Card	73%	176
Graphics reference	75%	203

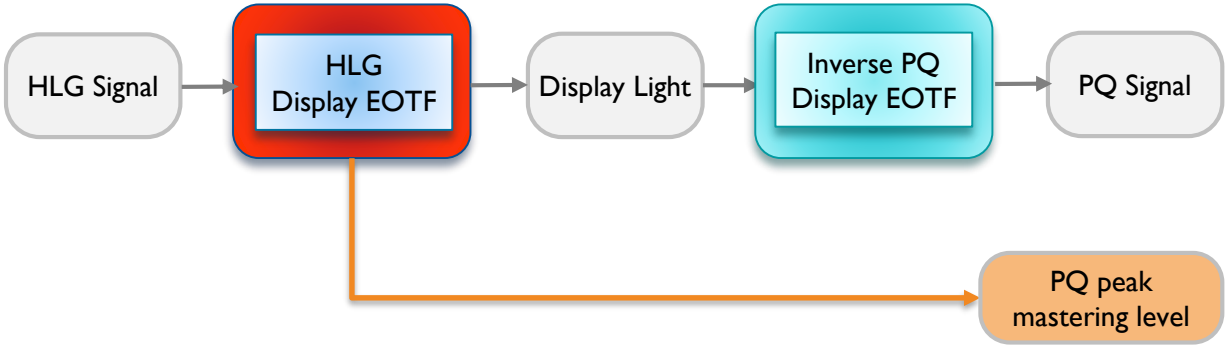
Ensuring Consistent Brightness in PQ & HLG Production

- Operational Practice Guidelines define reference levels
  - reference levels provide an “anchor”
  - similar to audio line-up levels
- Objective brightness measure also needed
  - similar to audio loudness, e.g. EBU R128, ATSC A/85
  - in development
- Comfort level tests underway to establish acceptable brightness range





Transcoding HLG to PQ



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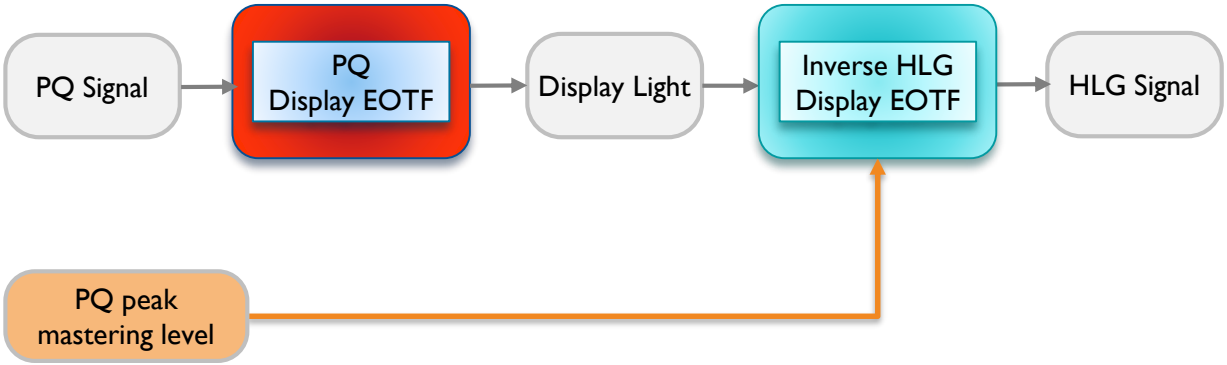
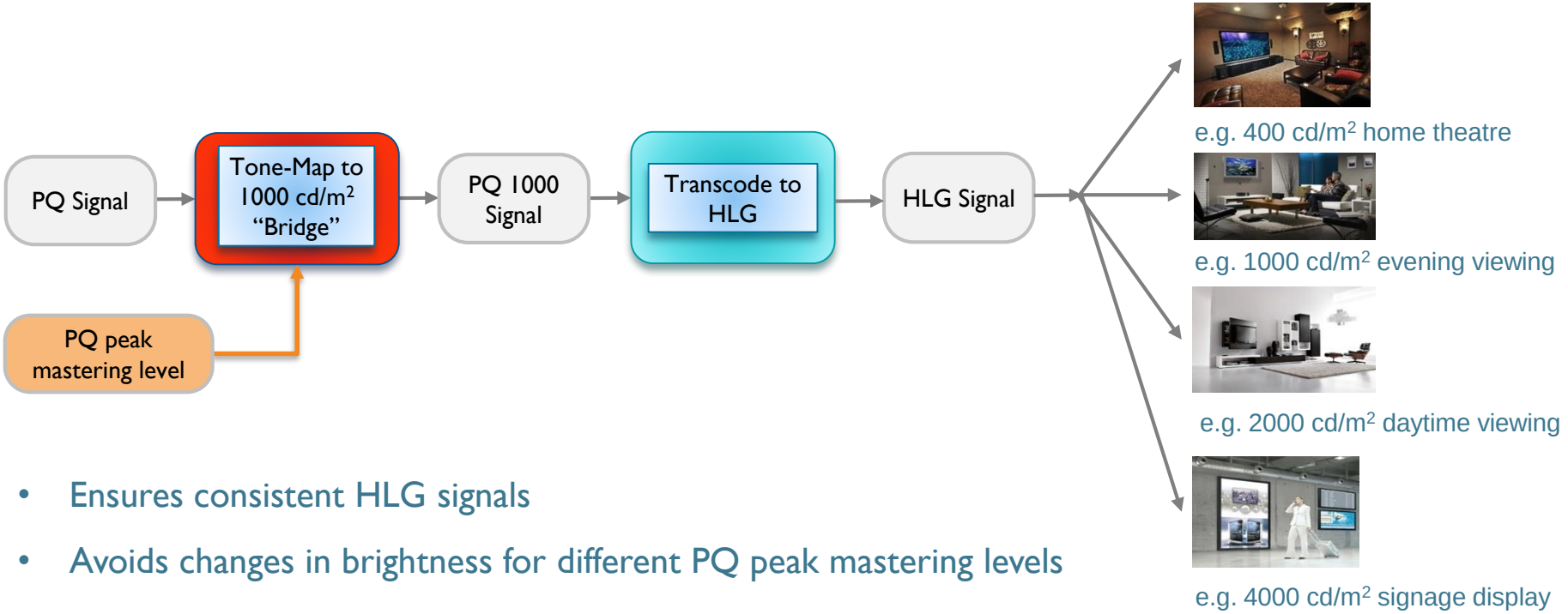
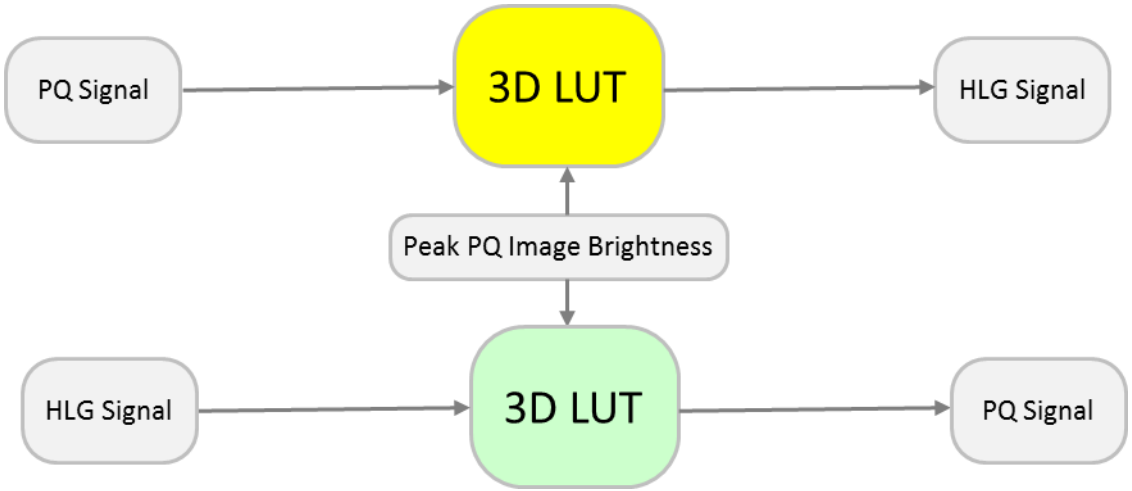


However "Conversion" from PQ to HLG is Recommended



- Ensures consistent HLG signals
- Avoids changes in brightness for different PQ peak mastering levels

PQ <-> HLG Interconversion Easily Implemented



- Already offered in grading software, distribution encoders and latest consumer silicon

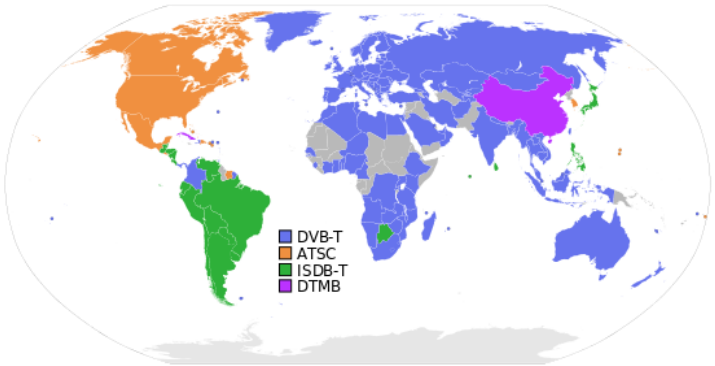
HLG HDR in Distribution

Both HLG and PQ Will be Supported in CE Devices in Most World Markets

HLG and PQ Included in,

- ARIB STD-B32, *Video Coding, Audio Coding And Multiplexing Specifications for Digital Broadcasting*
- DVB/ETSI TS 101 154 v2.3.1, *Specification for the use of Video and Audio Coding in Broadcasting Applications based on the MPEG-2 Transport Stream*
- Korea announced will support both HLG and PQ
- **YouTube HDR**

  https://support.google.com/youtube/answer/7126552
- HDMI 2.0b (HLG software upgrade)



Seven HLG TV Services Already "On-Air" Worldwide

- HLG Commercial Services
  - Sky Perfect Japan, launched October 2016
  - Travelxp 4K (Europe), launched January 2017

- Current HLG Test Services
  - SES Astra19.2°
    - HLG Test stream
    - NRJ (French Network) Test transmission
  - Eutelsat Hotbird 13.0°
    - 4-Ever Project Test Channel
  - Tour Eiffel, Paris, France
    - NRJ Test transmission
- NHK Super Hi-Vision
- BBC iPlayer

HLG HDR in the Home

Image Presentation

- HLG
  - **Brighter displays for brighter environments**
  - Image brightness changes with display brightness
  - Dynamic range of highlights **constant**
    - defined by diffuse white
- PQ
  - **Brighter displays for more highlights**
  - Image brightness constant with display brightness
  - Dynamic range of highlights **increases** with display brightness

Essential that HDR TV is suitable for HOME viewing environments

- BBC believes absolute brightness approach of PQ well suited to applications where viewing environments the same and similar to the grading environment (e.g. cinema, home movie theatre)

Essential that HDR TV is suitable for HOME viewing environments

- BBC believes absolute brightness approach of PQ well suited to applications where viewing environments the same and similar to the grading environment (e.g. cinema, home movie theatre)
- But, viewers should not have to draw curtains during the daytime to watch HDR-TV
- Relative brightness approach of HLG, well suited to diverse home TV viewing
  - To preserve details in the blacks, presentation needs to be brighter than in grading suite
  - To preserver the impact of highlights, consumer screens may need to be brighter than grading screens

Relative Light Approach of HLG allows HDR viewing all day long

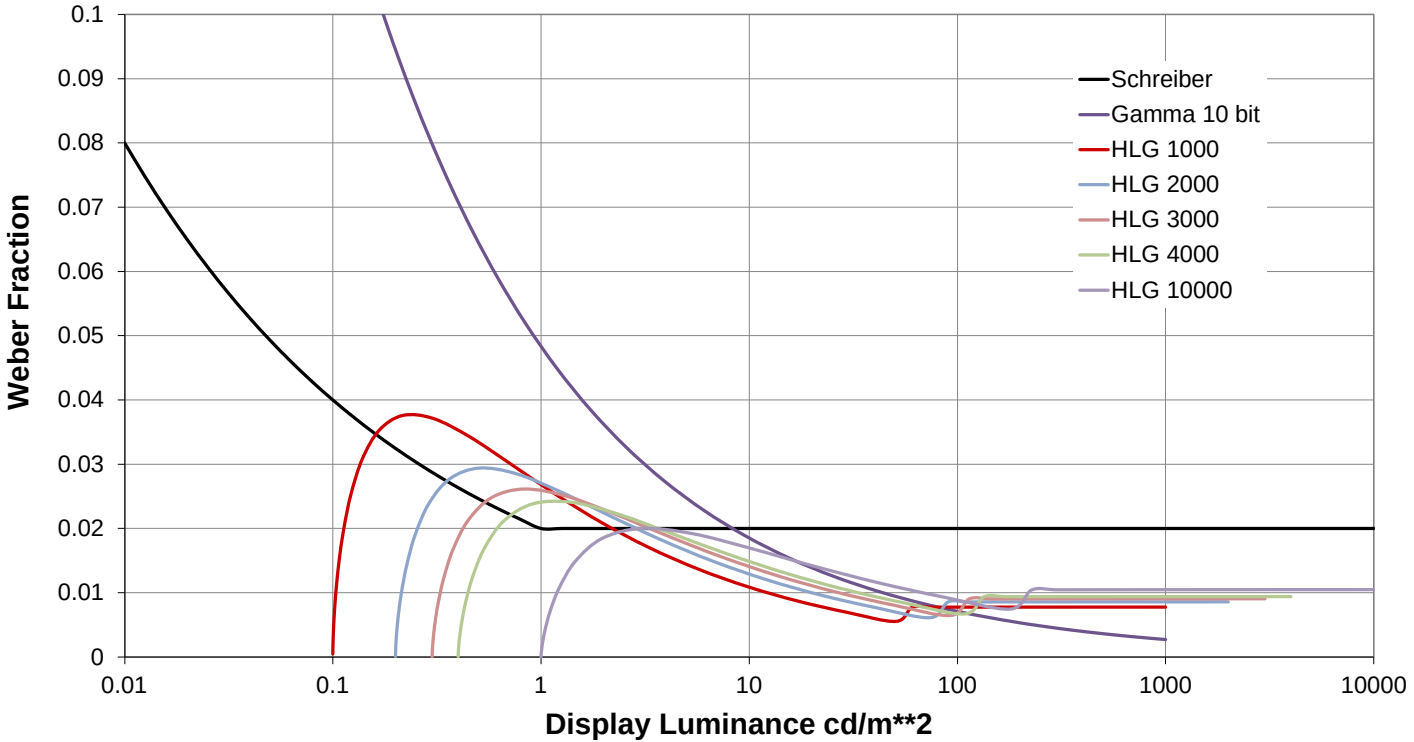
By design as HLG displays get brighter so does entire image, enabling HDR in brighter environments, e.g.,

Environment

Simulated images

- Home theatre projector
  - e.g. 400 cd/m2 peak
    - graphics "ref" (75% HLG), 100 cd/m^2
- Dim evening living room
  - e.g. 1000 cd/m2 peak
    - graphics "ref" (75% HLG), 203 cd/m^2
- Bright daytime living room
  - e.g. 2000 cd/m2 peak
    - graphics "ref" (75% HLG), 344 cd/m^2

Stretching the blacks in HLG



HLG Appearing in Consumer Equipment

Product Announcements CES 2017

- JVC
  - DLA-X5500, X7500, X9500 projectors
- LG
  - W7, G7, E7, C7 and B7 OLED
    - Updates for 2016 E6 and C6
- Panasonic
  - EZ1000/EZ1002 OLED
  - **Lumix GH5 DSLR**
- Sony
  - Sony Bravia A1/AE1 Series OLED
    - Updates for 2016 models
- Previously shown in TVs and projectors from
  - Panasonic, Samsung & Toshiba

CES Consumer Technology Association™
LAS VEGAS, NV
JANUARY 5-8, 2017

HLG Overview Summary

- HLG developed to allow straightforward migration to HDR Television
  - Supports a wide range of displays and environments
  - No need for metadata as OOTF is part of display EOTF
  - Can be displayed unprocessed on SDR screen

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- Both HLG and PQ include in DVB, ARIB and YouTube for HDR TV Distribution

Thank you

bbc.co.uk/rd

bbc.co.uk/rd/projects/high-dynamic-range

Email:
tim.borer@bbc.co.uk
andrew.cotton@bbc.co.uk

Twitter:
@bbcrd

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