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HDR Content Creation:
Creative and Technical Challenges

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Syllabus

Part I: Introduction *[15 min]* *TP*

- HDR 101 – Basic concepts
- Why HDR?
- HDR current status
- Terminology

Part II: Capture & Display *[30 min]* *TP*

- Capture
- Displays
- Tone Mapping
- Encoding – EOTFs
- Who defines HDR?
- HDR standardization

Part III: HDR Color Grading & Post Production *[30 min]* *JP*

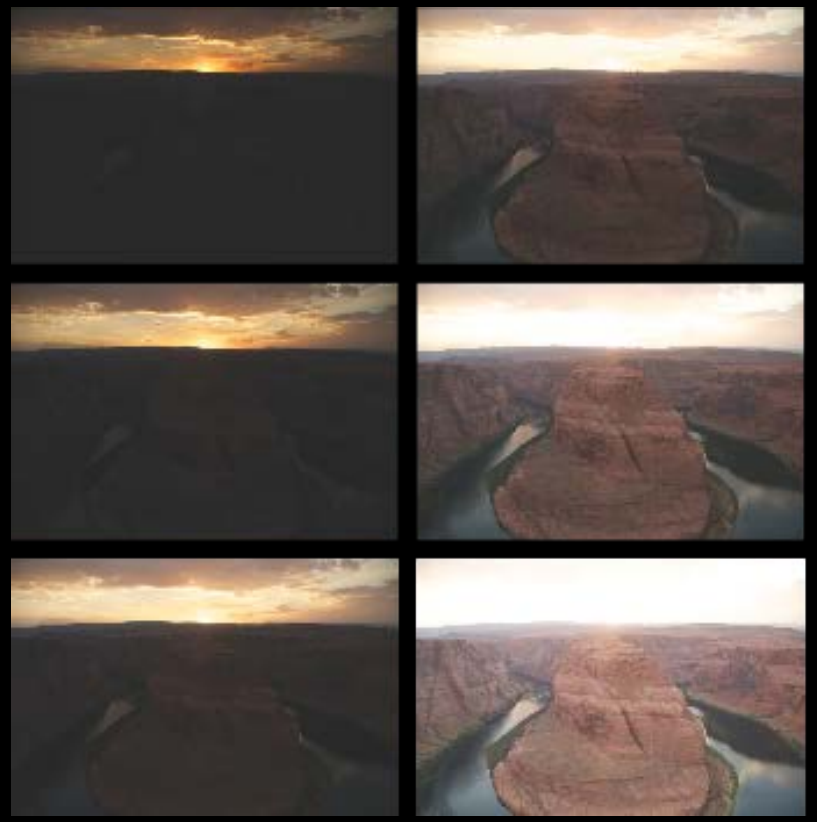
- The benefits of HDR
- HDR production workflows
- Theatrical vs Home
- Color space considerations
- Challenges & tradeoffs

Part IV: Q&A and Samples *[15 min]* *Both*

Part I: Introduction

High Dynamic Range Imaging 101

HDR technologies enable the capture, processing and display of images with a wider range of luminance and contrast



Individual exposures

HDR (prepared for display)

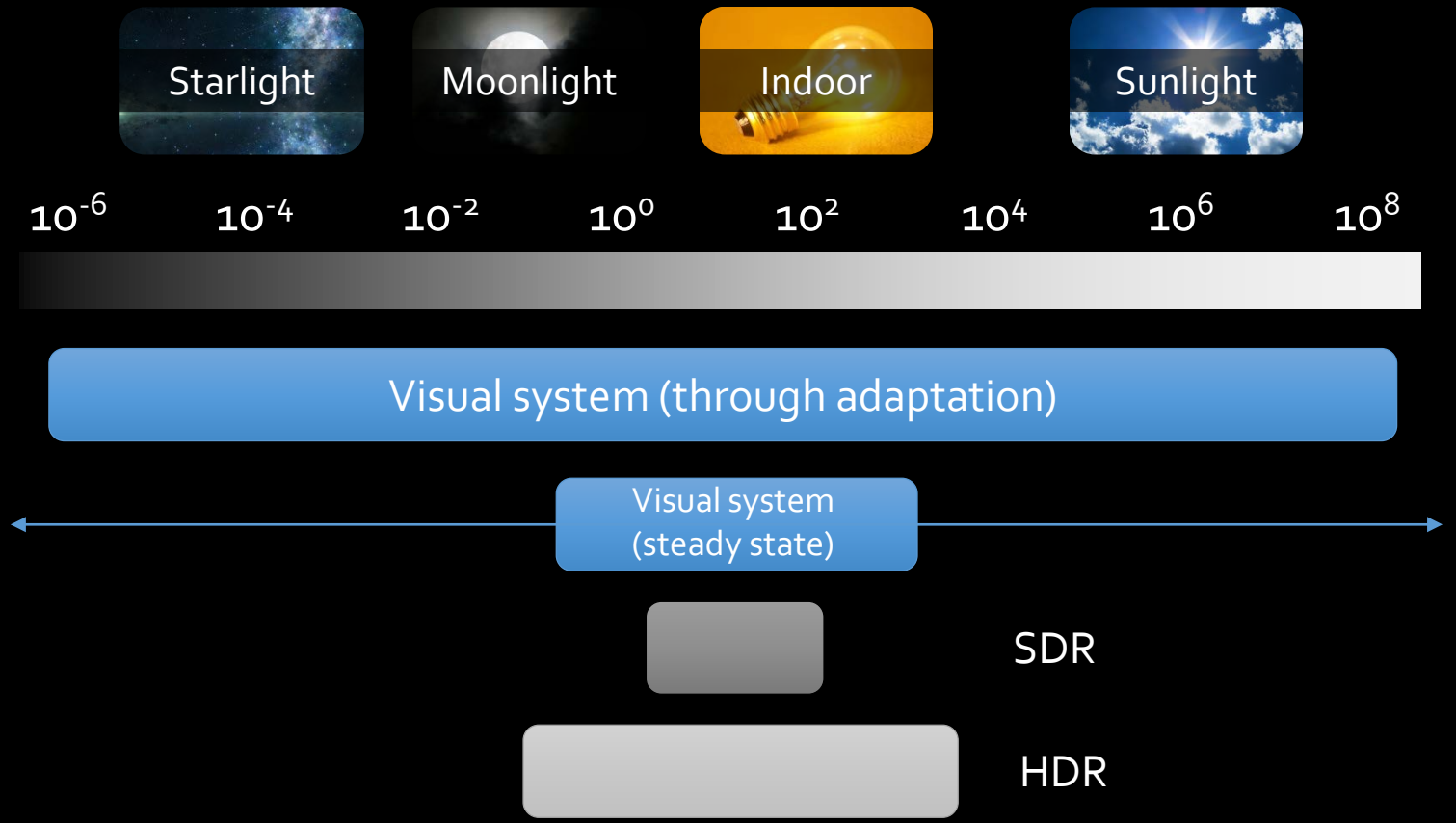
Why HDR?

- More details in shadows and highlights
- More control after capture
- Increased freedom during capture

HDR (prepared for display)

Why HDR?

Perceptually better match to real scenes



Why HDR?

- Visually superior experience
  - Closer to real scenes
  - More detail captured
- Better immersion
- Better depth
  - Higher contrast shown to increase perceived depth, even without stereo
- **More freedom for directors**

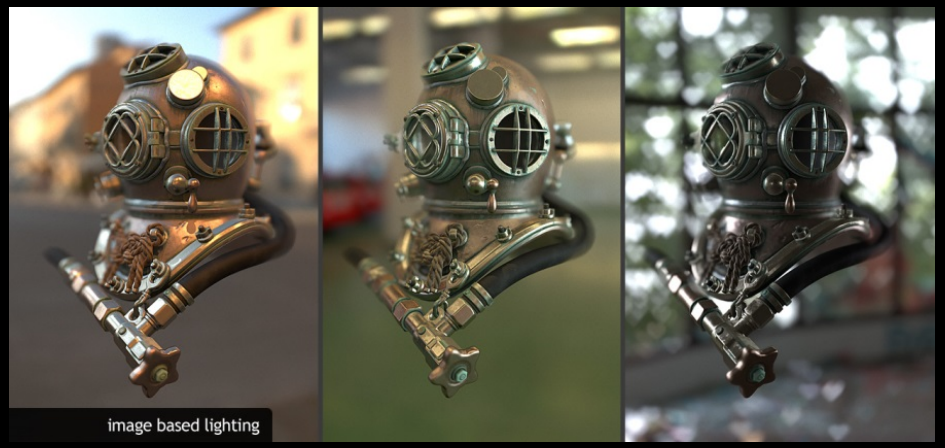
HDR – Current Status

Widespread use in:

- Special effects
- Games/rendering
- Security
- Photography

Up-coming:

- Standardization efforts under way
- Compression & encoding solutions
- HDR Cinema & post-production
- Consumer displays



Sony XD94 4K HDR TV

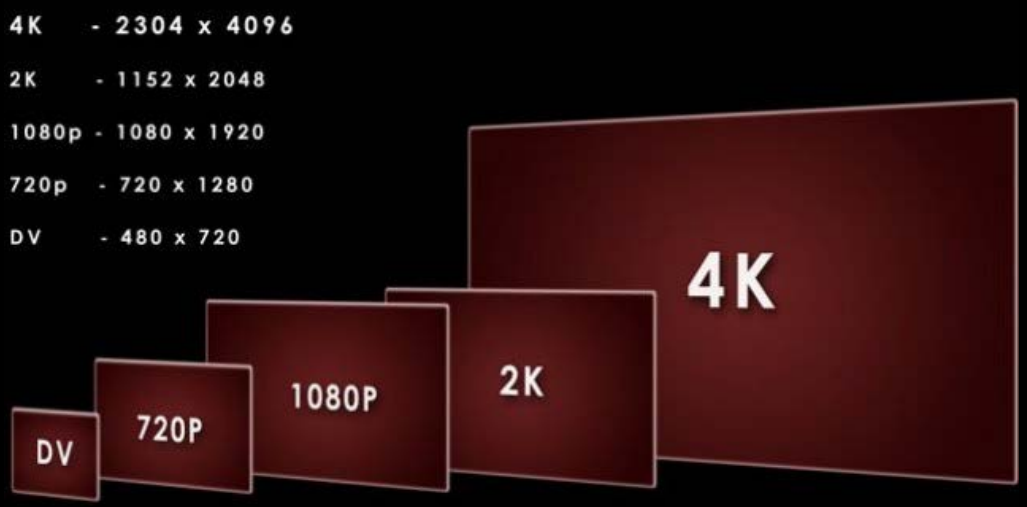
LG OLED 4K Smart TV

HDR – Current Status

- Next step for TVs/entertainment
- Introduced in parallel to 4K/Ultra HD
- More pixels vs better pixels

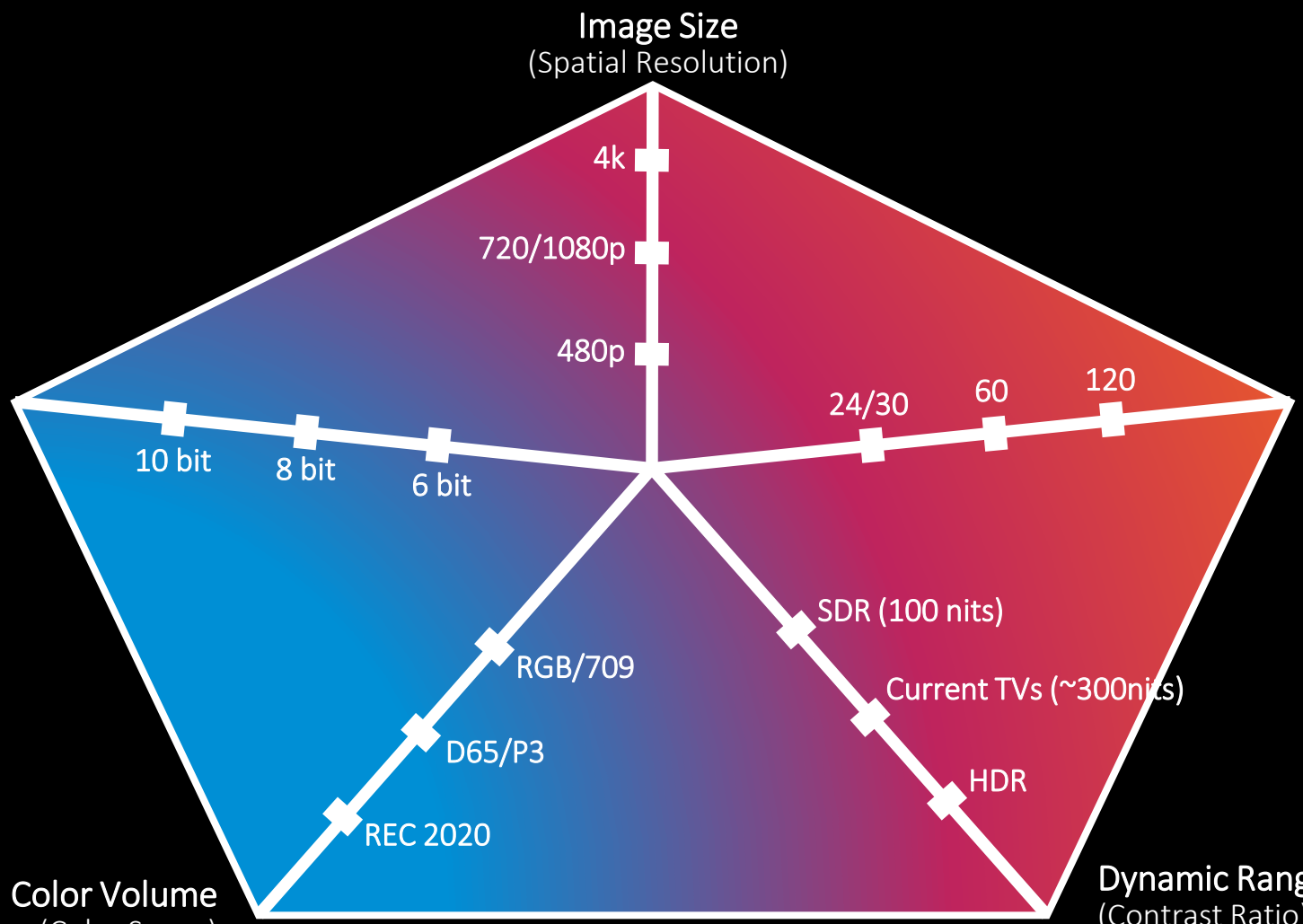
HDR complements 4K for the Ultra HD format

HDR - brighter images



4K - larger images

Dynamic Range Is One of 5 Key Dimensions of Video Quality



HDR Terminology

- **HDR**: High Dynamic Range
- **HDRI**: High Dynamic Range Imaging
- **WDR**: Wide Dynamic Range
- **EDR**: Extended Dynamic Range

- **LDR**: Low Dynamic Range
- **SDR**: Standard Dynamic Range

- **Tone mapping/Tone compression/Tone reproduction/TMO**: Solutions for compressing the dynamic range of HDR content
- **ITM/ITMO/rTMO**: Solutions for expanding the dynamic range of content

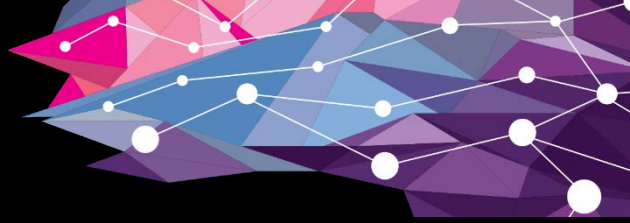
Part II: Capture & Display

Trends

- **Content acquisition & creation**
  - HDR cinema & broadcasting cameras are starting to appear
  - Up-conversion of existing content towards HDR
    - To take advantage of existing content libraries
  - Most VFX are HDR-ready

- **Display**
  - Professional/prototype displays up to 4000 cd/m^2
  - Consumer displays up to ~1000 cd/m^2
  - HDR projectors for cinema
  - New encoding schemes being adopted & standardized

HDR Video Capture



- Single Sensor
  - Ideal solution but overly expensive
  - 14 – 18 f-stops claimed at 4K capture
  - Current sensors suffer from noise in low light
- Temporal Bracketing
  - Alternating frames 2-6 f-stops apart
  - Introduces ghosting artefacts in moving scenes
  - Typically requires high frame rate for video
- Spatial Bracketing
  - Beam splitters or mirrors redirect some of the light to additional sensors
  - Need to correct the geometric disparity between images
  - No temporal mismatches = no ghosting

Single Sensor

- Ideal solution is to make every pixel capture a higher dynamic range
  - Technically challenging
  - Up to 18 f-stops of dynamic range claimed
  - Difficult to manage noise
  - Concurrent push for higher resolution

Arri Alexa

- Trade-off:
  - Resolution
  - Noise
  - Dynamic range
  - Price!

Sony F65

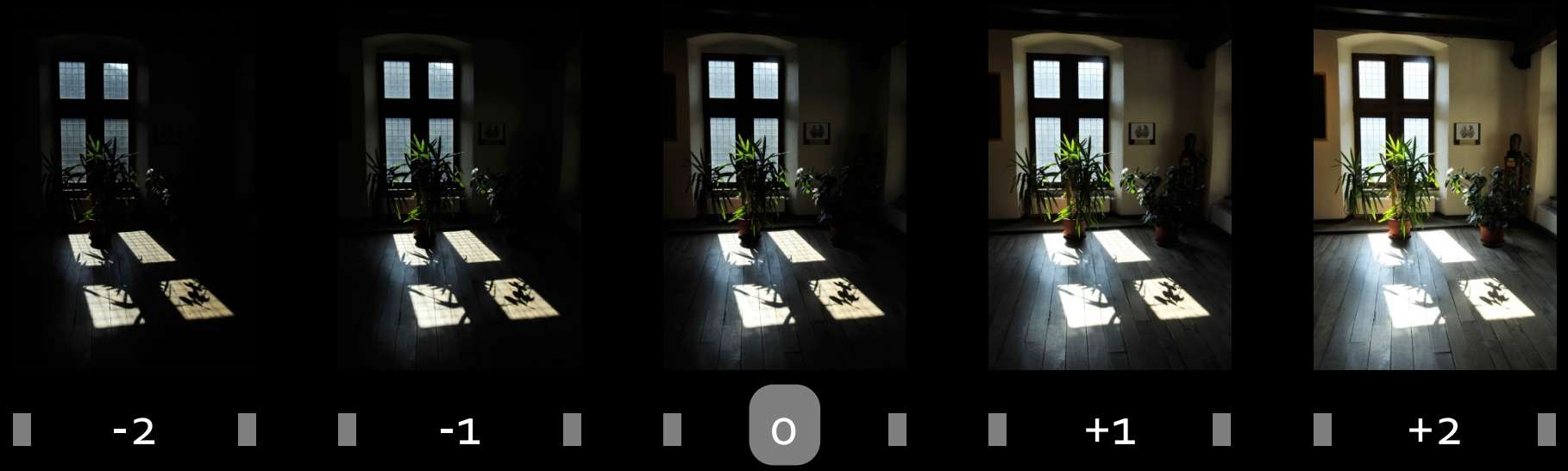
Temporal Exposure Bracketing

- E.g. RED Epic Cameras (HDRx)
  - >18 f-stops claimed for RED Epic Mysterium
- 2 or more exposures taken one after the other
- (+) Possible even on smartphones
- (-) Not well suited to moving content

- **Trade off:**
  - Ghosting vs dynamic range

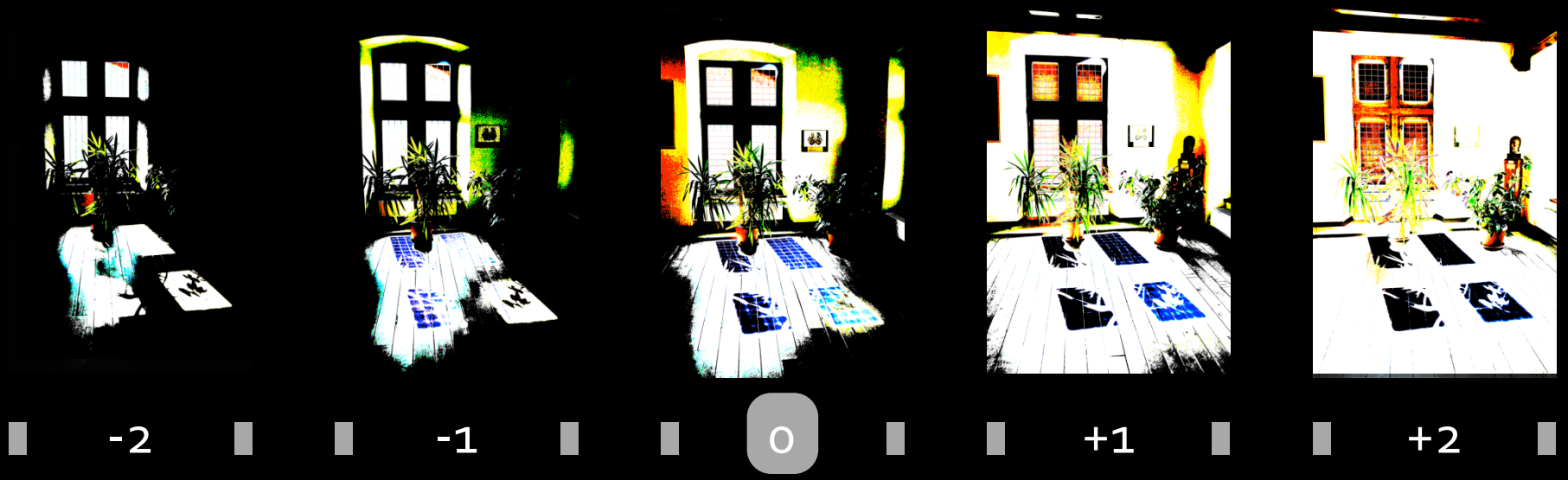
Temporal Exposure Bracketing

- Commonly used in still photography
  - E.g. HDR mode in iPhone
- Multiple shots of the same scene
- Vary exposure by a factor



Temporal Exposure Bracketing

- Each exposure correctly captures part of the scene
- Exposure stack can be merged into HDR image
  - Keep only ‘good’ pixels



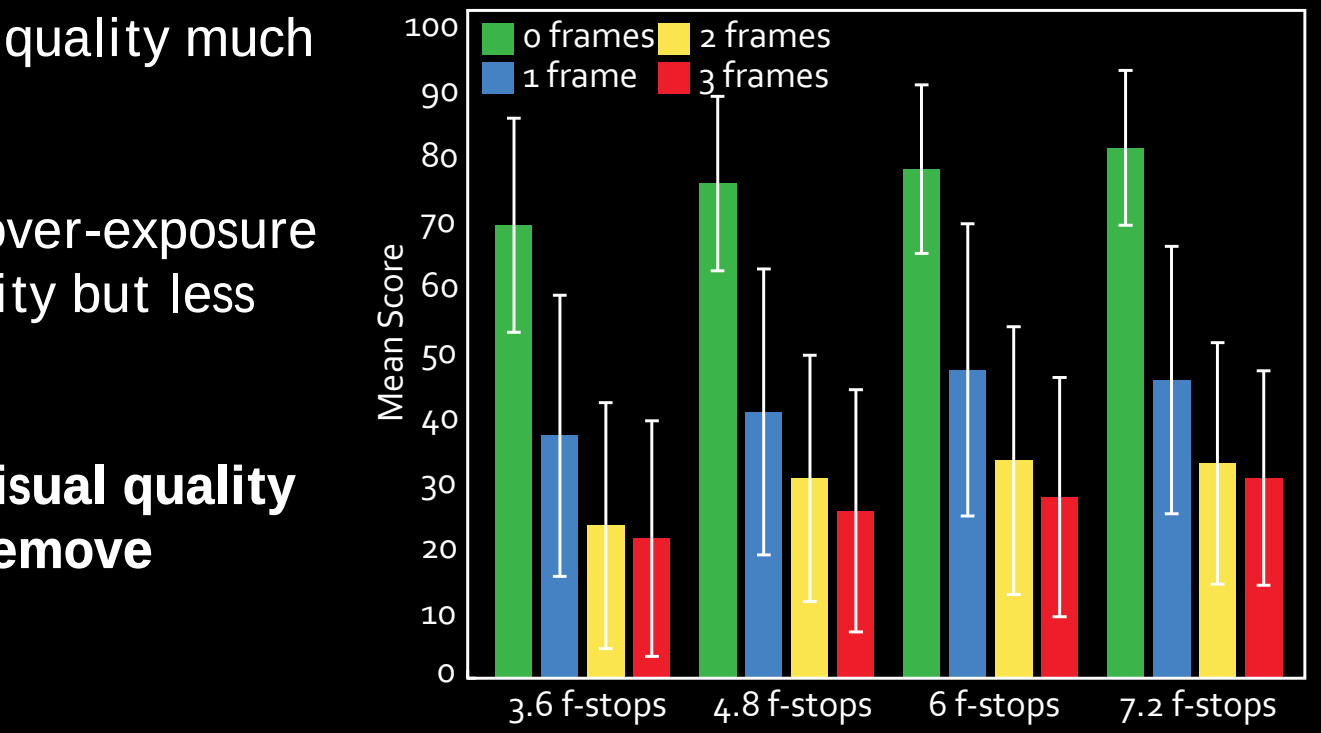
Temporal Exposure Bracketing

- Moving objects will be in different positions in each exposure
- Creates **ghosting** when combining into HDR

Ghosting vs Over-exposure

- Is ghosting this bad?
- We did a user study to assess this trade-off

- Ghosting affects quality much more
- Clipping due to over-exposure also affects quality but less severely
- **HDR improves visual quality only if we can remove ghosting!**



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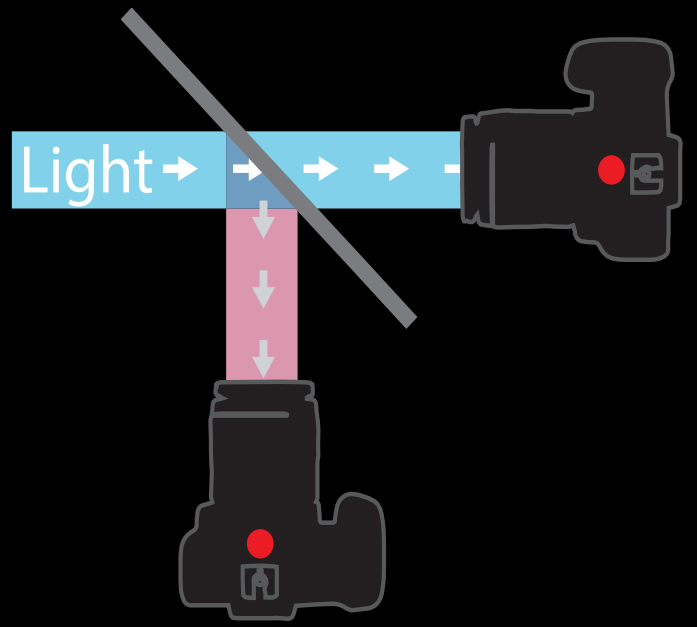
Gryaditskaya, Y., Pouli, T., Reinhard, E., Myszkowski, K., & Seidel, H. P. (2015, July). Motion aware exposure bracketing for HDR video. In Computer Graphics Forum (Vol. 34, No. 4, pp. 119-130).

Spatial Bracketing

- Light can be split and redirected to different sensors
- In front or behind the lens
- Exposures are captured simultaneously
  - Optical filters control the amount of light reaching each sensor
  - No temporal mismatches = No ghosting
  - But requires modifications to the optical system
  - Alignment difficult, requiring post-processing
  - Optical + chromatic differences
- Repurposing stereo rigs



Contrast HDR Camera

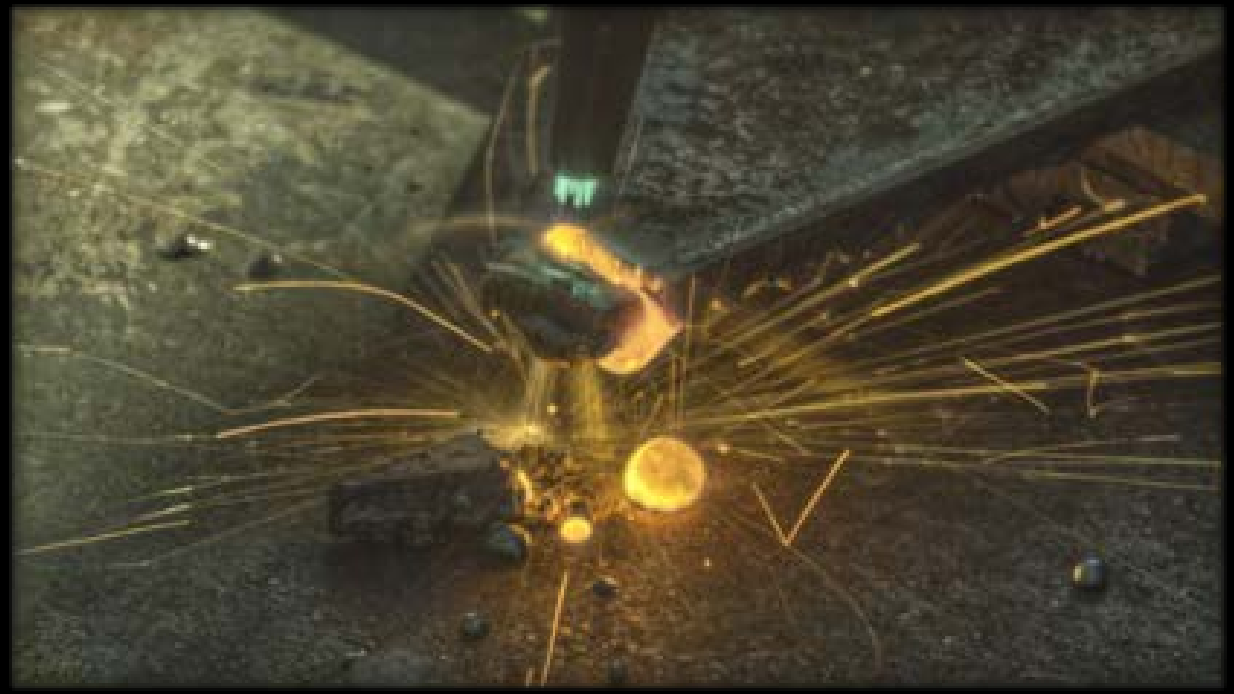
Capture multiple SDR images simultaneously (high, medium, long exposure)

- Structurally identical images means no ghosting
- Large dynamic range
- Single lens but multiple sensors
- Light-efficient, very little light lost
- ~17 f-stops claimed

Tocci, M. D., Kiser, C., Tocci, N., & Sen, P. (2011). A versatile HDR video production system. *ACM Transactions on Graphics (TOG)*, *30*(4), 41.

Contrast HDR Camera

Final HDR frame (tone mapped)



Long

Medium

Short

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Tocci, M. D., Kiser, C., Tocci, N., & Sen, P. (2011).
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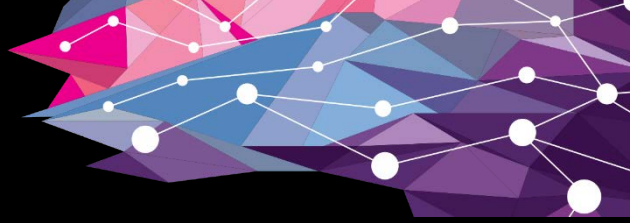
Camera Dynamic Range Comparisons



Data taken from
http://wolfcrow.com/blog/where-cameras-stand-in-dynamic-range-film-vs-digital/

Camera	f-stops
Red Dragon Sensor	18
Sony F55/F5	14
Arri Alexa	14
Kodak Vision3	14
Red Epic	13.5
Blackmagic Cinema Camera	13
Canon C300/C100	12
Canon C500	12
Sony F3	11.5

Camera	f-stops
Canon 1DC	11.5
Nikon D800	11.4
Nikon D600	11.2
Sony FS100/FS700	11
Sony A99	11
Nikon D4	10.1
Panasonic AF100	10
Canon 6D	9.1
HDC1500	9

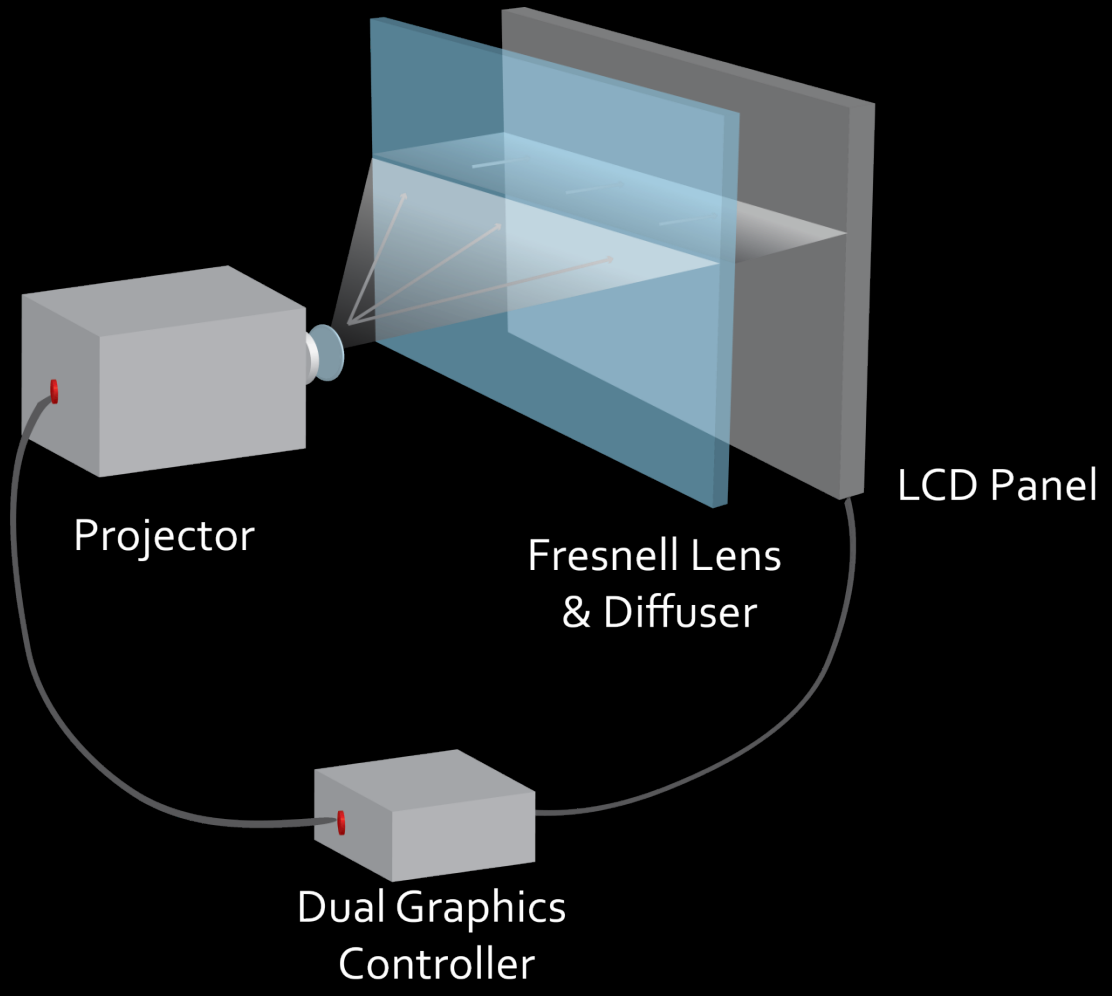
Display Overview

- HDR Displays
  - Allow HDR content to be displayed directly
  - Dual modulation of light (LED/LCD)
  - OLED
- Tone mapping
  - Display HDR content on SDR displays
  - Compress luminance while preserving details
- Inverse Tone mapping
  - Display SDR content on HDR displays
  - Methods to ‘upgrade’ legacy content

Double Modulation Projection

Core idea:
Spatially varying backlight
behind LCD panel

Final image = backlight x LCD



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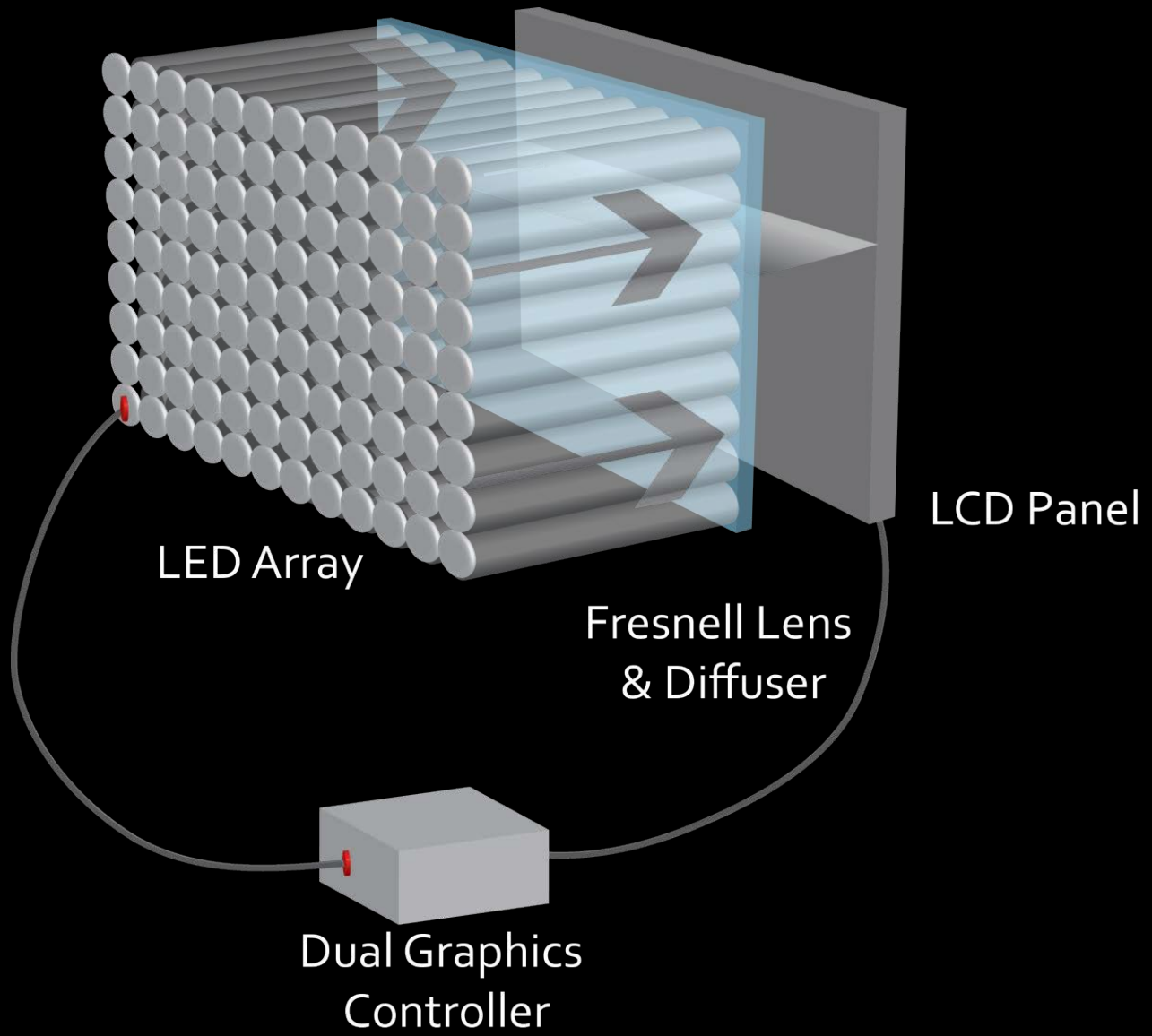
Seetzen, H., Heidrich, W., Stuerzlinger, W., Ward, G., Whitehead, L., Trentacoste, M., Ghosh, A., & Vorozcovs, A., High dynamic range display systems. ACM Transactions on Graphics, 23(3), 760-768 (2004)

Double Modulation Displays



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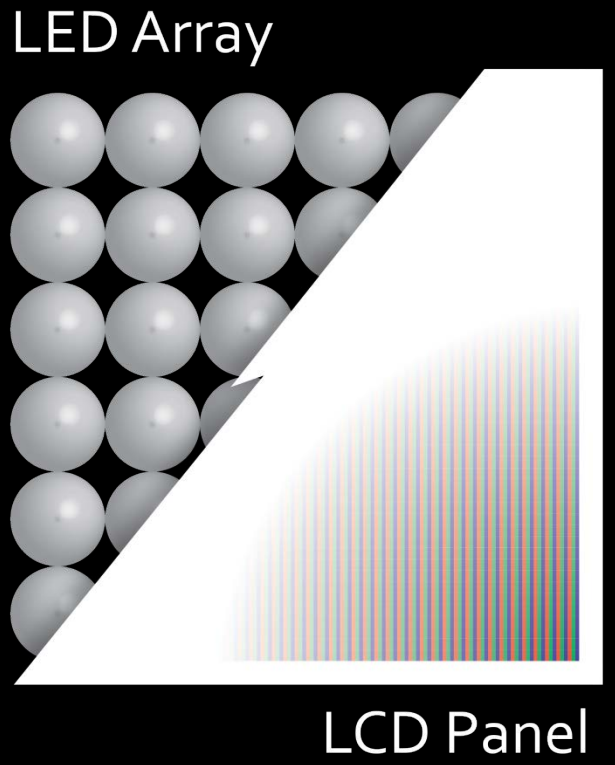
Seetzen, H., Whitehead, L. A., & Ward, G.,
A High Dynamic Range Display Using Low and High Resolution Modulators,
The Society for Information Display Digest, (2003)

Double Modulation Displays

- LED Array uses bright LEDs to expand the dynamic range
  - Spatially varying
  - Individually controlled
  - But low res
- LCD Panel displays detail
  - High resolution
  - But low luminance range



Seetzen, H., Whitehead, L. A., & Ward, G.,
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Existing HDR Displays

- One of the core technologies already exists in your living room for several years (LED TVs)
- Second core technology is OLED

- Limited availability high luminance displays:
  - SIM2 HDR display: 4000 cd/m^2
  - Dolby Pulsar: 4000 cd/m^2

- Reference monitors:
  - Dolby PRM: 600 cd/m^2
  - Sony BVM-X300: 1000 cd/m^2

- Consumer TVs hitting the market: ~1000 cd/m^2
- Many current phones and tablets: 500-700 cd/m^2

HDR Consumer TVs

All major TV manufacturers have demonstrated High Dynamic Range (HDR) TVs at CES 2016

HDR Consumer TVs

Source: IHS 2016

North America

Year	UHD	with HDR	% with HDR
2016	11.6M	489K	4%
2017	17.0M	3M	18%
2018	19.1M	5M	26%
2019	20.1M	6.4M	32%

Adapting content to displays

How to ensure interoperability?

HDR Content

SDR Content

Inverse Tone Mapping

Tone Mapping

HDR displays

SDR displays

HDR to SDR

- Dynamic range of content and display not always matched
- Mapping HDR content to SDR displays requires dynamic range **reduction**
- **Tone Mapping**

- **Goals:**
  - Compress range
  - Preserve details

Why do we need tone mapping?

Linear compression

HDR luminance color map
(4 orders of magnitude - 13 f-stops)

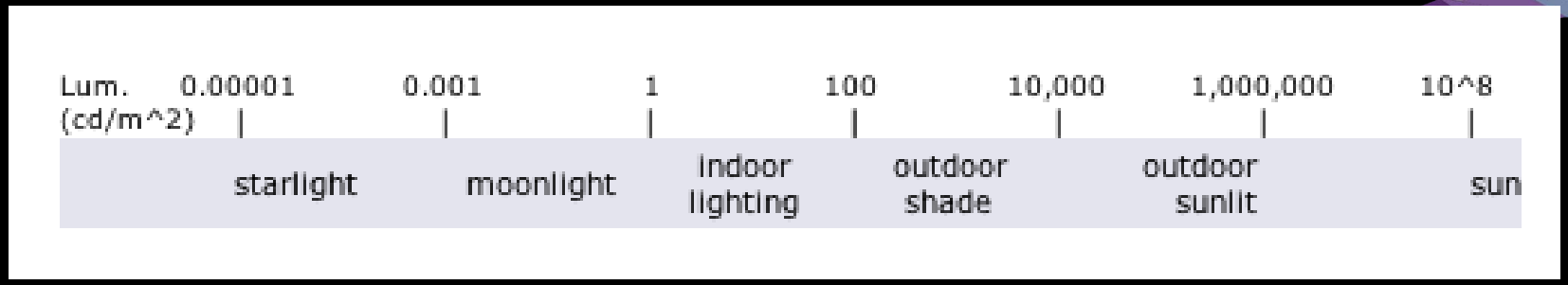
Tone mapped

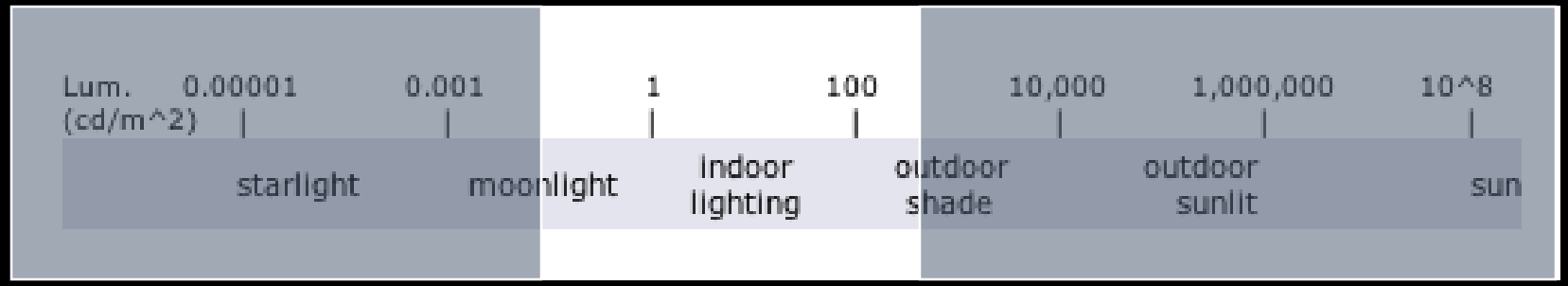
Tone Mapping

or

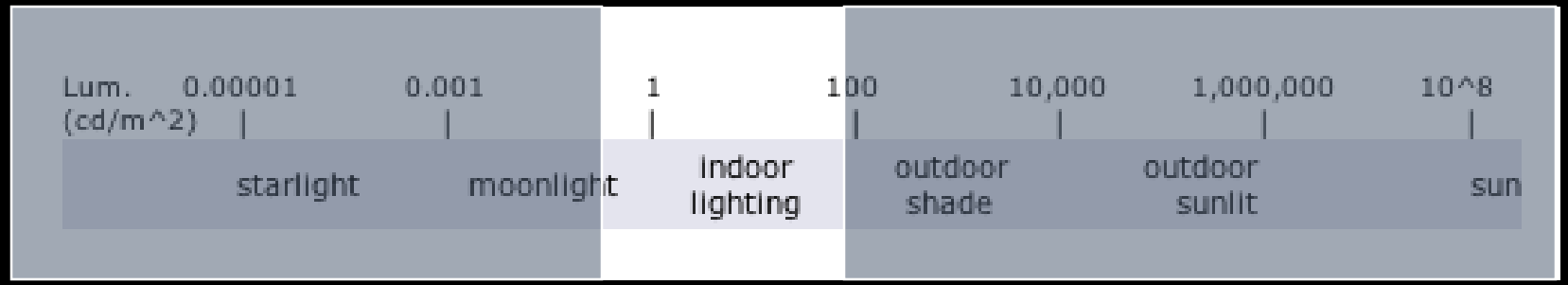
"…oh, that's what all that s-curve stuff is all about…"

real world dynamic range



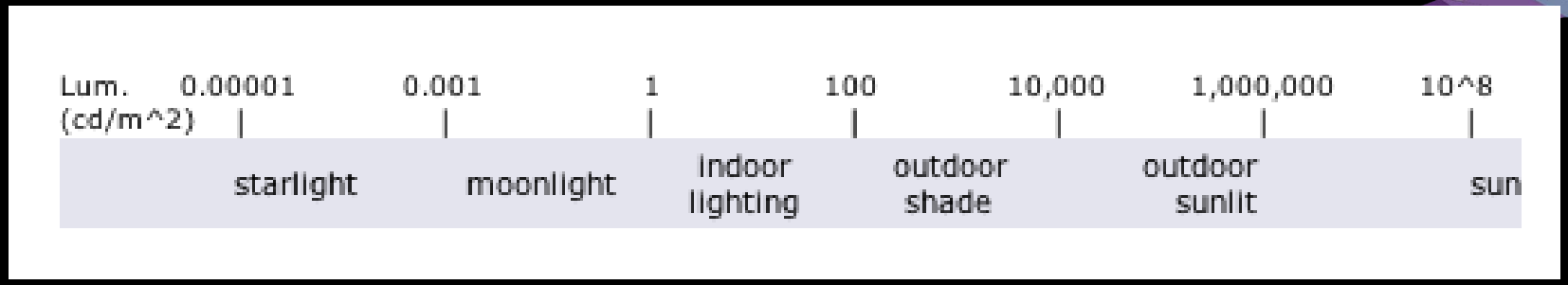


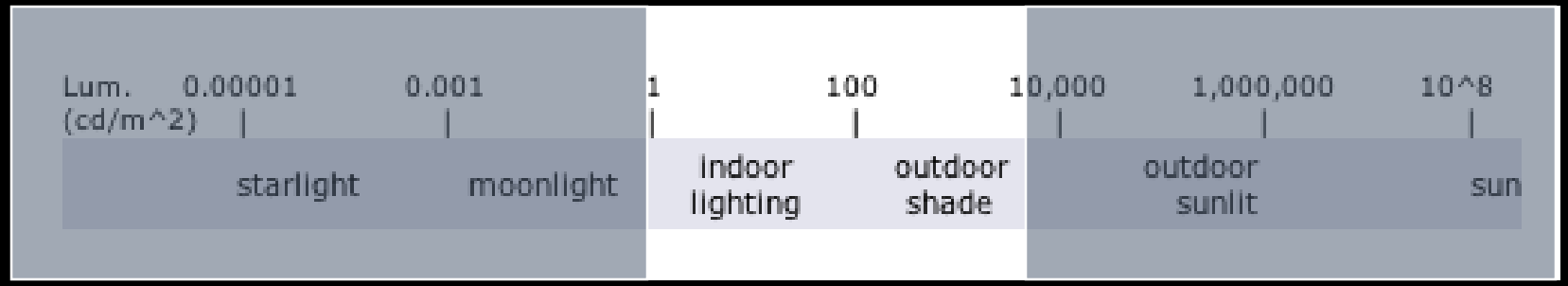
camera acquisition dynamic range



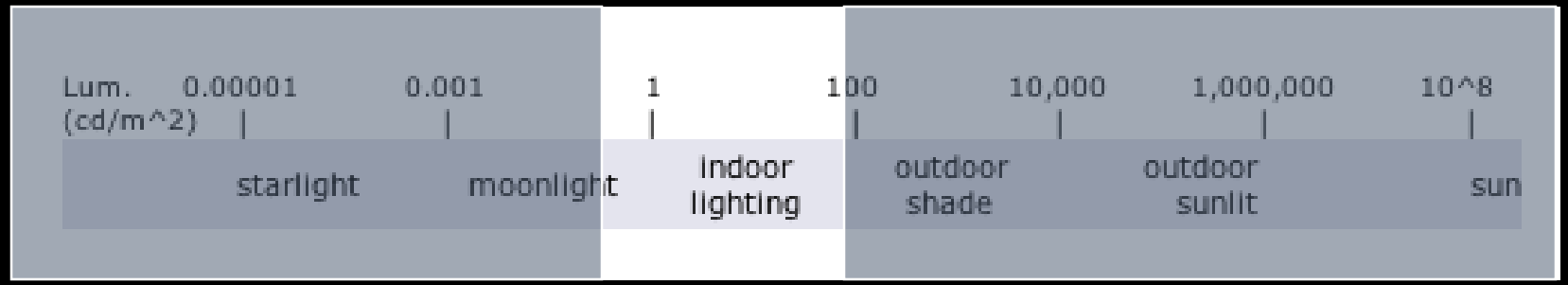
display dynamic range

real world dynamic range





camera acquisition dynamic range



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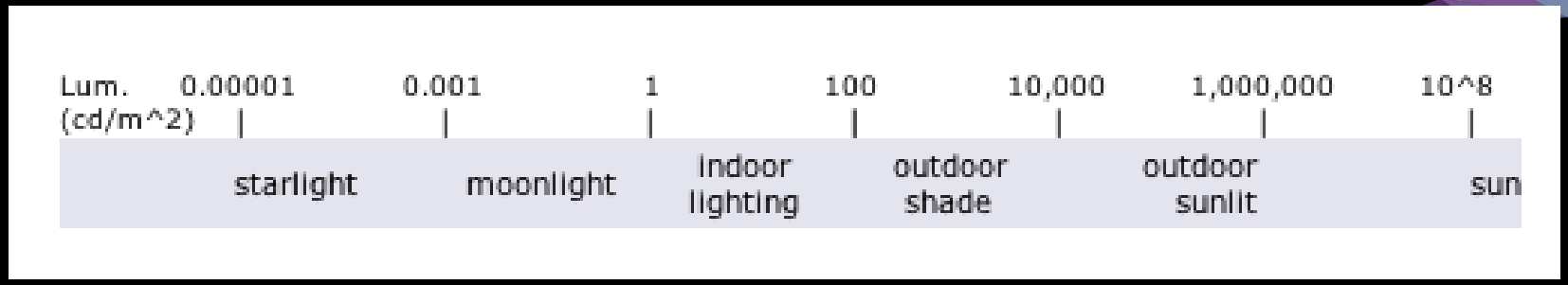
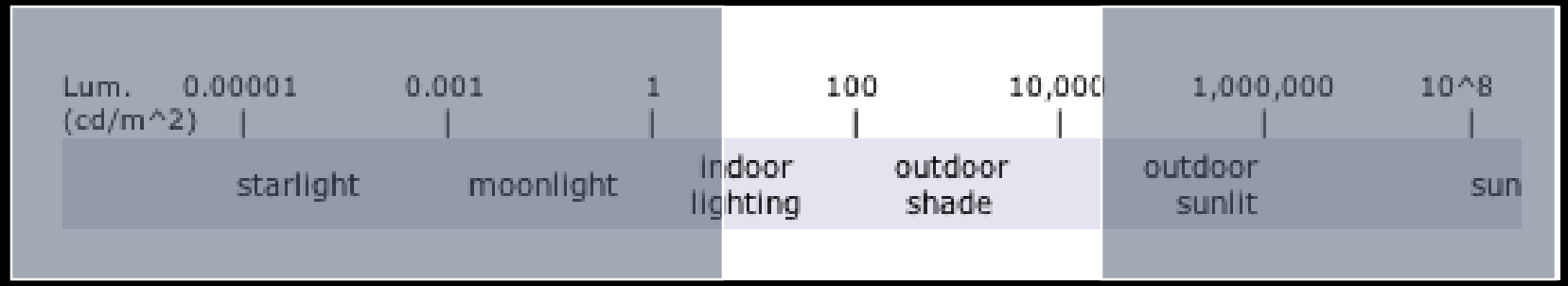
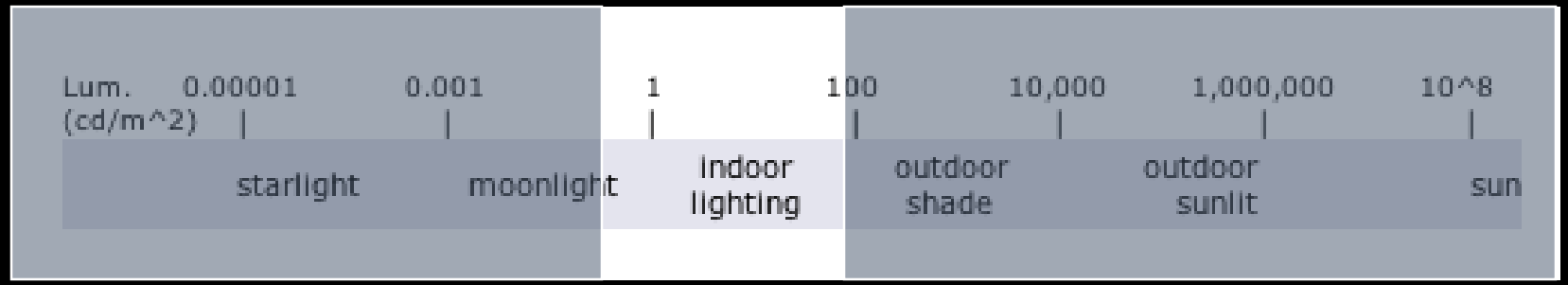


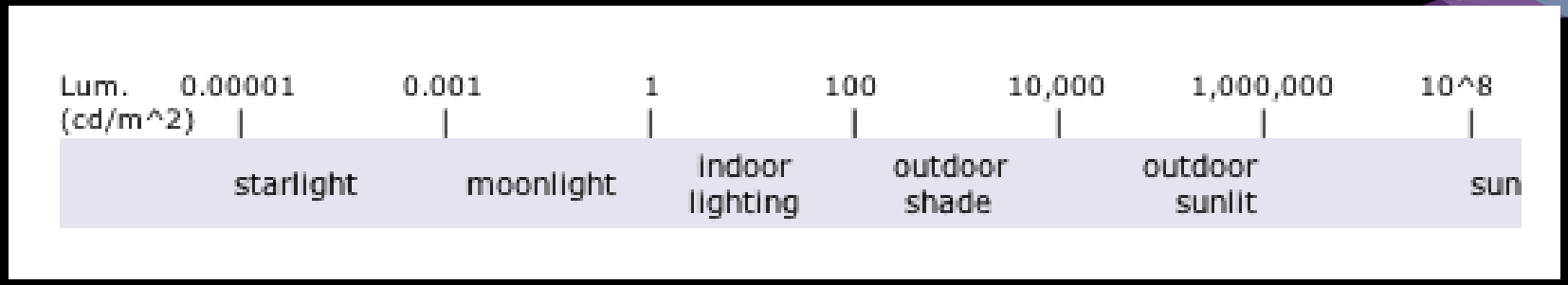


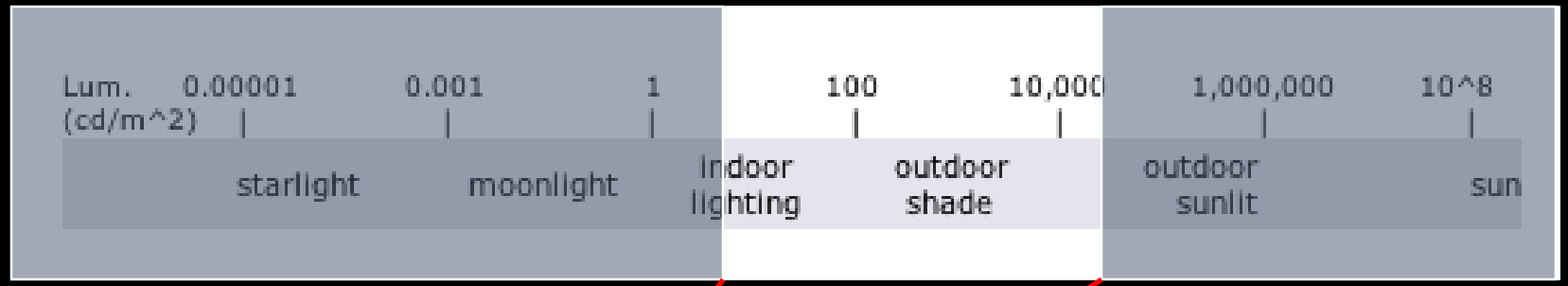
camera acquisition dynamic range



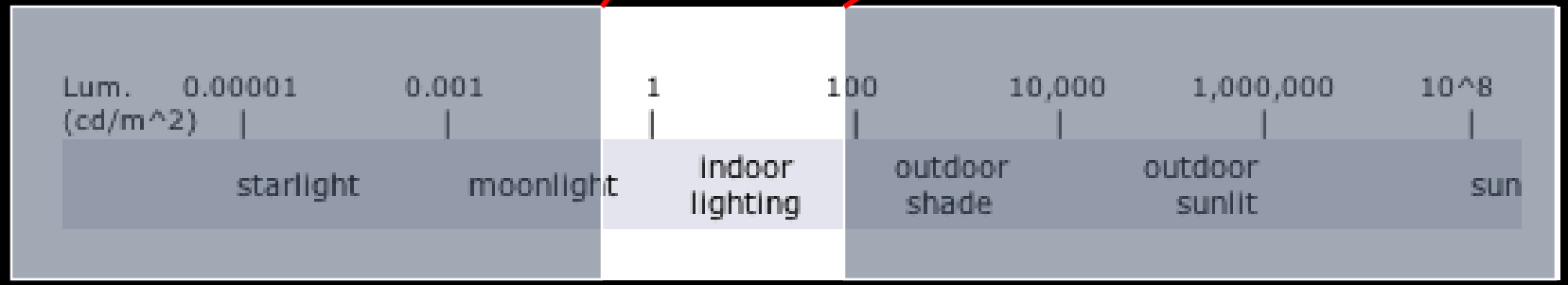
display dynamic range

real world dynamic range





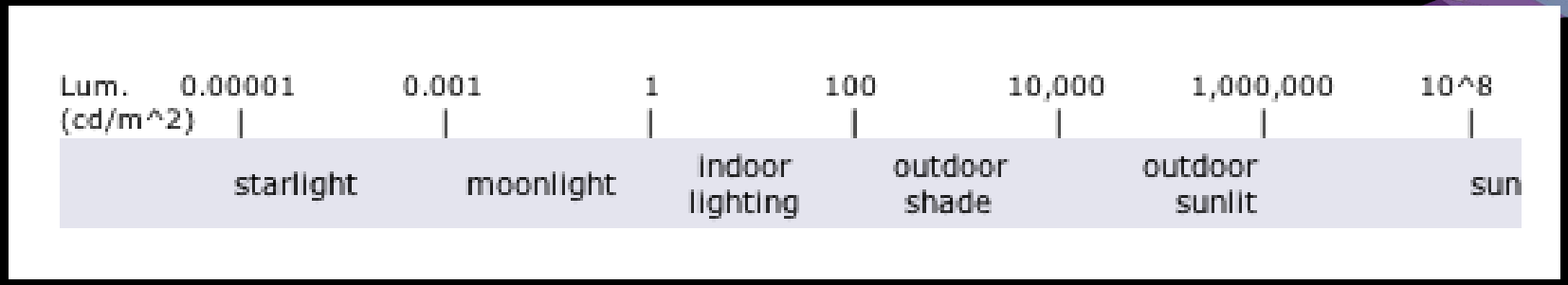
camera acquisition dynamic range

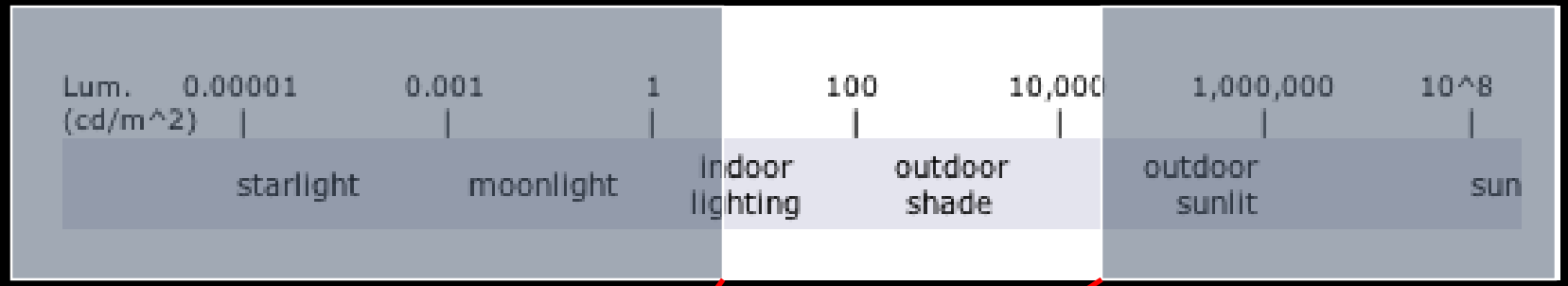


display dynamic range

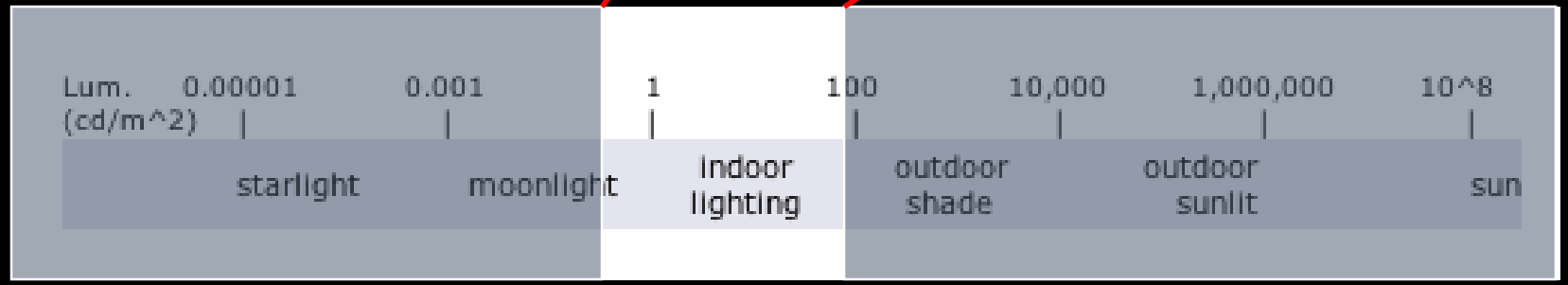
Full range acquisition scaled to display dynamic range (and gamma corrected)

real world dynamic range



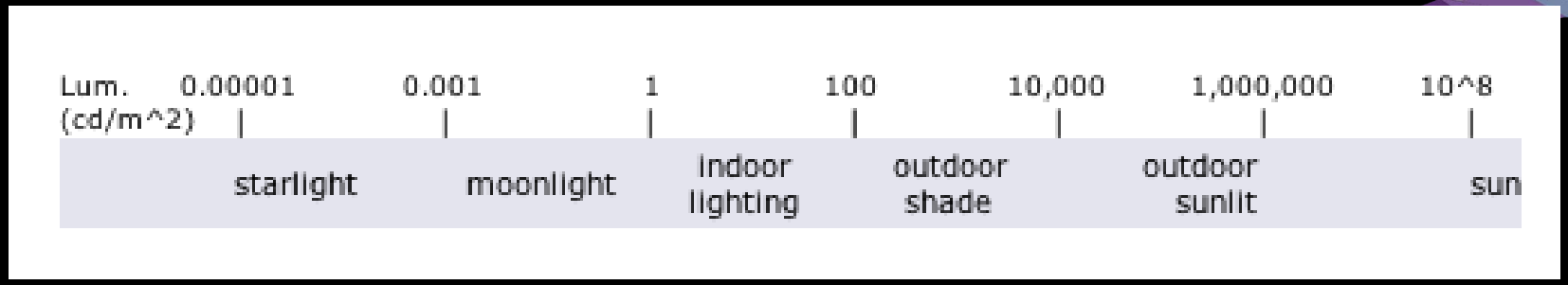


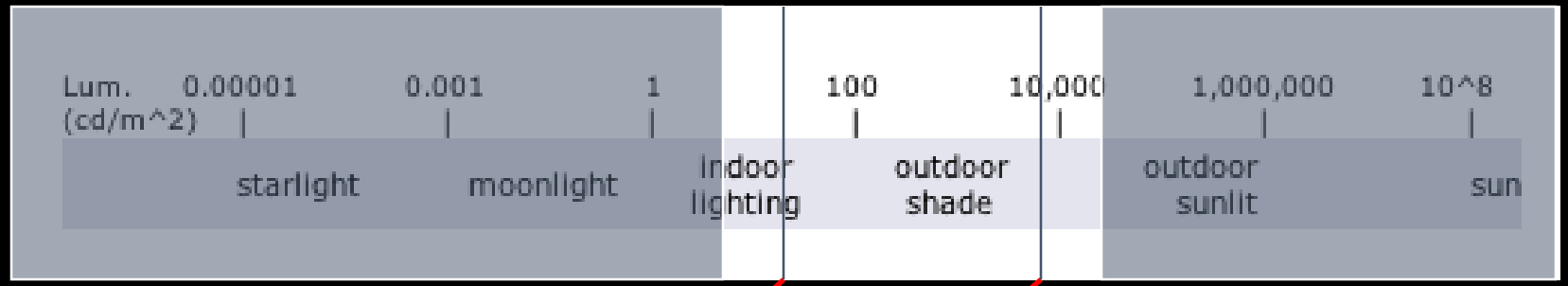
camera acquisition dynamic range



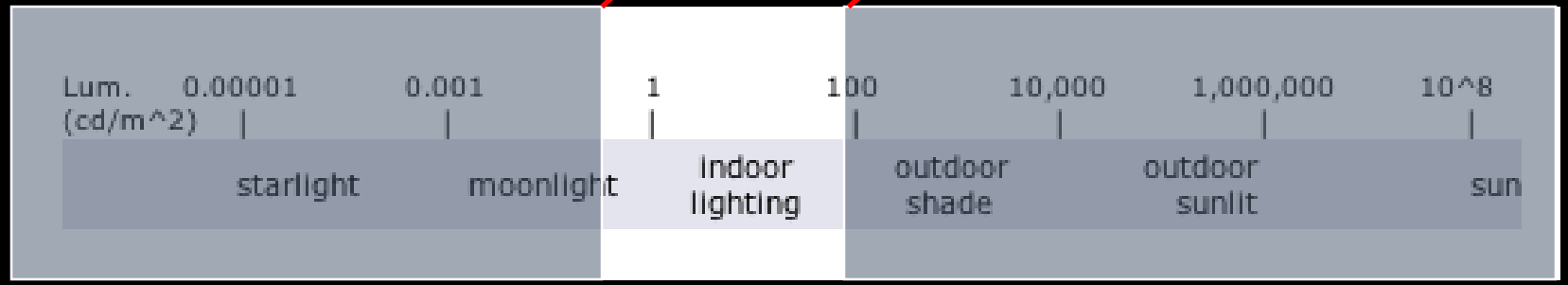
display dynamic range

real world dynamic range



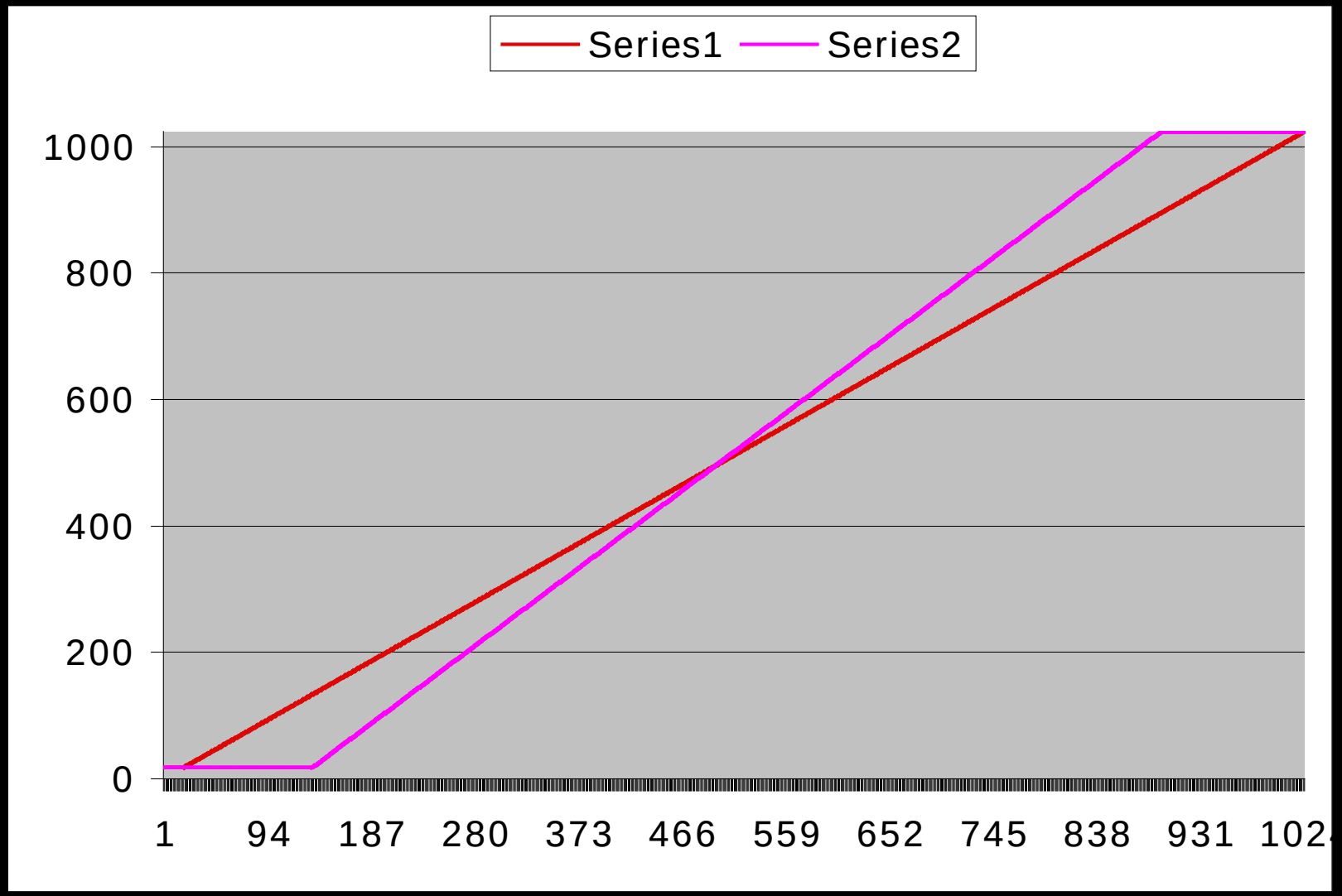


camera acquisition dynamic range



display dynamic range

Match display dynamic range instead of full acquisition dynamic range



Full range acquisition scaled to display dynamic range (and gamma corrected)

Match display dynamic range from acquisition preserving relative intensities

Limiting to display's dynamic range while preserving relative intensities is an improvement - but still looks "low contrast" - **why?**

Limiting to display's dynamic range while preserving relative intensities is an improvement - but still looks "low contrast" - **why?**

- **Stevens effect** - perceived contrast decreases at lower luminance
- **Hunt effect** - perceived "colorfulness" also decreases at lower luminance


445, 445, 445
Kodak
KODAK Digital LAD Test Image
445, 445, 445
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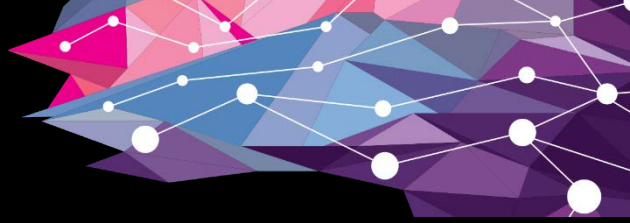
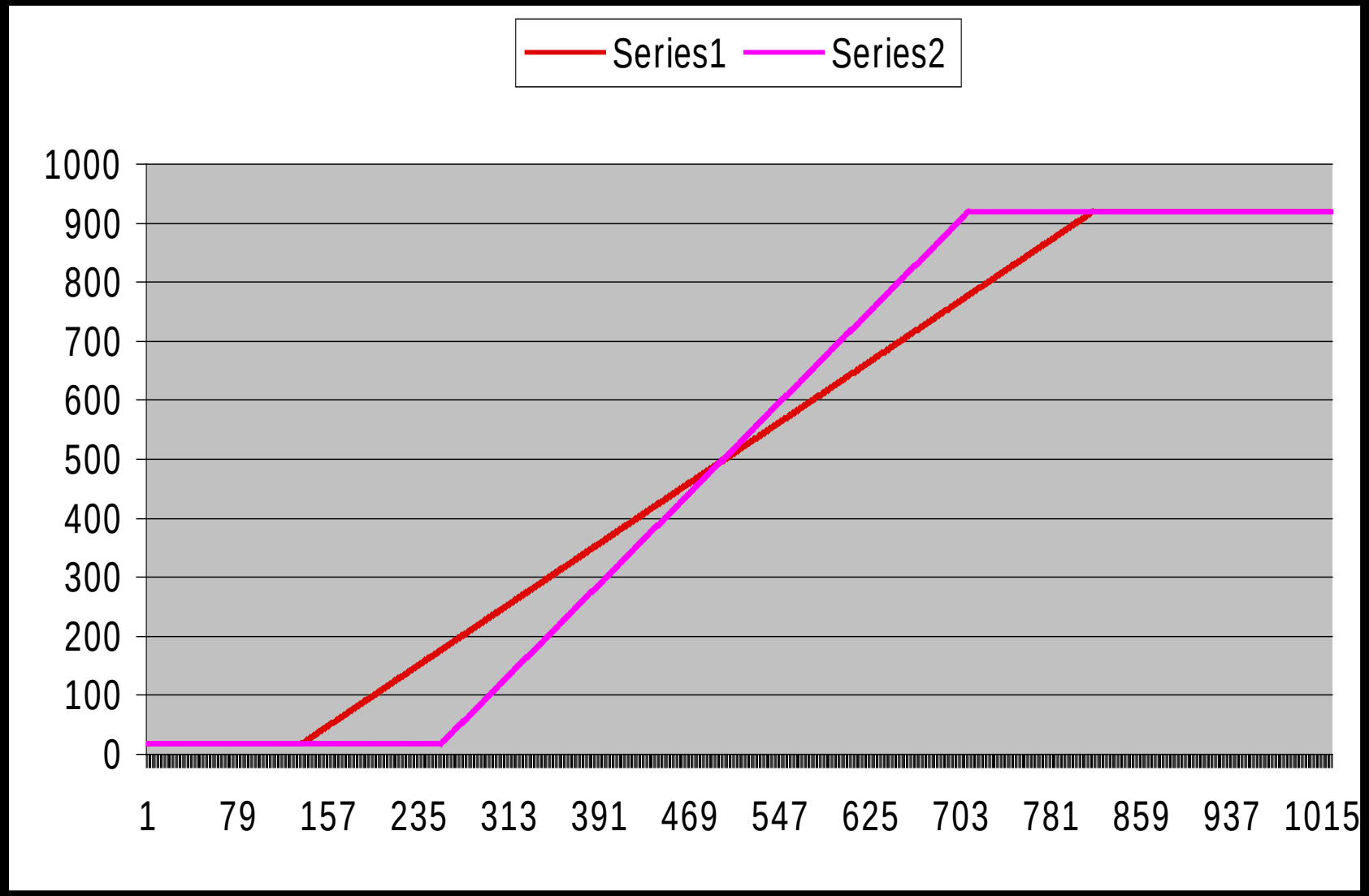


Limiting to display's dynamic range while preserving relative intensities is an improvement - but still looks "low contrast" - **why?**

- **Stevens effect** - perceived contrast decreases at lower luminance
- **Hunt effect** - perceived "colorfulness" also decreases at lower luminance
- Display flare characteristics reduce contrast
- **Bartleson-Breneman effect** - a "dark" surround decreases perceived contrast

Solution - increase contrast!



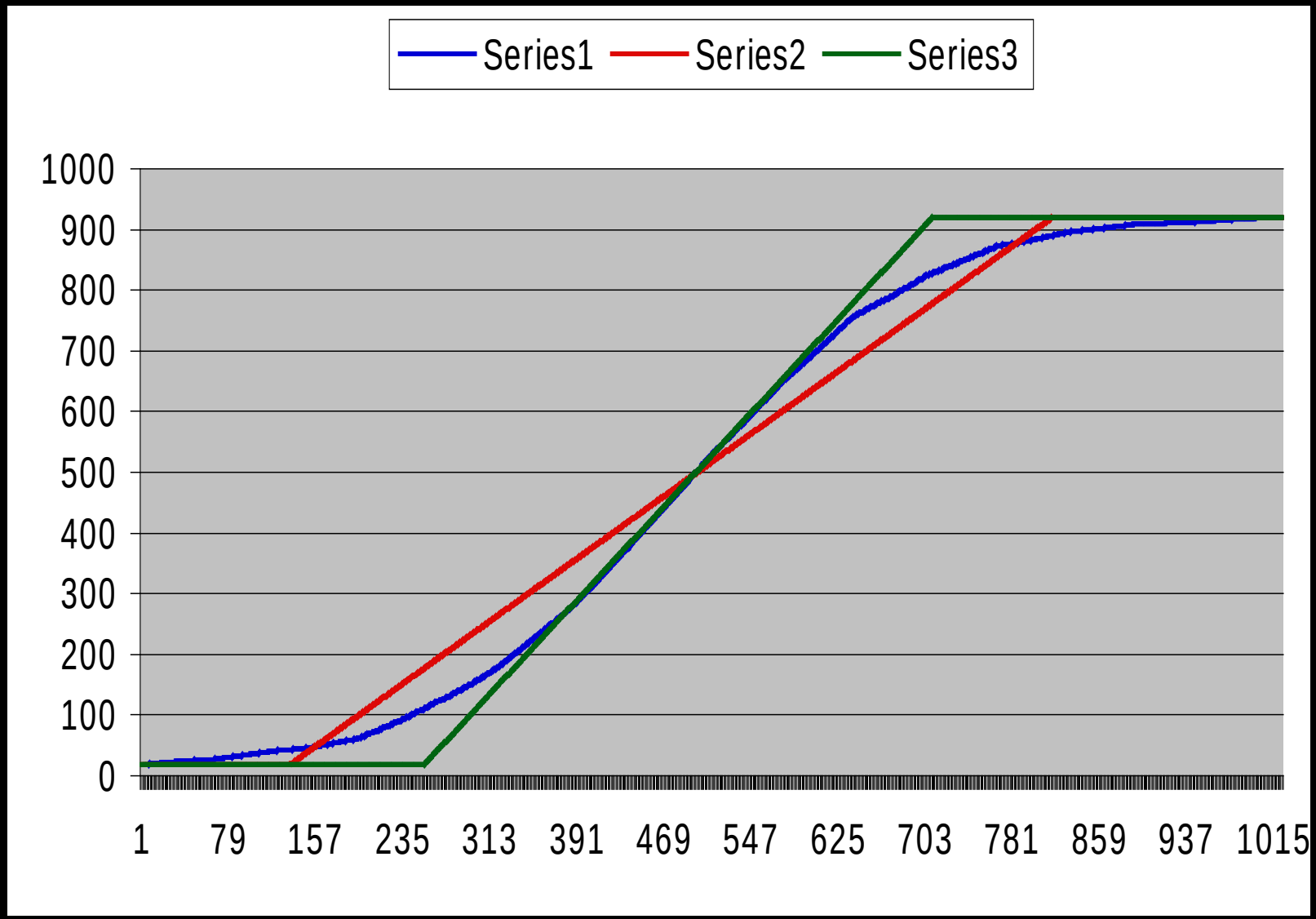
Match display dynamic range from acquisition preserving relative intensities

Match display dynamic range
+ add contrast (1.25 - 1.50)

…but now we've added clipping artifacts

- add "toe" and "shoulder" to reduce clipping artifacts
- …which also brings back some shadow and highlight detail

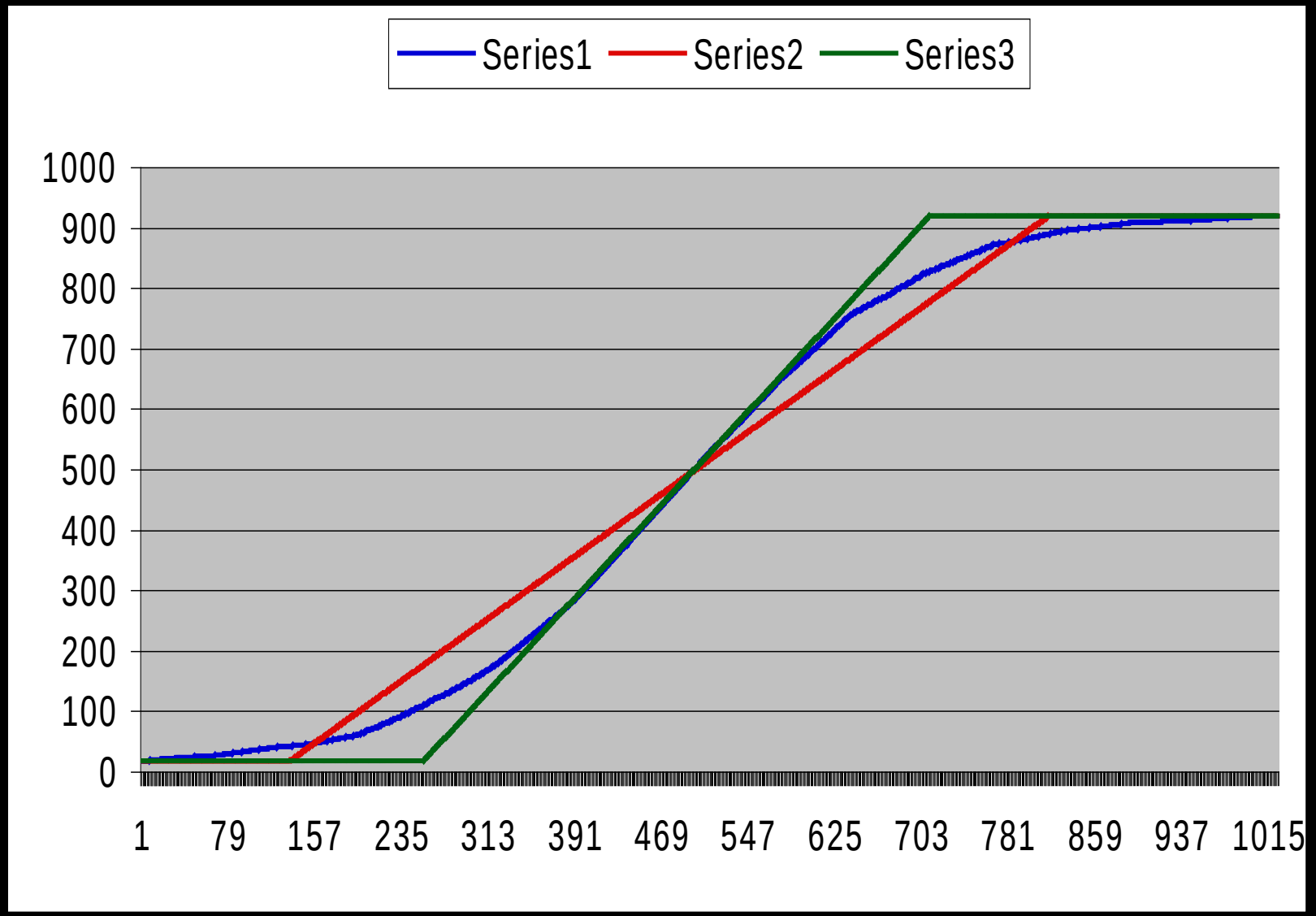
Solution - increase contrast + add toe and shoulder (the infamous “S-curve”)



Display dynamic range
+ add contrast (1.25 - 1.50)

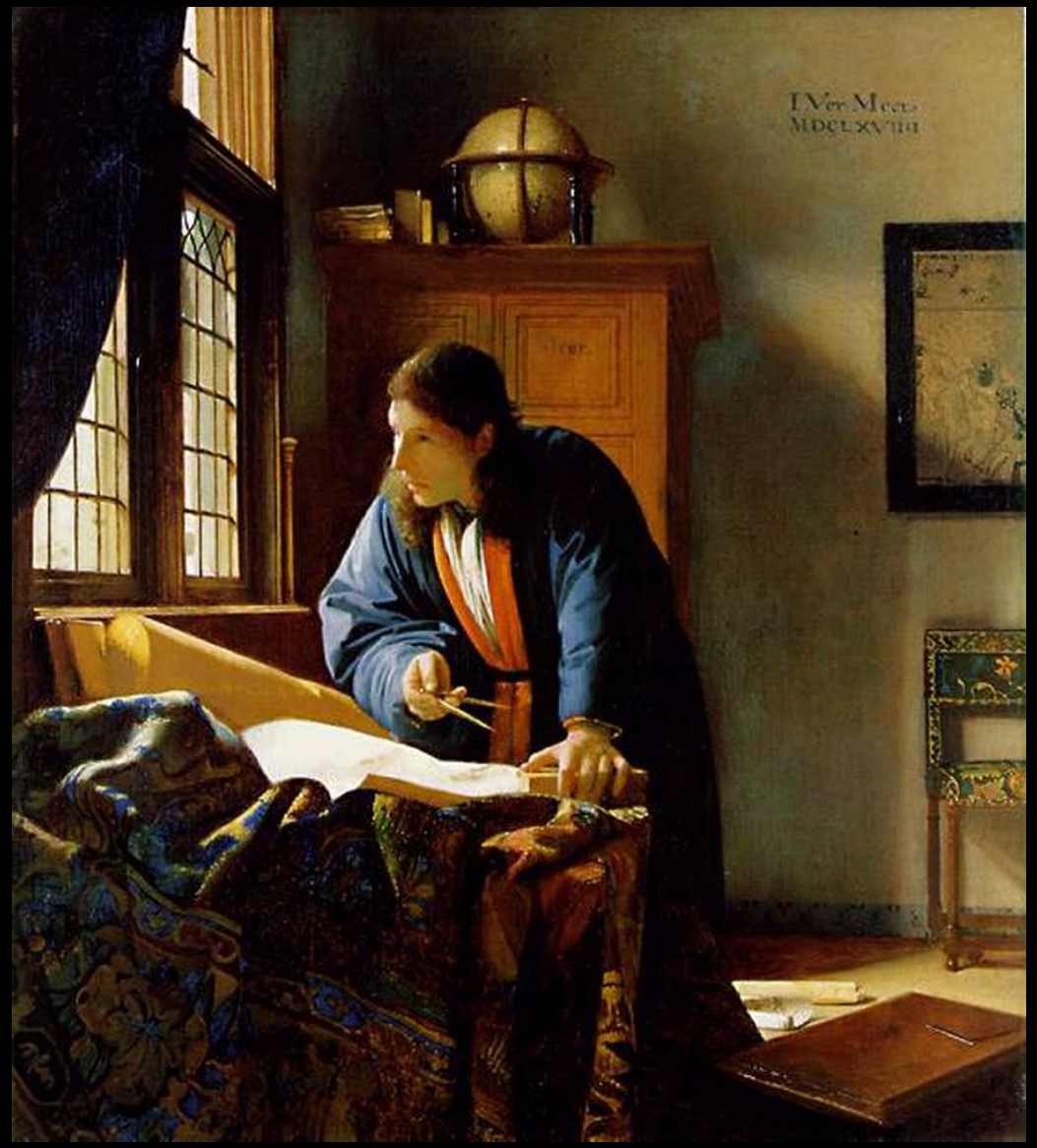
Display dynamic range + add contrast
+ add toe and shoulder

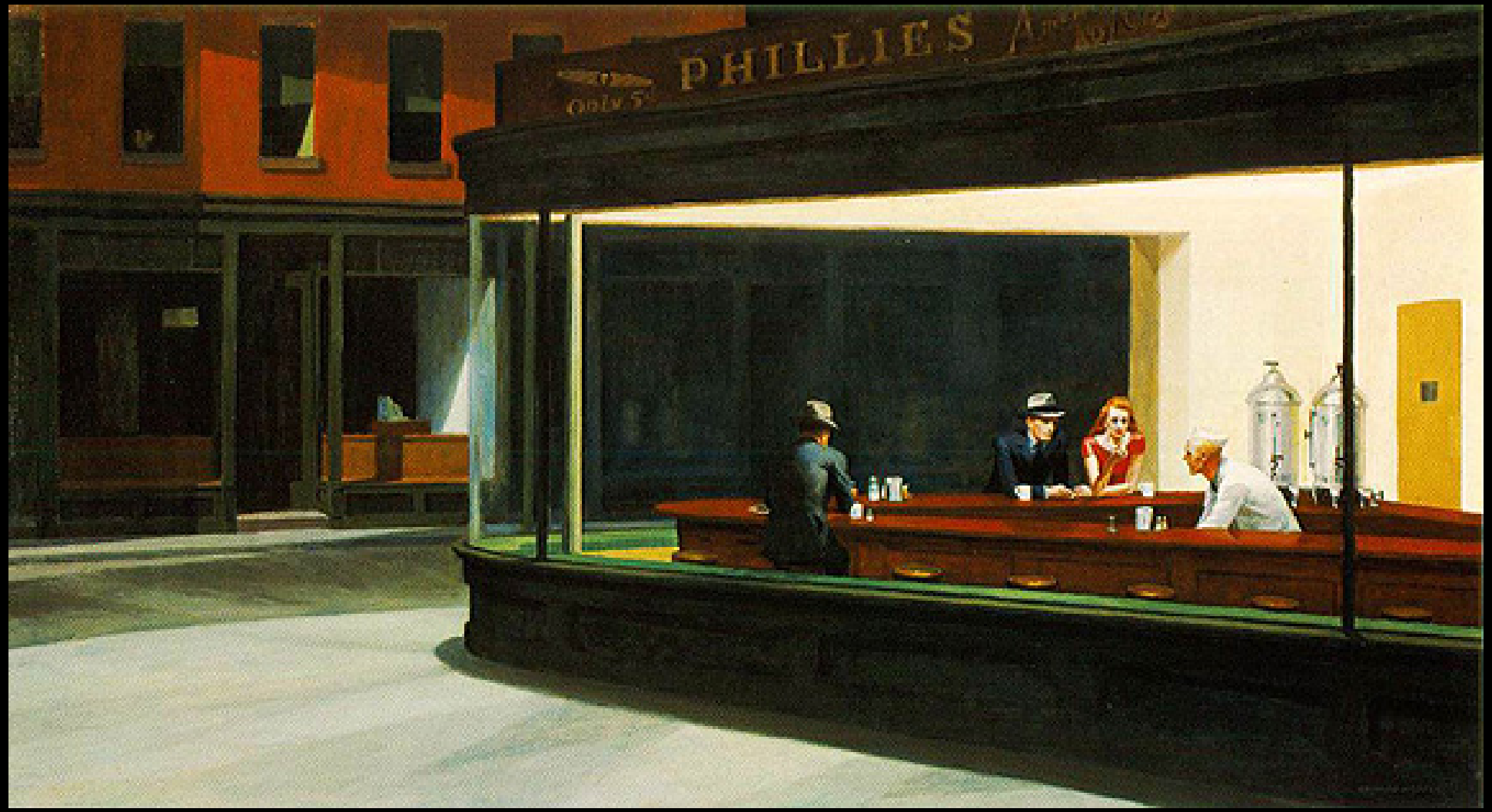
“S-curve” tone mapping is your friend.



A brief history of tone mapping…

Cave painting, Lascaux, France, 15,000 to 10,000 B.C.




PHILLIES

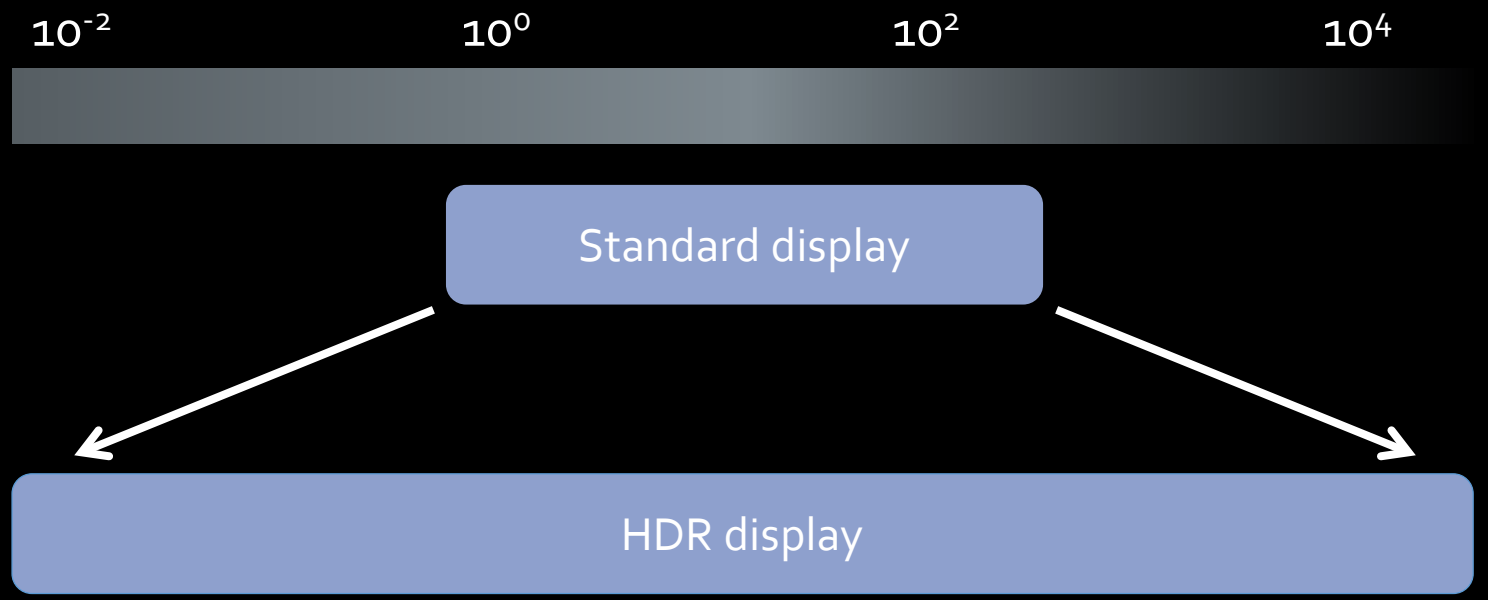
(end of rant on how “tone mapping” is the secret underlying technical basis for the entire history of visual arts that you’ll never hear about in that art history class)

Tone Mapping Approaches

- **Single global curve**
  - E.g. log, sigmoid, power function
  - Easy implementation (LUT)
  - No artifacts
  - But limited local contrast

- **Local processing**
  - Split image into layers (e.g. base/detail)
  - Global curve on base layer
  - Detail enhancement for detail layer
  - Recombine at the end
  - Preserves or even enhances local contrast
  - But can create artifacts and unrealistic image look

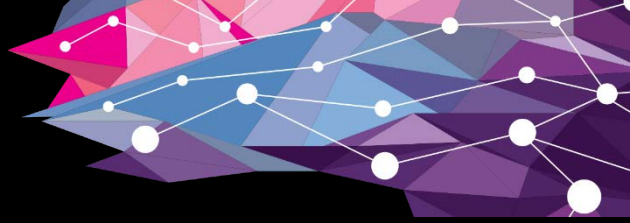
SDR to HDR



Goal:

Use extra dynamic range to improve visual experience while preserving artistic intent

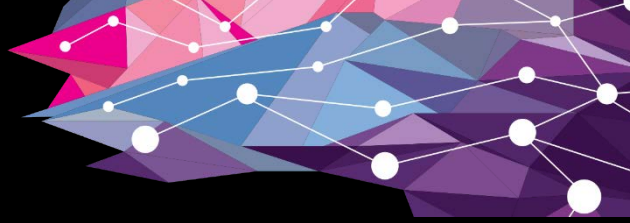
Why do we need inverse tone mapping?



- Existing content libraries are SDR
- Adverts
- DVD menus

- How do we adapt it to HDR displays?
  - Luminance expansion
  - Preservation of director's intent
  - Temporal coherence

Inverse Tone Mapping Approaches

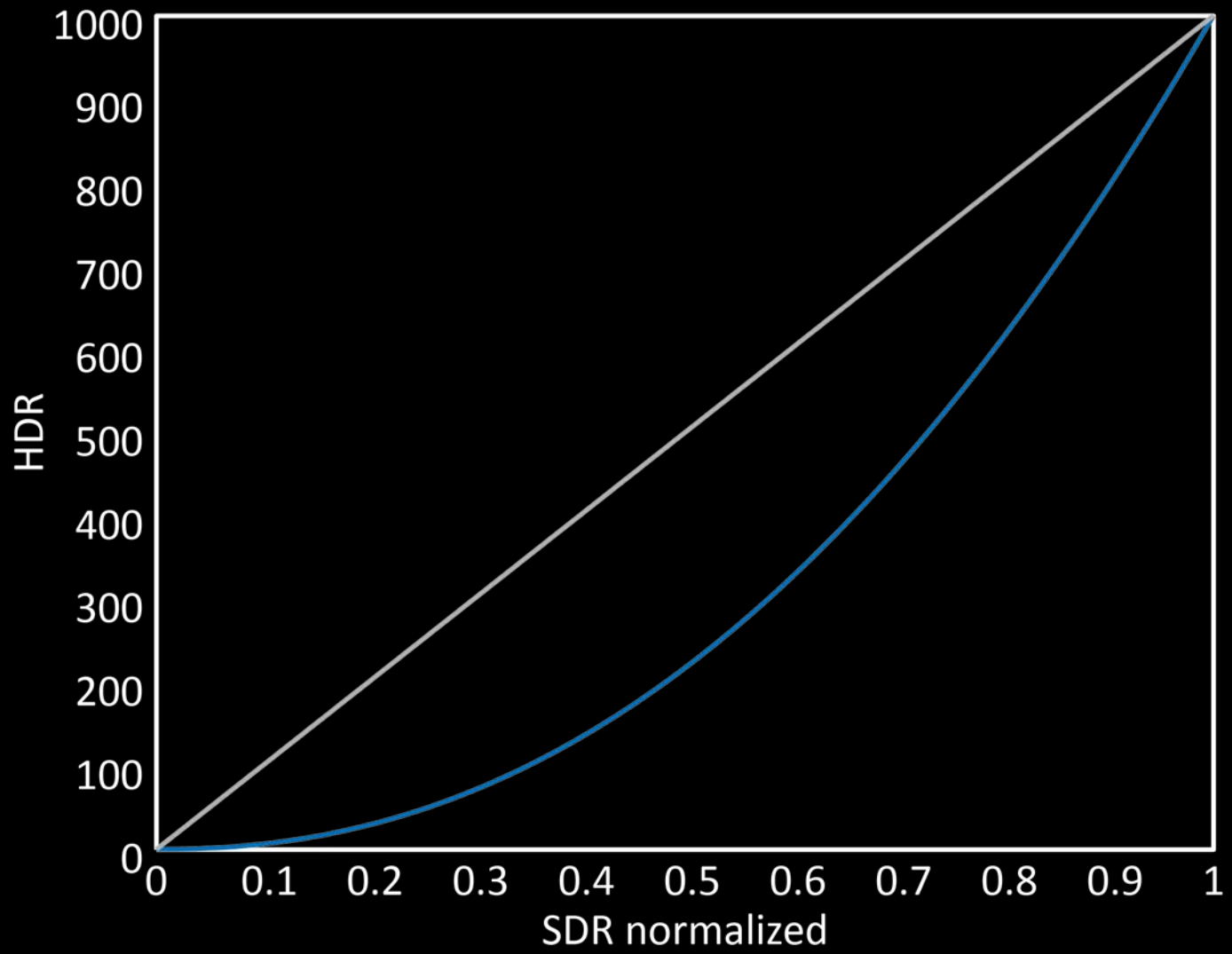


- **Global curve**
  - Early approaches involved *inverting* tone mapping curves
  - Similar benefits
  - Typically different expansion for shadows-midtones and for highlights (preserve midtones, stretch highlights)

- **Local processing**
  - Here local processing is for separating highlights and treating differently
  - Also for handling noise, banding and compression artifacts

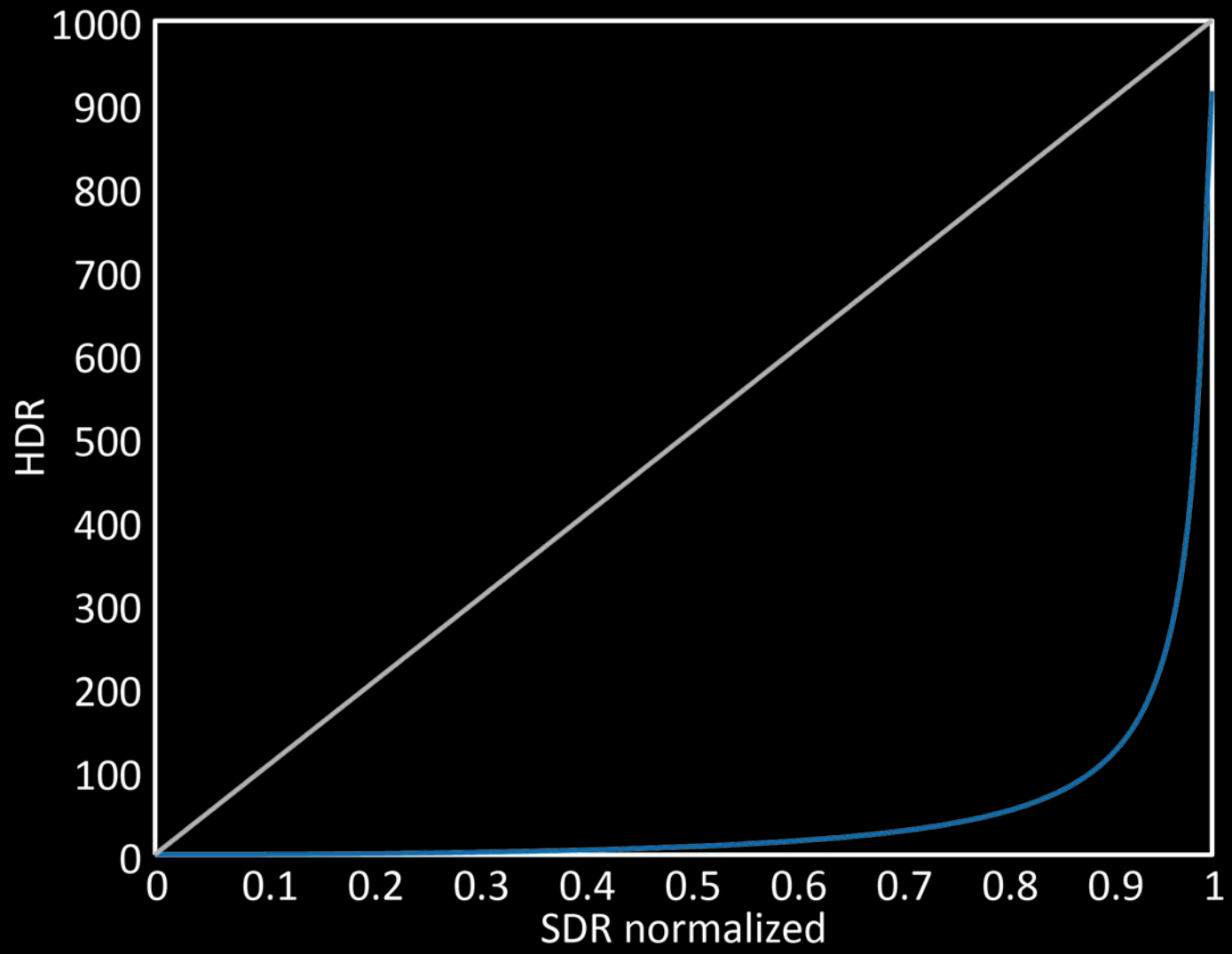
Inverse Tone Mapping

Simple gamma:



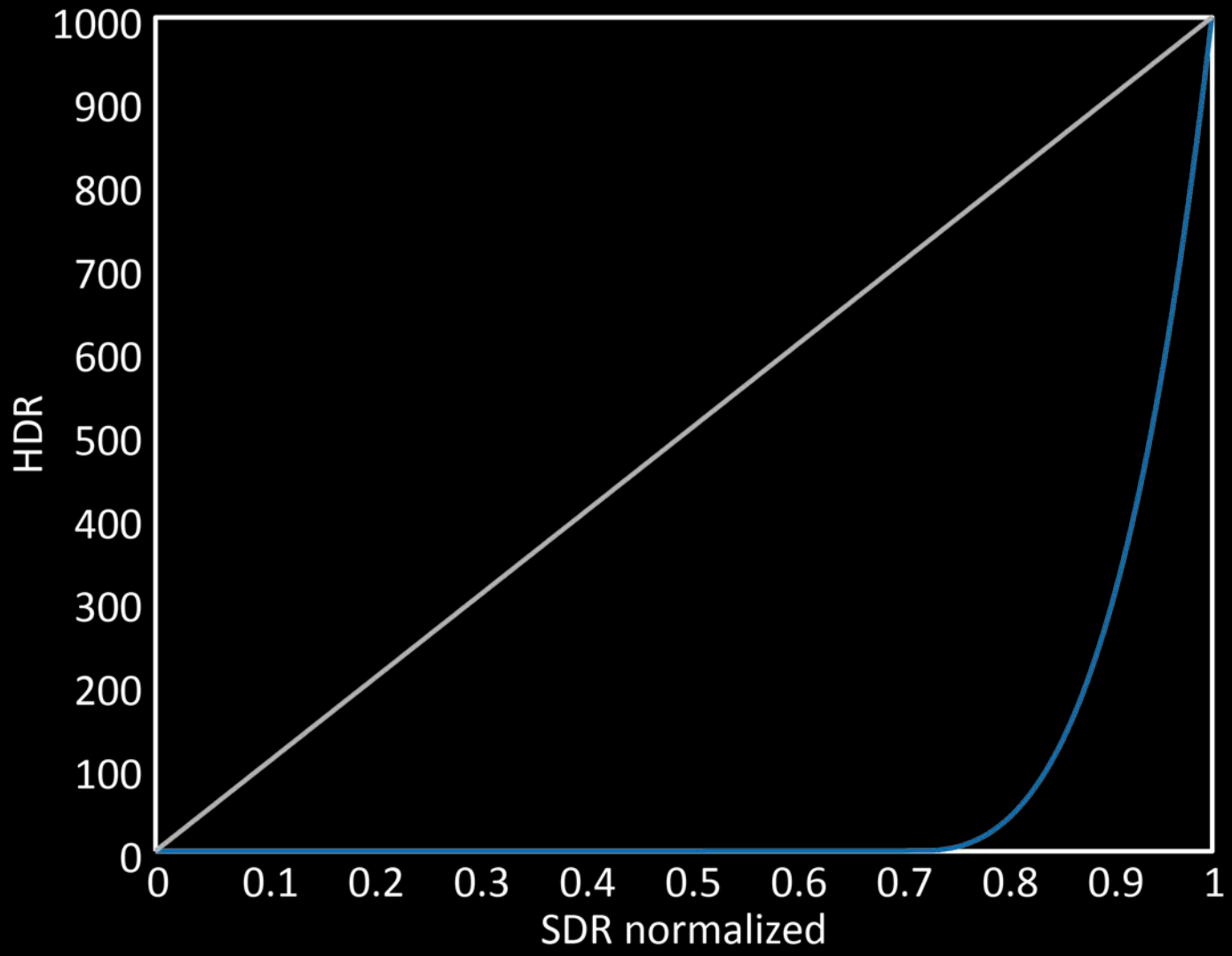
Inverse Tone Mapping

Compressing shadows, expanding highlights:



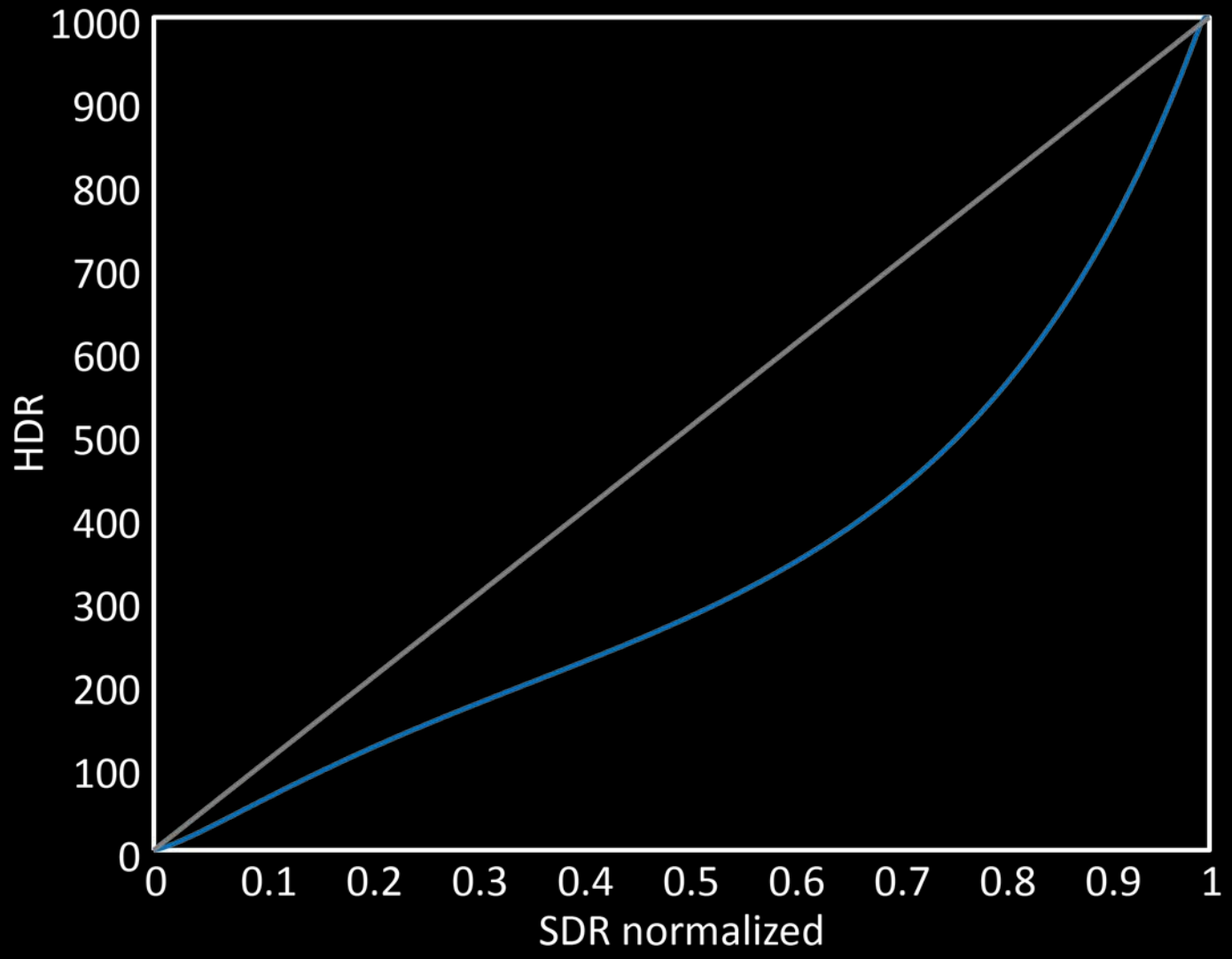
Inverse Tone Mapping

Compressing shadows, expanding highlights:



Inverse Tone Mapping

Moderate highlight stretching, shadow preservation:



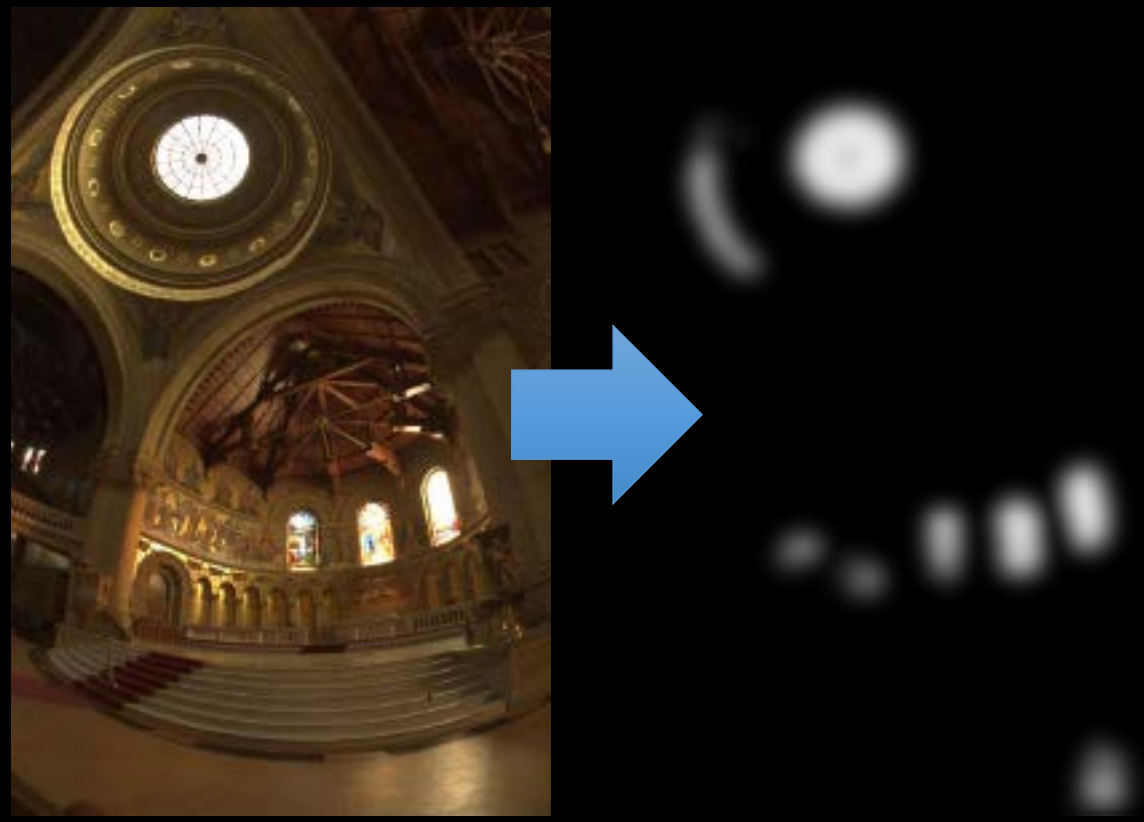
Inverse Tonemapping

- How do we deal with highlights?
- In SDR -> clipped
- In HDR -> Extra expansion for highlights – **expansion map**

- Challenge:
  - Distinguish specularities, light sources and diffuse white areas
  - Recover texture & color in clipped areas - **declipping**

Inverse Tone Mapping

- Several methods rely on an **Expansion Map** defining which areas should be treated as highlights



Banterle, Francesco, et al. "Inverse tone mapping." *Proceedings of the 4th international conference on Computer graphics and interactive techniques in Australasia and Southeast Asia*. ACM, 2006.

Declipping

- Highlights are usually clipped
  - Texture information lost
  - Hue shifts towards white

Abebe, Mekides Assefa; Pouli, Tania; Kervec, Jonathan and Larabi, Chaker "Color Clipping and Over-exposure Correction." EGSR 2015

Colorfront Transkoder

- Latest version includes HDR mastering functionality
- Dual SDR + HDR grades
- Dolby Vision support
- High Dynamic Range expansion

colorfront

ITM – Autodesk Lustre Plugin

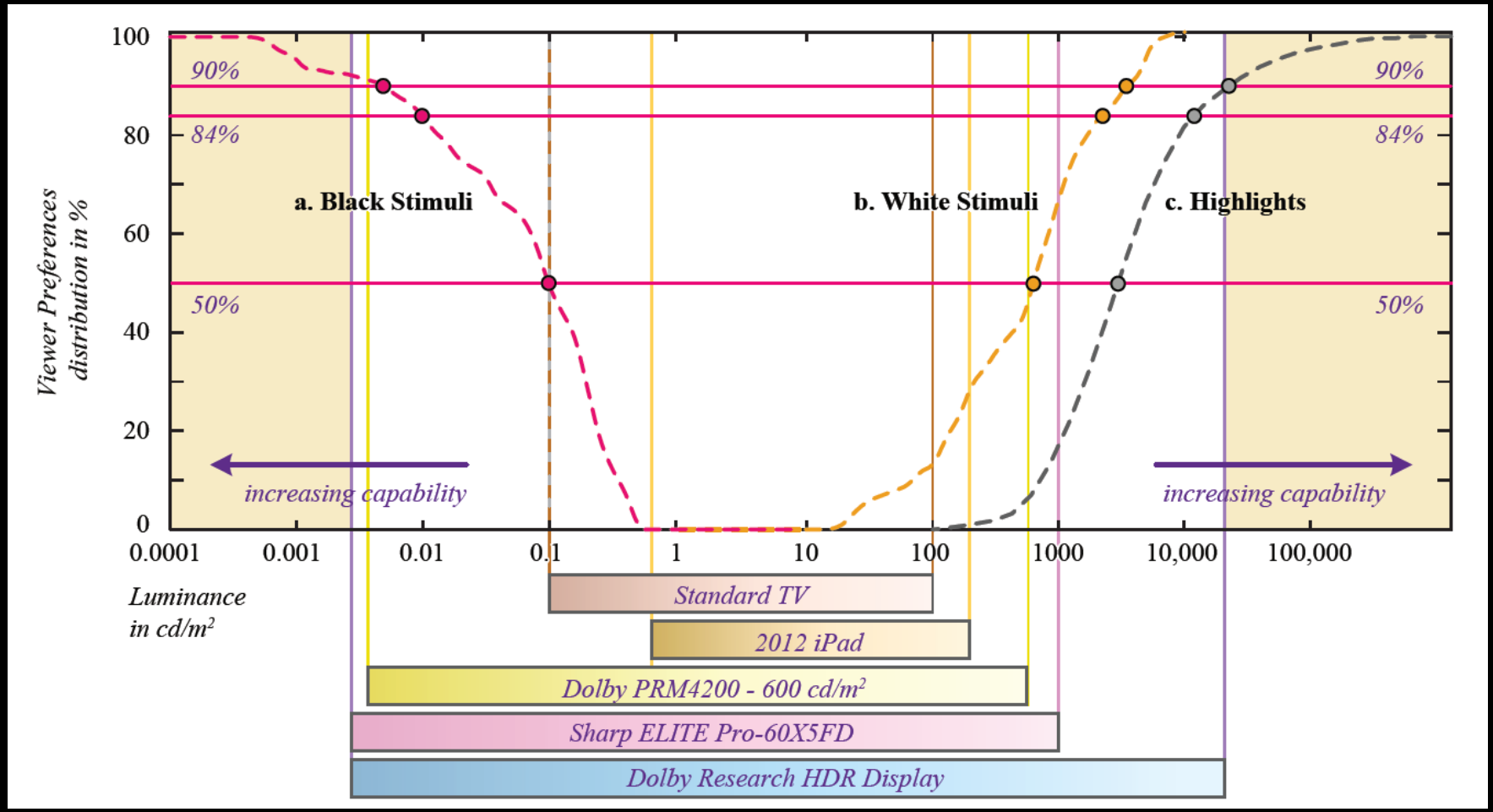
What would we call HDR?

- Required ingredients:
  - Peak luminance
  - Local contrast
  - Black level
  - Bit depth
  - *Color gamut*

- A good approach to decide how much of each:
  - Aim to maximize engagement / immersion
  - But preserve director’s intent!
  - Perform visual psychophysics
    - This could help determine values for the above parameters

Viewer Preferences

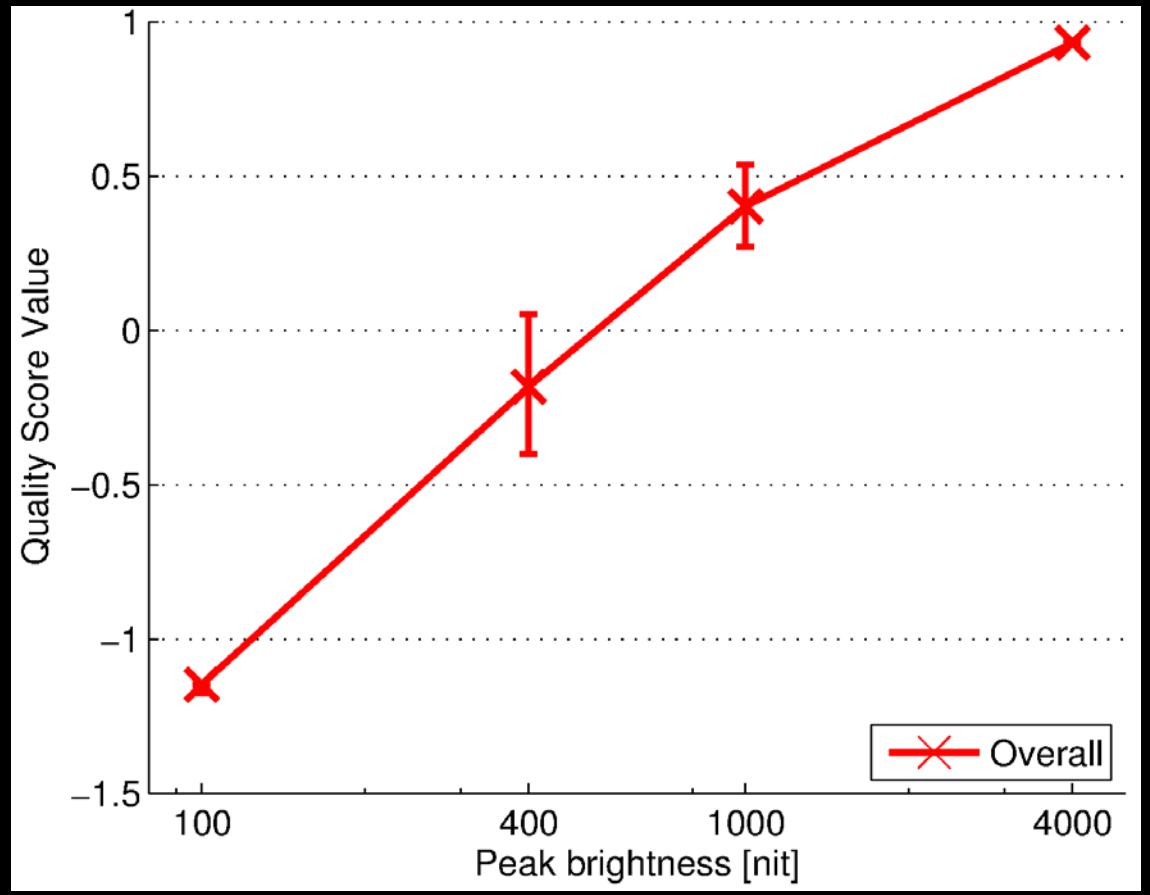
Assessment of preferred white and black levels

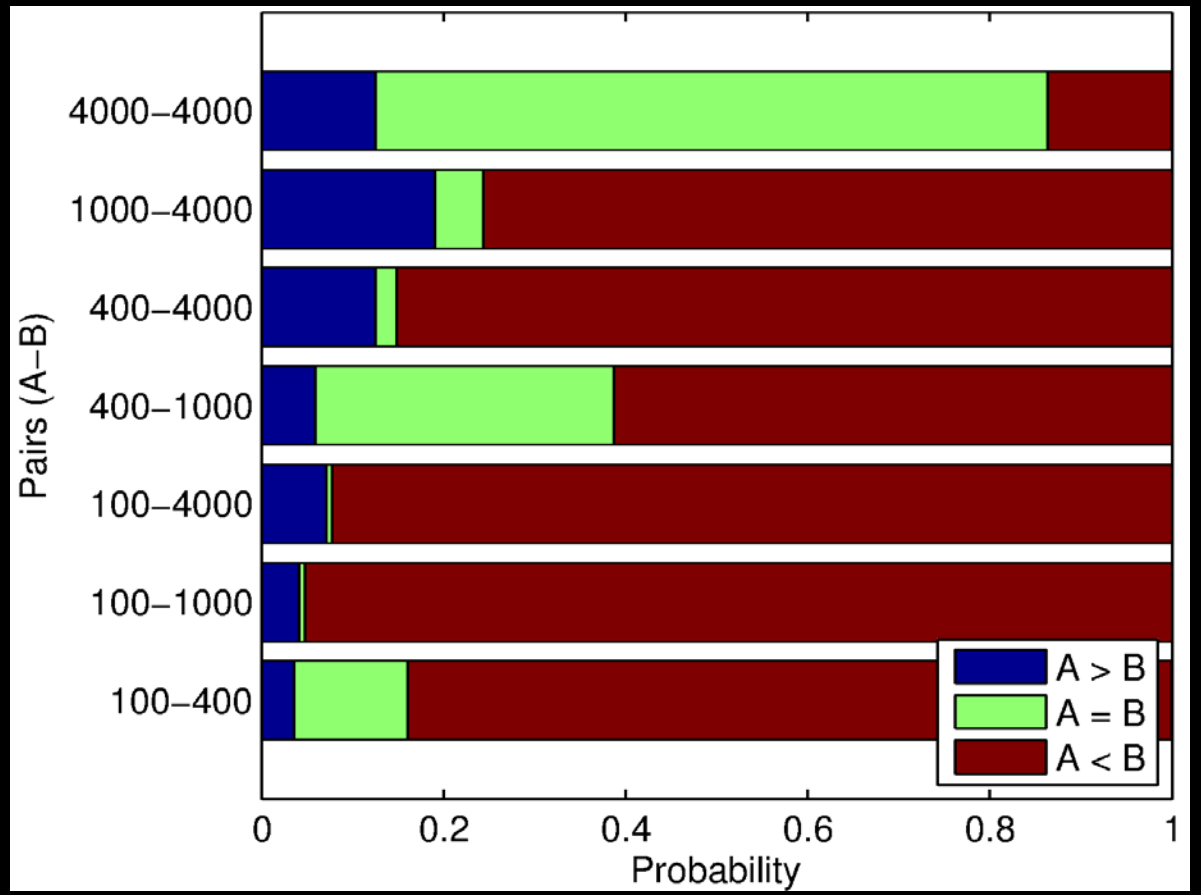


Daly, Scott, Timo Kunkel, Xing Sun, Suzanne Farrell, and Poppy Crum. "41.1: Distinguished Paper: Viewer Preferences for Shadow, Diffuse, Specular, and Emissive Luminance Limits of High Dynamic Range Displays." In *SID Symposium Digest of Technical Papers*, 2013.

Viewer Preferences

Comparison of different luminance levels

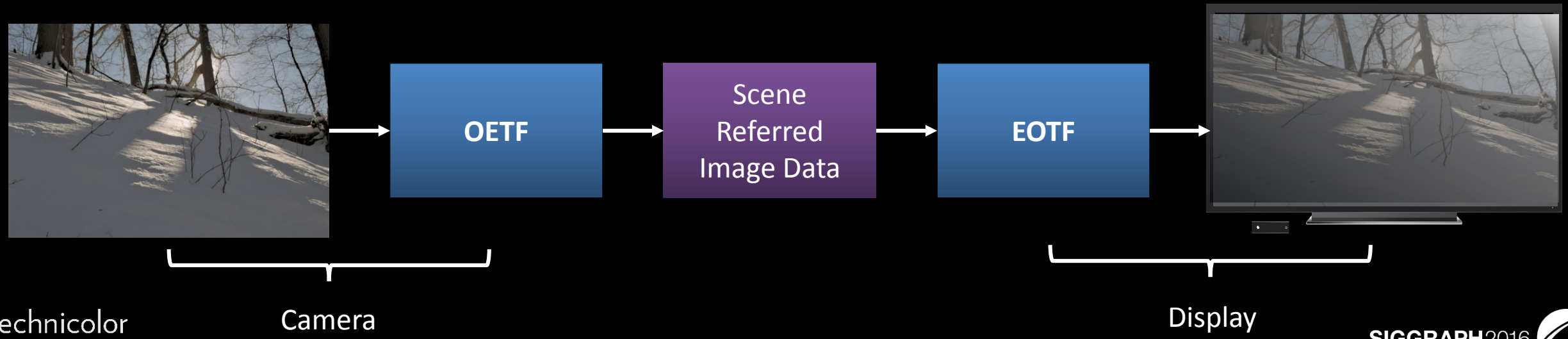




Hanhart, Philippe, Pavel Korshunov, and Touradj Ebrahimi. "Subjective evaluation of higher dynamic range video." In *SPIE Optical Engineering+ Applications*, pp. 92170L-92170L. International Society for Optics and Photonics, 2014.

How to Encode HDR Signal?

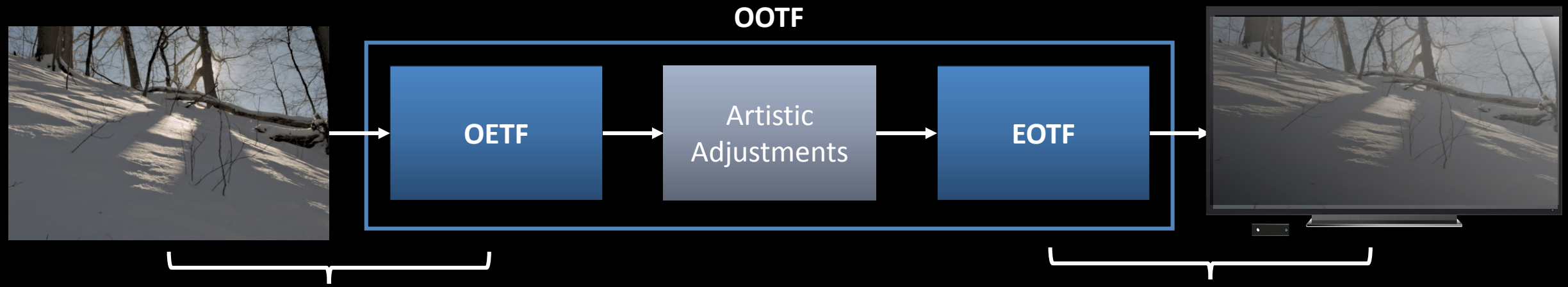
- **OETF:** Opto-electronic Transfer Function
  - Defines how scene luminance is encoded into image
- **EOTF**: Electro-optical Transfer Function
  - Conversion between electrical signal into optical data (i.e. light)
  - First defined based on CRTs
  - Up to now displays followed from CRTs – more efficient use of bits than linear
  - Newer (HDR) displays need new EOTF



How to Encode HDR Signal?

- **OOTF:** Opto-Optical Transfer Function
  - It has the role of applying the “rendering intent”
  - Compensates for differences between scene and display viewing environment
  - May include artistic adjustments

- Only two of OETF, EOTF, OOTF are needed to compute the third



How to Encode HDR Signal?

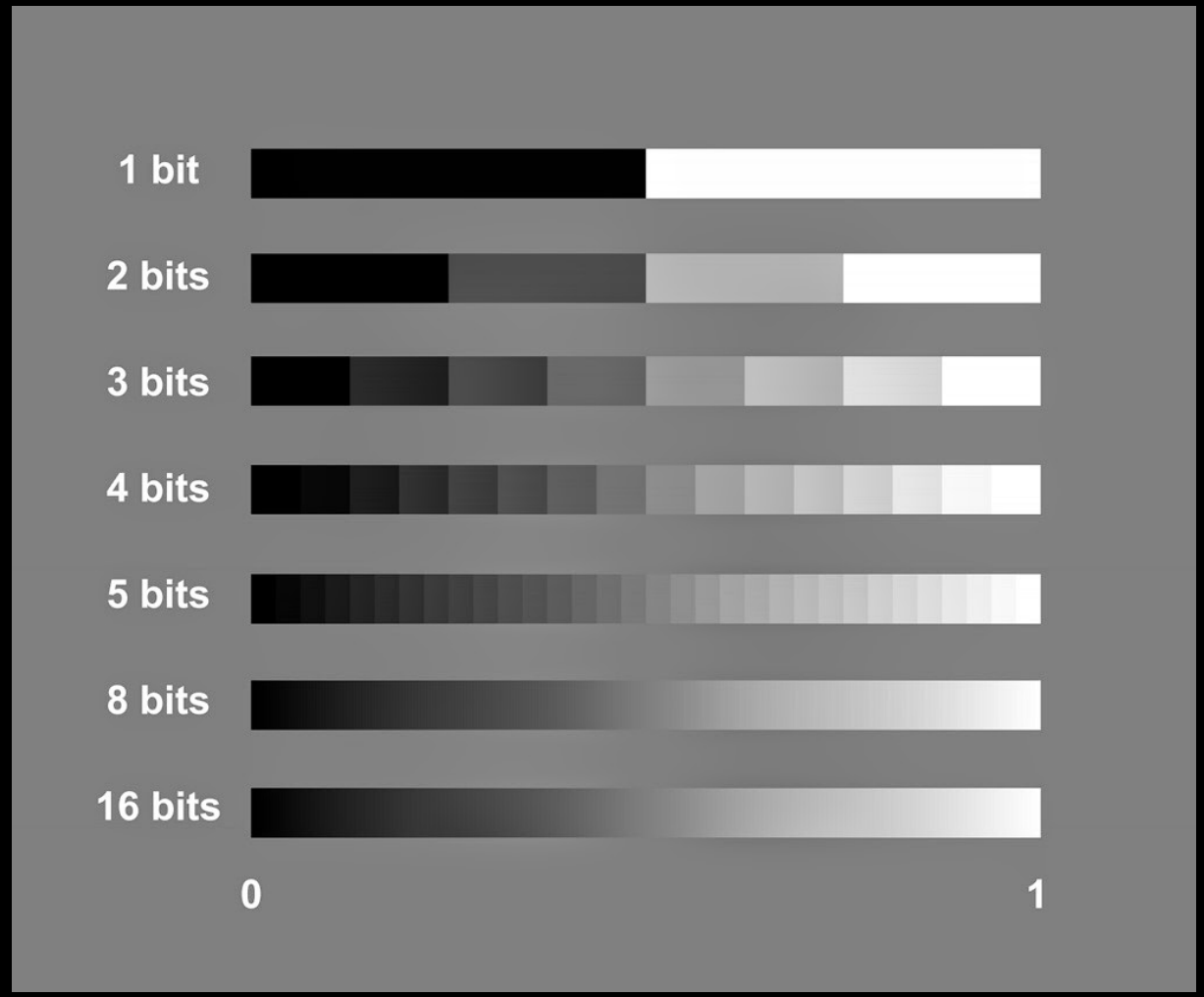
- For SDR signal, gamma worked well enough for CRT displays
  - Sort of follows perception
  - But only at relatively low luminance levels and narrow dynamic ranges

- For HDR signal, several proposals on the table
  - 1: stretching gamma to squeeze a bit more brightness and dynamic range out of our current system
  - 2: develop a fully new EOTF based on the study of perceptual quantization of HDR signal
  - 3: combinations of the two, i.e. use gamma for lower parts, something more perceptual for higher parts

- **Backwards compatibility is a challenge!**

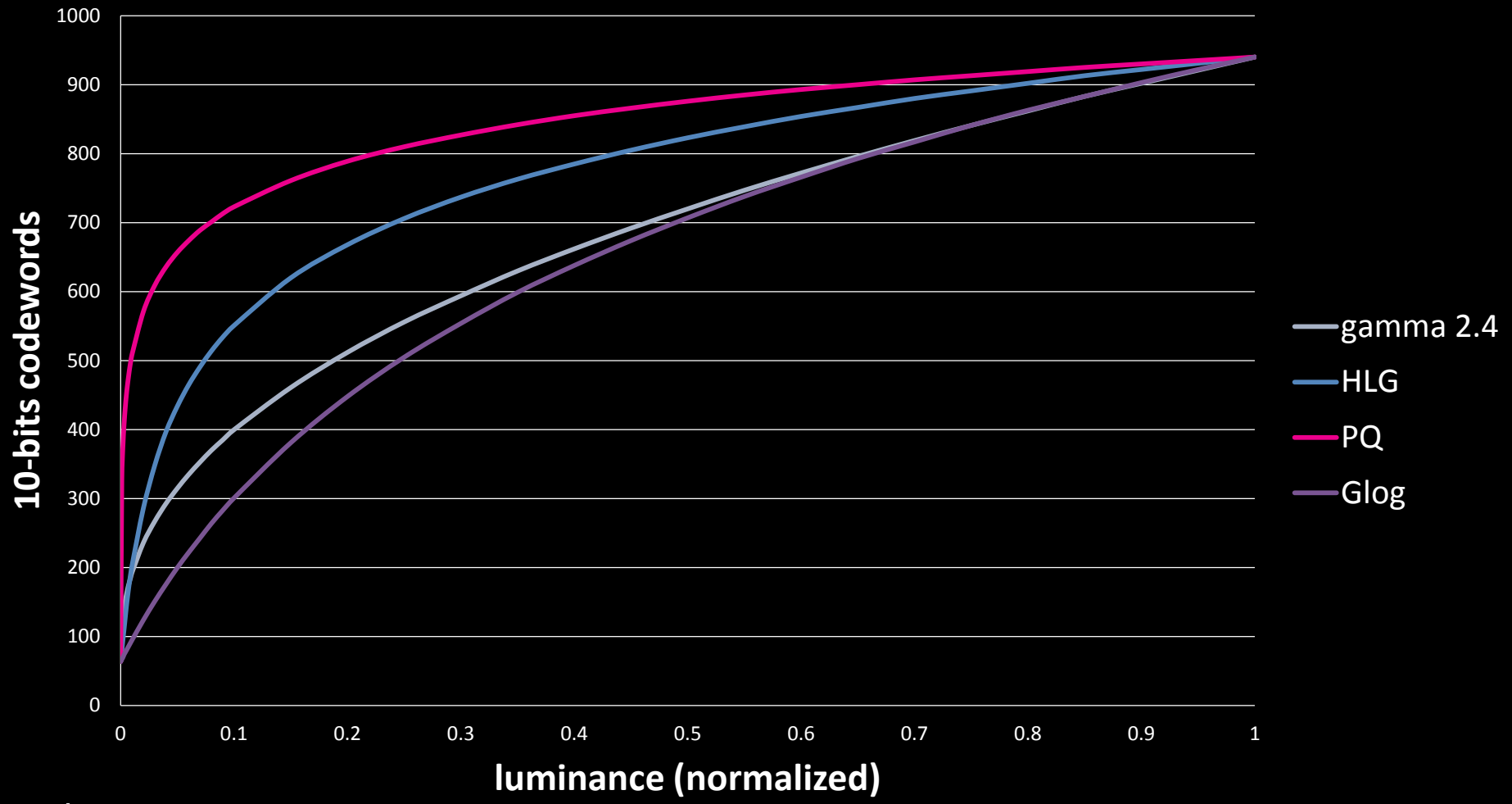
How to Encode HDR Signal?

- Bitdepth matters!
- More bits = more quantization steps
  - Smoother gradients
  - Avoids posterization artifacts
- But full pipeline needs to be compatible, which means
  - Increased costs
  - Increased bandwidth requirements
  - More storage
- For HDR tending towards 10 bits



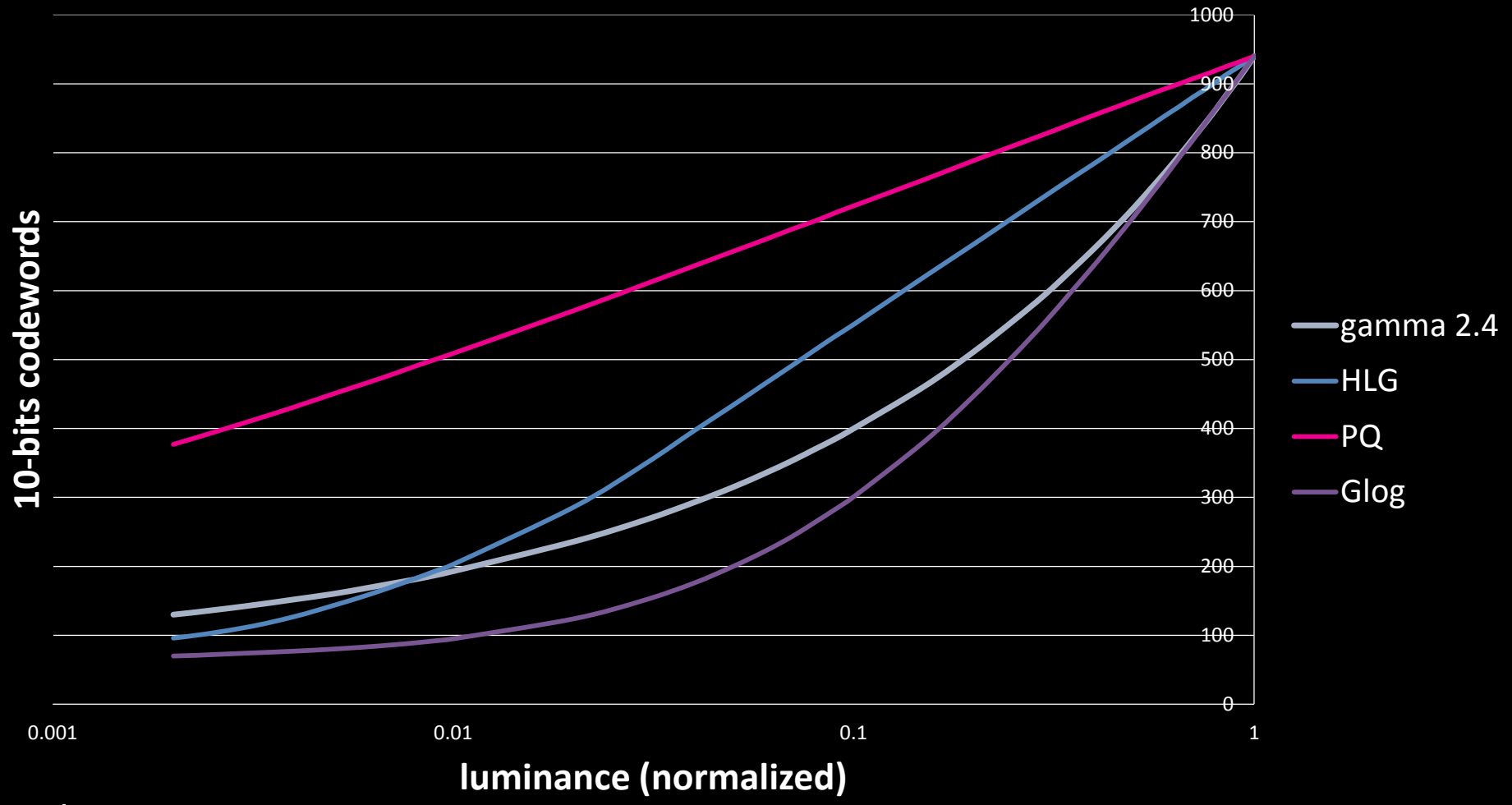
How to Encode HDR Signal?

Different OETF proposals on the table



How to Encode HDR Signal?

Different OETF proposals on the table



Who defines HDR?

- **Very recent ITU spec:** Recommendation ITU-R BT.2100-0
- **SMPTE baseline standard:** 2084 (PQ EOTF) and 2086 (mastering monitor metadata)
- **The CEA — The Consumer Electronics Association initiative:** “HDR Compatible” defines a TV that can play HDR content but is not necessary an HDR display.

- **The UHD Alliance initiative:** criteria to define a premium home entertainment experience
  - “ULTRA HD PREMIUM” logo unveiled at CES 2016
  - 13 devices from 3 manufacturers showed the Premium Ultra HD logo at CES.
  - Content, Distribution and Devices can all carry the logo.

ITU-R BT.2100-0

"…specifies HDR-TV image parameters for use in production and international programme exchange using the Perceptual Quantization (PQ) and Hybrid Log-Gamma (HLG) methods."

- Hot off the press – July 2016
- Aimed directly at HDR
  - >= 1000 nits peak display luminance
  - <= 0.005 nits display black level
  - 10 and 12 bit encoding
  - Two possible encodings – PQ or HLG

SMTPE HDR Standards

- **SMPTE ST2084-2014**
  - Defines EOTF for HDR content
  - Based on *perceptual quantizer* (PQ) function proposed by Dolby
  - Encodes linear, absolute luminance values between 0-10,000 cd/m^2
  - Perceptually motivated – each step should be below visible threshold
  - Output floating point 0-1

Ultra HD Premium

- **EOTF:** SMPTE ST 2084 (i.e. PQ EOTF)
- **Color Sub-sampling:** 4:2:0 (for compressed video sources)
- **Bit Depth:** 10 bit
- **Peak Luminance:** 1000 cd/m^2
- **Color Primaries:** ITU-R BT.2020 (container)
- **Metadata:** SMPTE ST 2086, MaxFALL, MaxCLL
  - Defines mastering color space

The UHD Alliance

- Alliance to support an ***open standard*** for production, distribution and display of UHD & High Dynamic Range video
- Minimum specifications for video quality and metadata
- Room for licensors to innovate on top ensures competition
- Certification scheme to ensure compliance
- Logo program for content and devices

The HDR Standards Ecosystem

CONTENT CREATION

CONTENT DISTRIBUTION

CONTENT RENDERING

Advanced Imaging Society

DVB

ATSC

The UHD Forum

Consumer Electronics Assoc.

HDMI

SCSA and UltraViolet (DECE)

Blu-ray Disc Association

The Guilds

DEG

SMPTE

MPEG

ITU-R

Marketing

UHD Alliance

Technical

Digital Cinema Initiatives (DCI)

Part III: HDR Color Grading & Post Production

Benefits of HDR

For the viewer

- More impressive images
- Increased immersion
- More detail visible
- Higher realism
- Can benefit existing content
  - Justifies buying new TV

Benefits of HDR

For the content creator

- Brighter brights give more of a wow effect
- Deeper and more detailed shadows draw viewers in
- More room for storytelling
- Better able to capture usable shots even under challenging lighting
  - E.g. for documentaries or live sports

HDR Content Creation

3 Use Cases:

1. **Upgrading existing SDR content**

2. **Dual grades (SDR/HDR) for active projects**

3. **HDR targeted production**

Use Case 1: Upgrading existing SDR Content

- Useful for existing content libraries
- Using ITM-like process for semi-automatically upgrading content to HDR
- Could even be done at viewer side (TV, set-top box)

- But can we do HDR ‘one size fits all’?

Use Case 2: Dual SDR & HDR grades

- HDR pass as secondary deliverable
- Current approach since HDR is not yet widely adopted
- Good for active projects where all assets are available

Two approaches:

- SDR master -> HDR pass for specific characteristics
- HDR master -> SDR pass + HDR pass

Use Case 2b: Remastering HDR from archived assets

Use Case 2: Dual SDR & HDR grades

Several projects have already included an HDR grade!

Theatrical for HDR projection:

Revenant
Jungle Book 2d and 3d
Captain America: Civil War
BFG 2D and 3D
Tomorrowland
Inside Out
Star Wars - The Force Awakens

Theatrical for HDR pass on monitor:

Revenant
Jungle Book
Spy
Poltergeist
Fantastic Four
Mike and Dave Need Wedding Dates
The Huntsmen

Broadcast and Streaming:

Bosch
Casanova
The Man In The High Castle
Mozart In The Jungle

Use Case 3: HDR Targeted Production

- Not there yet…

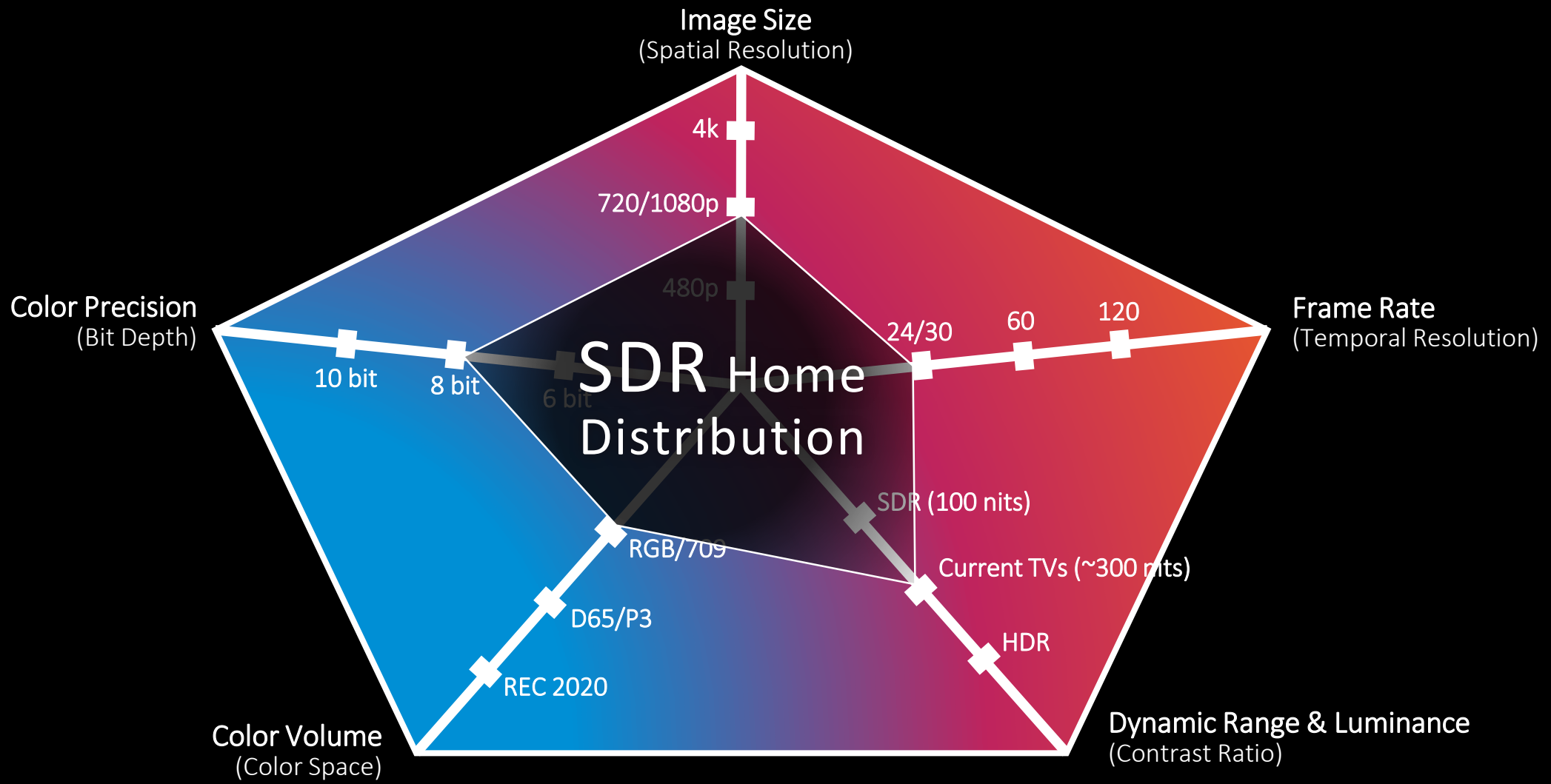
- Full adaptation of capture & production workflow to HDR
- Many challenges not yet addressed
  - On-set?
  - Dailies?
  - Editorial?
  - Visual Effects?

Theatrical vs Home

- **HDR for cinema/theatrical releases is not the same HDR as for home!**
- It was the case for SDR too but the differences are less pronounced

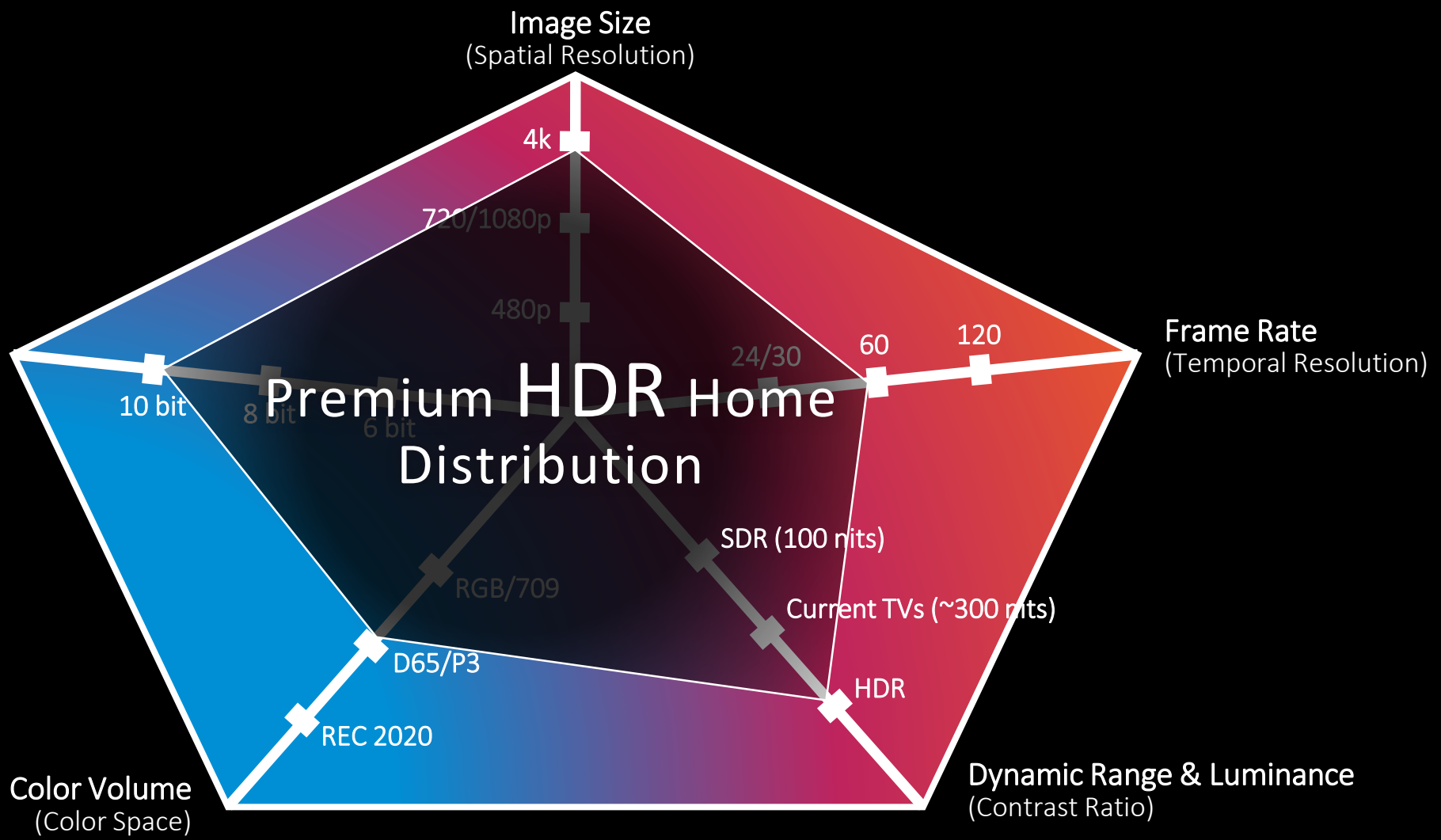
- Several aspects to consider
  - Peak white
  - Black levels
  - Local contrast
  - Color gamut
  - Bit depth
  - Frame rage
  - Resolution
  - …

Home Distribution - SDR



Home Distribution - HDR

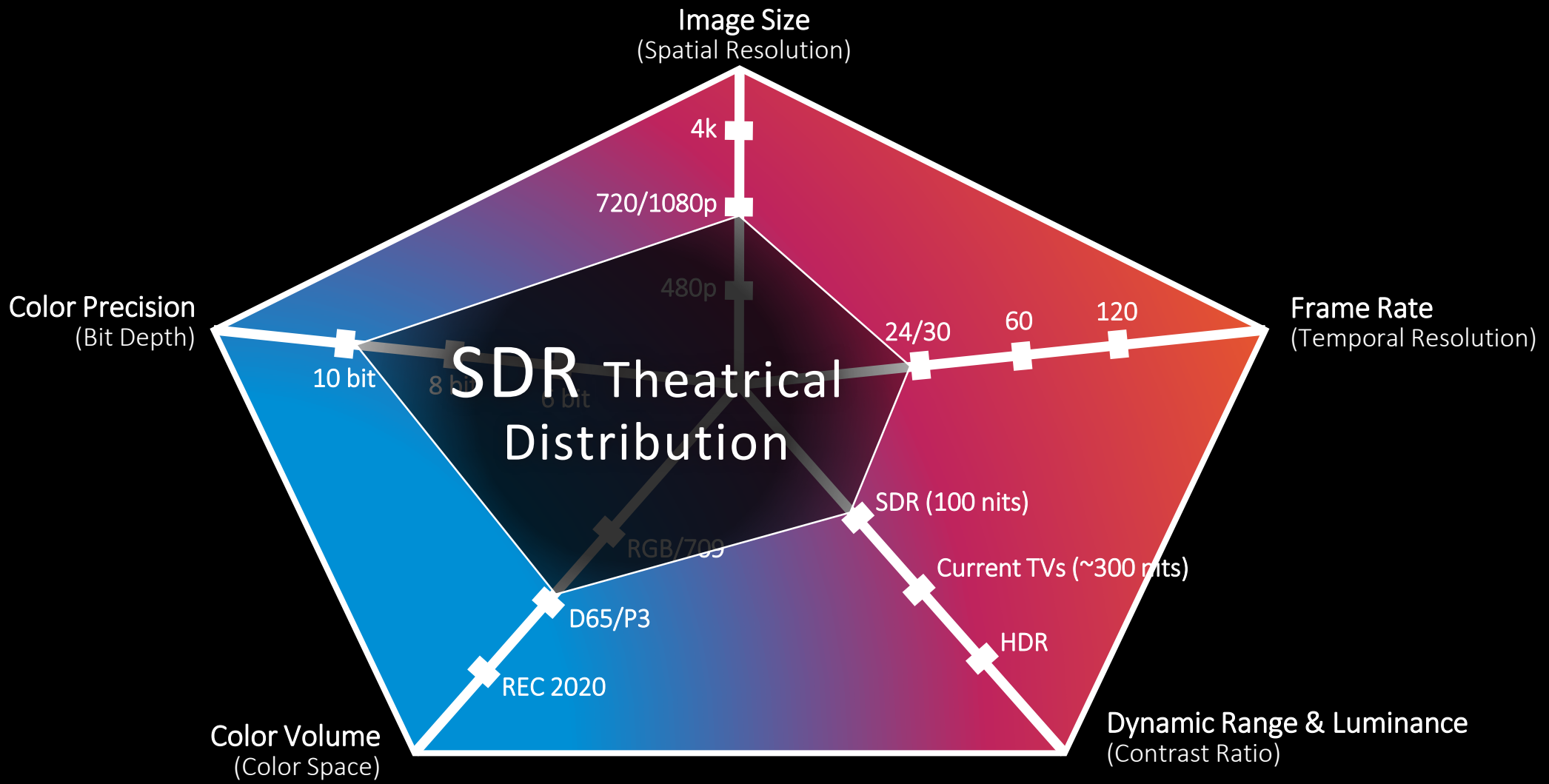
ULTRA HD™ PREMIUM



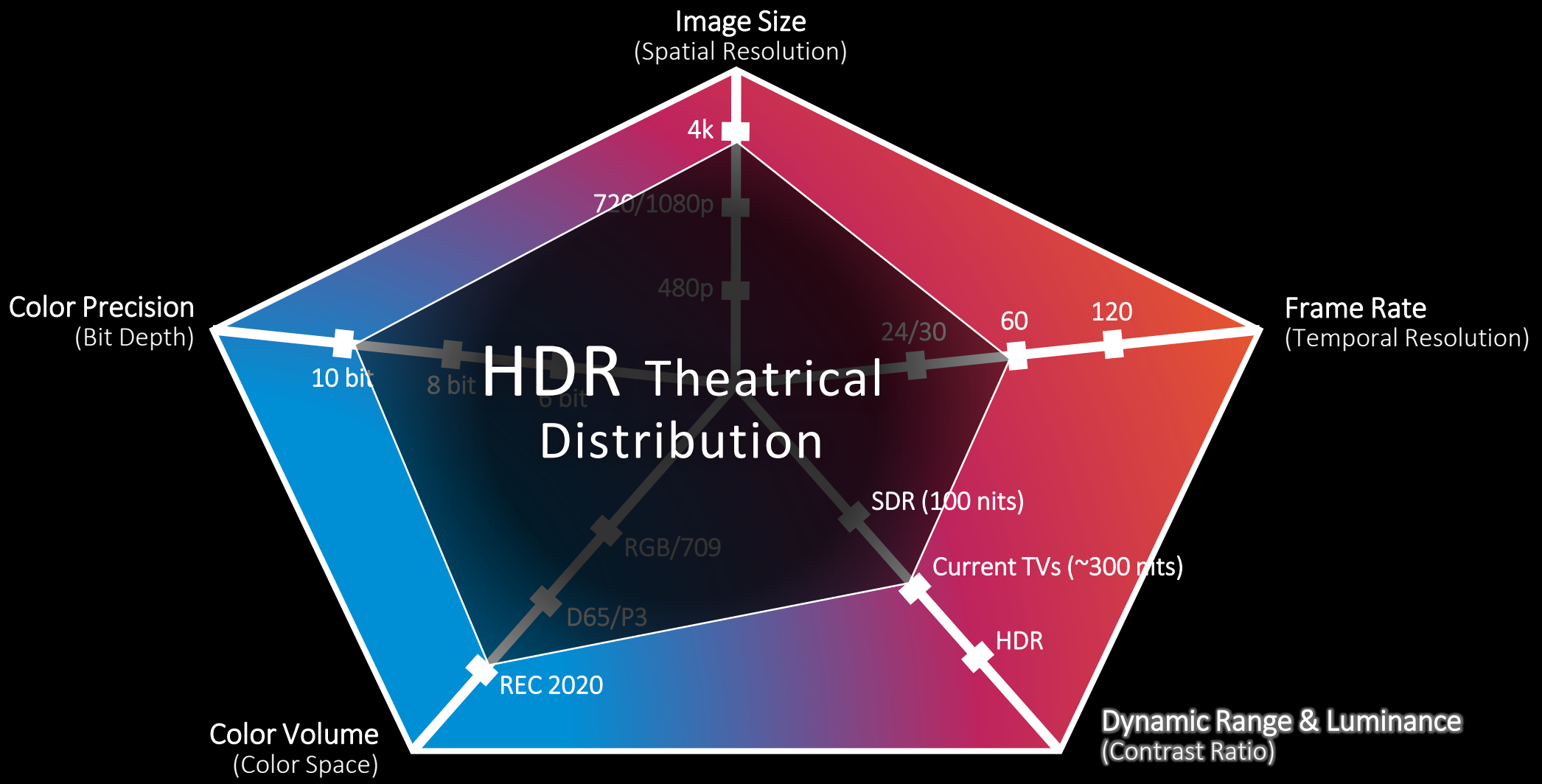
technicolor

SIGGRAPH2016

Theatrical Distribution - SDR



Theatrical Distribution - HDR



Home Master

			
	SDR Reference Screen	**Dolby Pulsar**	**Sony X300**
Local Contrast	1000:1	>133,000:1	> 10,000,000:1
Peak White Level	100 nits	4000 nits	1000 nits
Black Level	~0.1 nits	<0.03 nits	<0.0000 nits
Color Gamut	Rec.709	P3	P3
White Point	D65	D65	D65
Open/Proprietary	Open Standards Based	Dolby Proprietary	Open Standards Based
Target Monitor for:	All SDR Content	Approved/Sponsored Projects Only	All Open HDR Content (exceeds the UHDA specifications for both consumer parameter sets)
Availability	General	Limited	General

Theatrical Master

Simpler story…

		
	Standard Theatrical Projection	**HDR Laser Projector**
Peak White Level	48 nits	~100 nits
Color Gamut	P3	>P3

SDR Home Workflow

WORKFLOW

MASTERS

DISTRIBUTION

SDR Mastering Display

SDR Master

SDR

SDR Video

HDR Home Workflow: Single HDR Master

WORKFLOW

MASTERS

DISTRIBUTION

HDR Mastering Display
(Sony X300)

HDR Master
(UHDA)

ULTRA HD PREMIUM

HDR10

HDR Video

Single Stream
(3rd party TMO)

HDR+ Metadata

SDR Video

SDR

SDR Video

HDR Home Workflow: Dual Master

WORKFLOW

MASTERS

DISTRIBUTION

HDR Mastering Display

Trim pass

SDR Mastering Display

HDR Master (UHDA)

ULTRA HD PREMIUM™

SDR Master

HDR10

HDR Video

Single Stream (3rd party TMO)

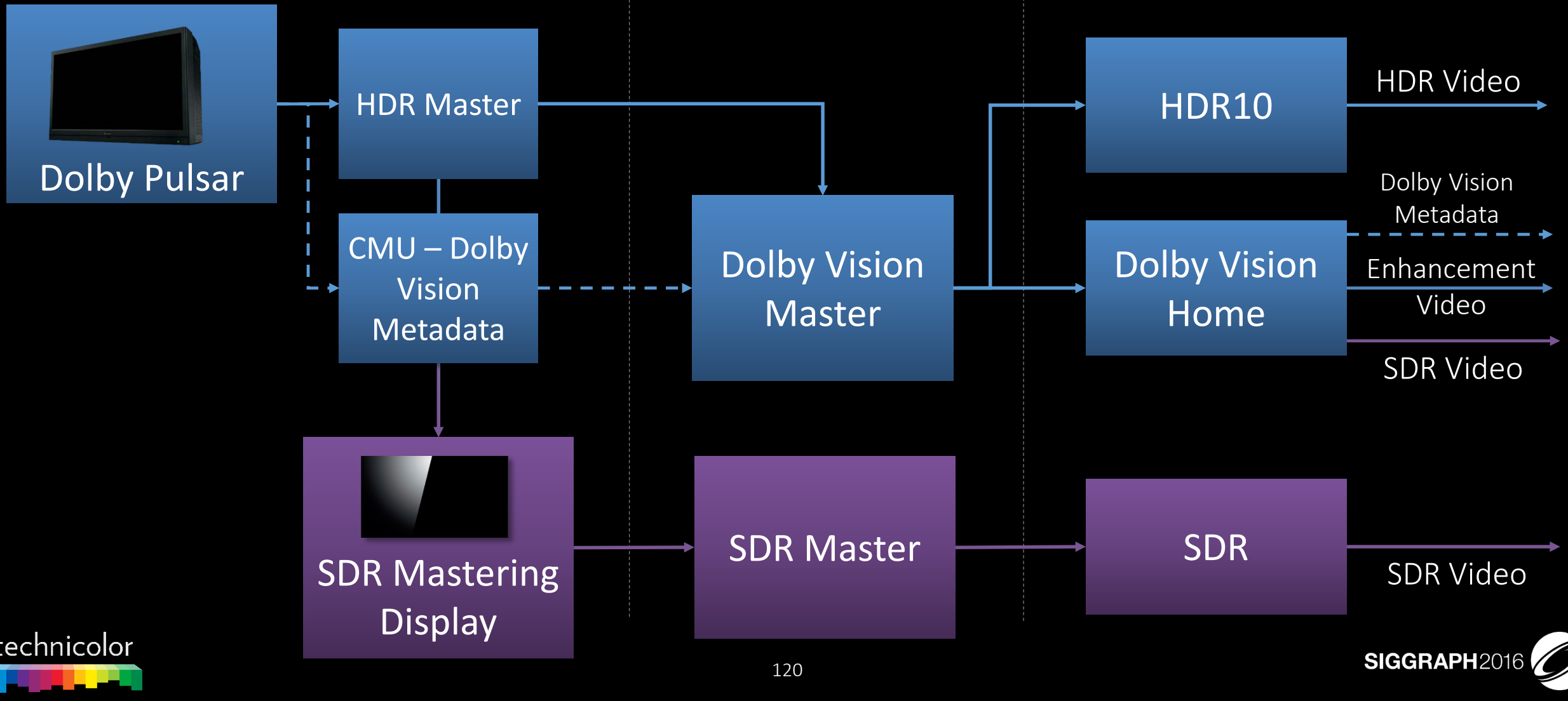
HDR+ Metadata

SDR Video

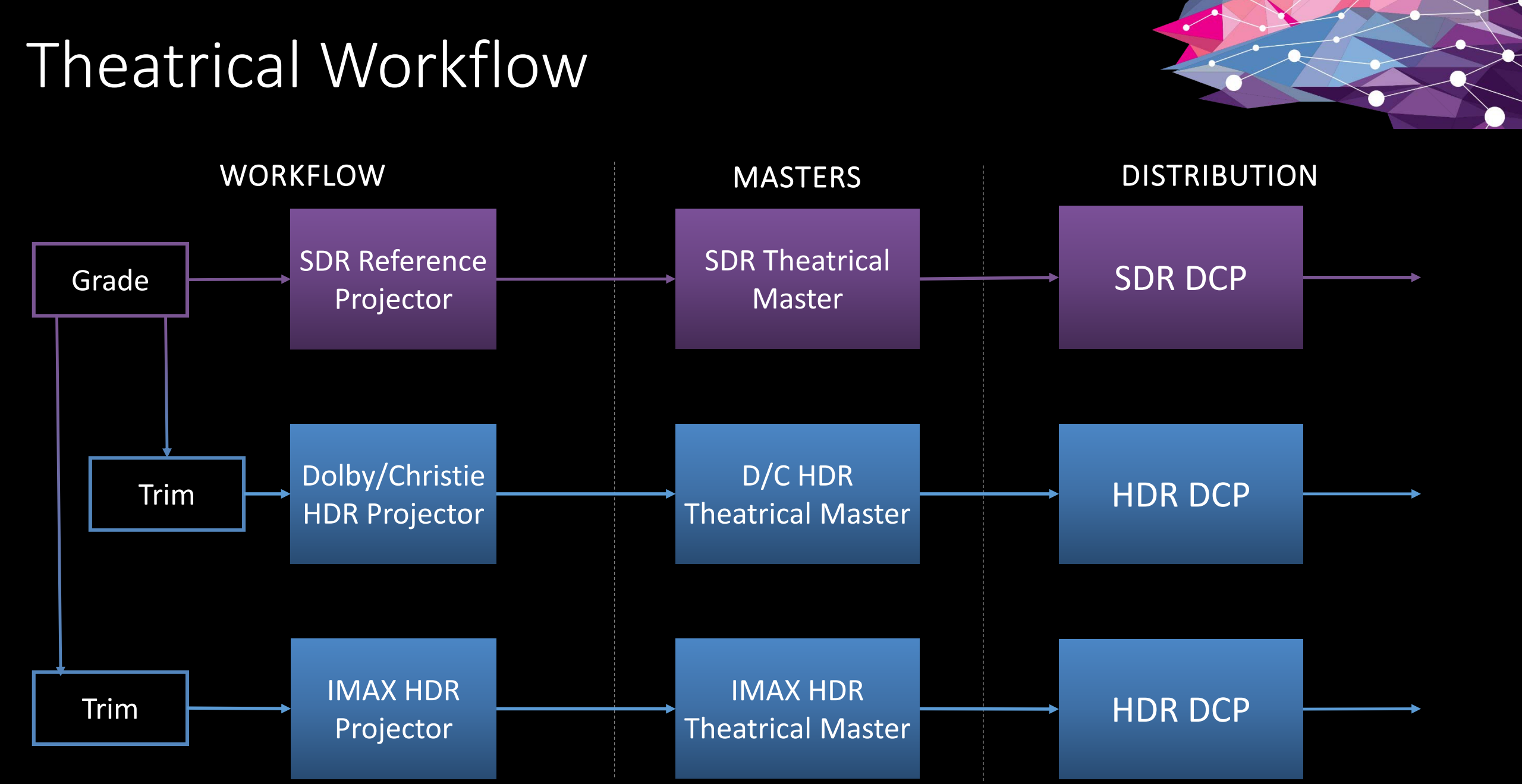
SDR

SDR Video

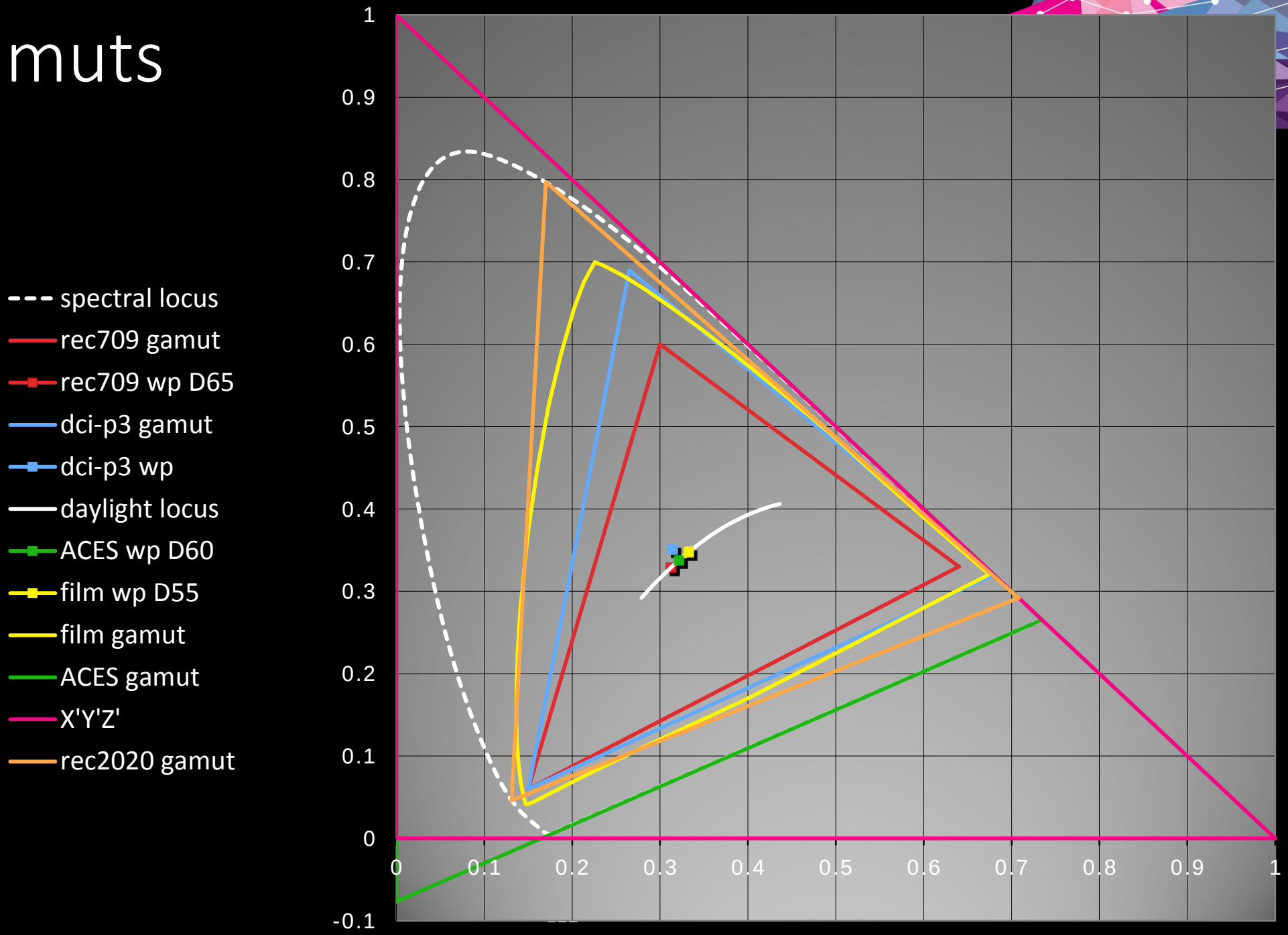
Dolby Vision Workflow



Theatrical Workflow

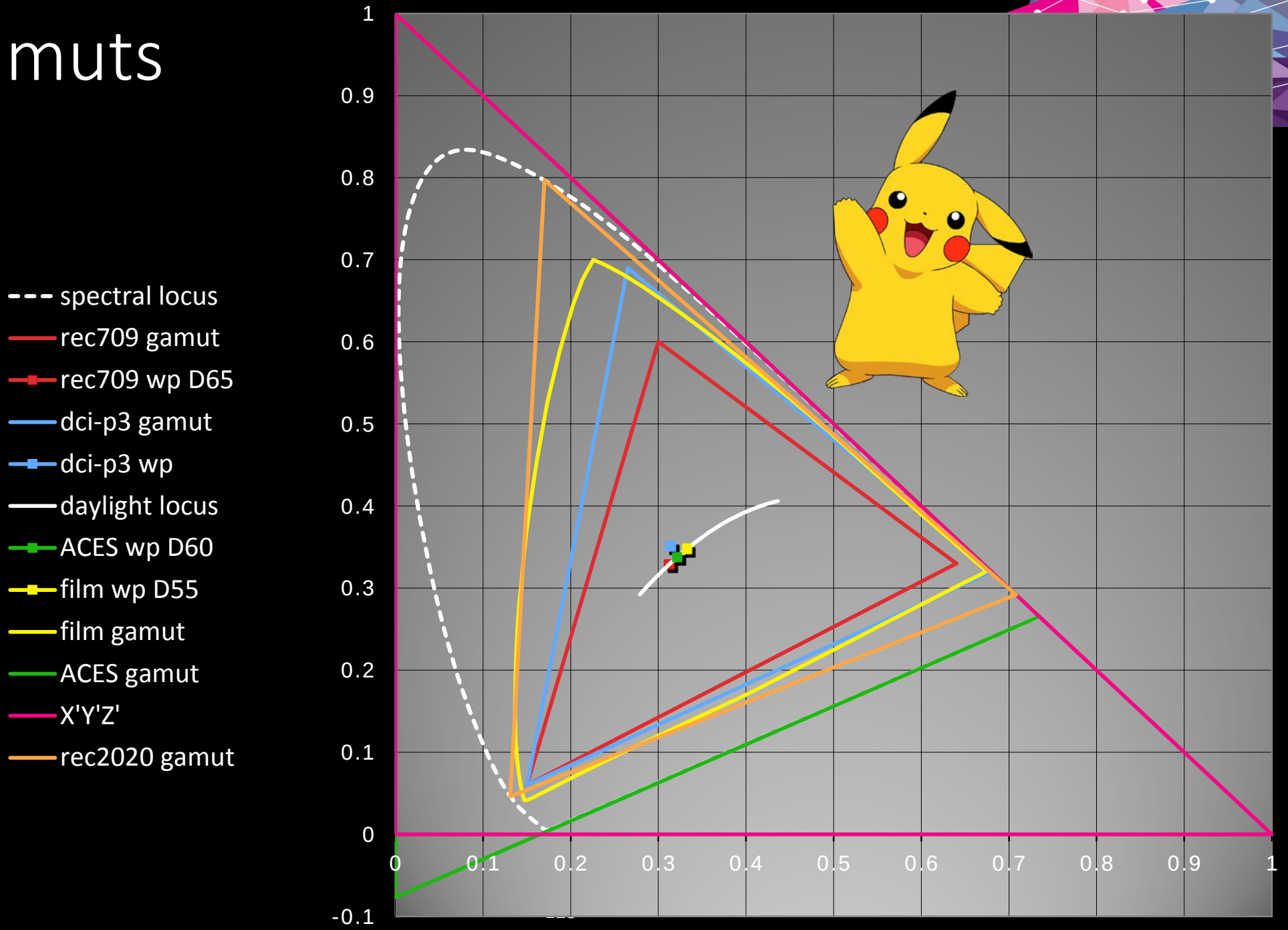


Color Gamuts



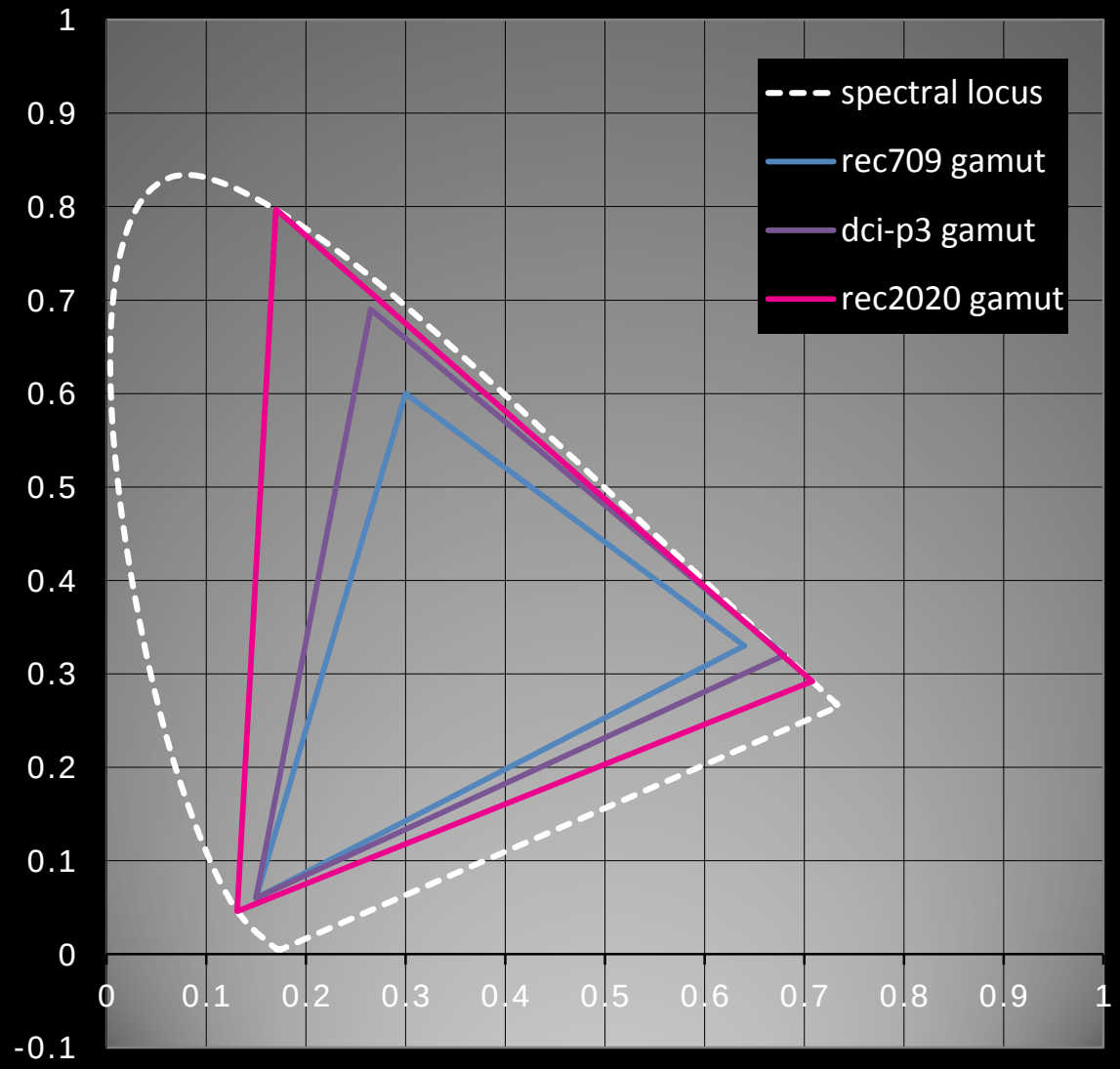
technicolor

Color Gamuts



technicolor

Color Gamuts



REC. 709 Color Space

- Broadcast TV, Blu-ray, OTT

P3 Color Space

- Digital Cinema
- Coming to TVs
- White point varies…

Rec. 2020 Color Space

- New standard for UltraHD TVs
- Achievable (mostly) on laser projection
- Currently used as a container

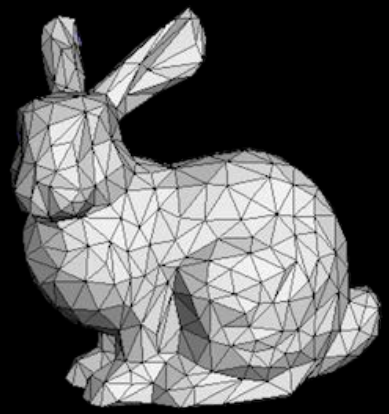
technicolor

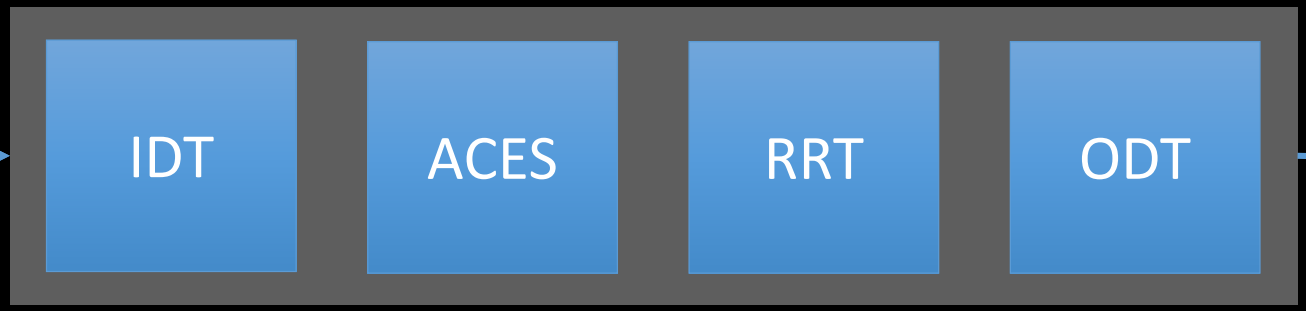
HDR Capable Workflow – Post-Production

- HDR requires changes to the workflows used in post production
- Academy of Motion Picture Arts and Sciences (AMPAS) creates **ACES**
  - **A**cademy **C**olor **E**ncoding **S**ystem
  - New color management and image interchange system
  - Well suited for HDR & Wide gamut content
- Encoded in 16bit half-float EXR format

ACES

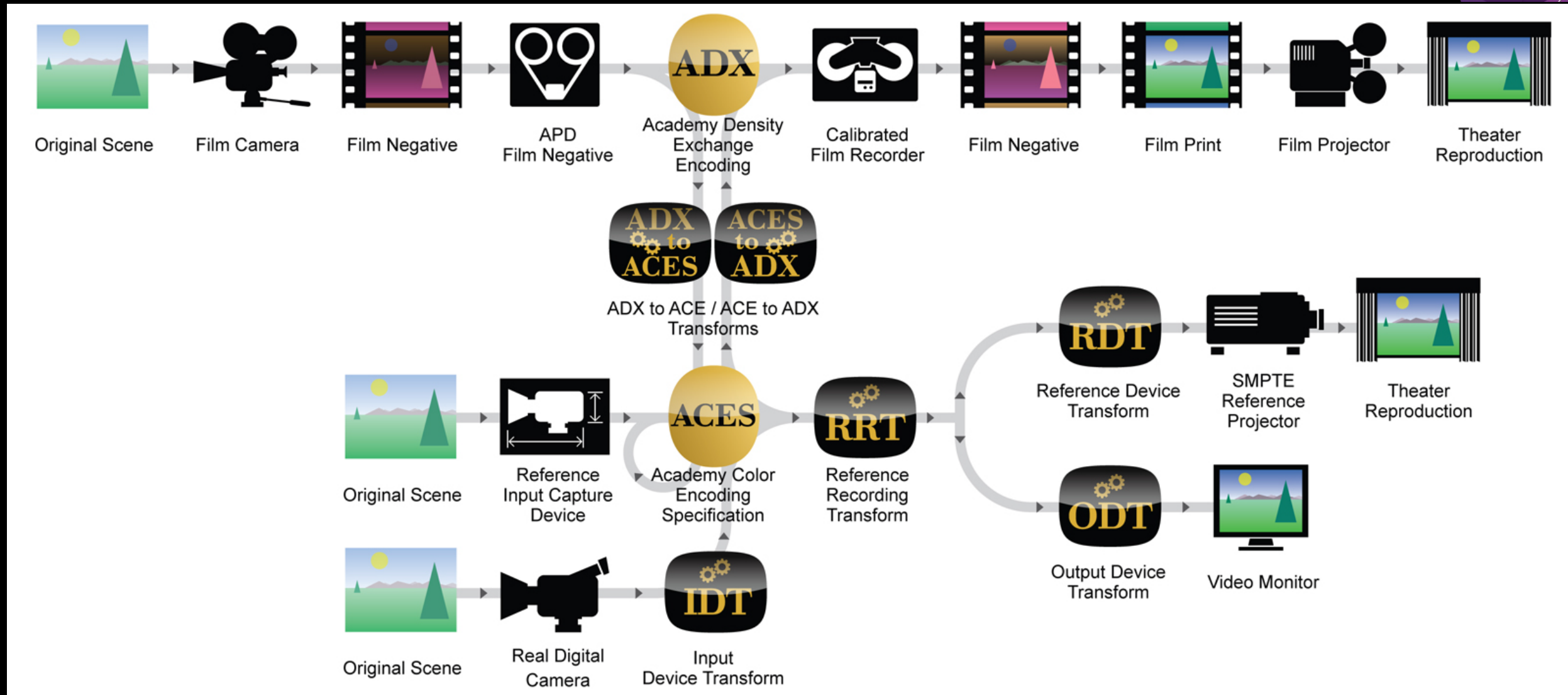
- Workflow overview:





IDT: Input Device Transform
RRT: Reference Rendering Transform
ODT: Output Device (Color) Transform

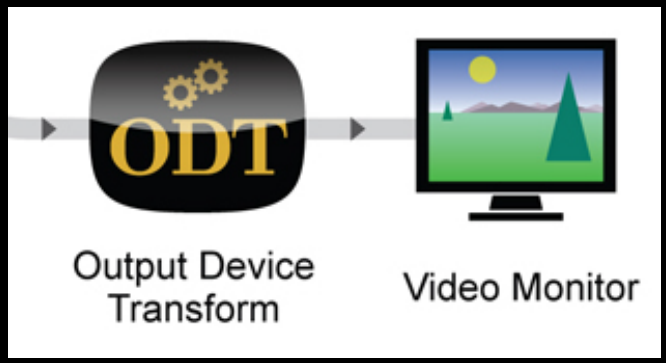
ACES Idealized Block Diagram



ACES

- HDR ODTs recently added to ACES
- Targeting specific display luminance levels

- ODT.Academy.P3D60_PQ_**1000**nits.a1.0.0.ctl
- ODT.Academy.P3D60_PQ_**2000**nits.a1.0.0.ctl
- ODT.Academy.P3D60_PQ_**4000**nits.a1.0.0.ctl



HDR Challenges

- HDR can give more creative freedom
- But it also brings new challenges

- We discuss a few based on experience:

1) Fatigue **vs** Wow factor
2) How to use extra dynamic range
3) Noise amplification
4) Clipping

Part IV: Conclusions - Q&A