4K Primer

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4K is a part of our world. It's already very common in production as a shooting format, and it's now available for recording on your cell phone, or delivery to your home- 4K content can be screened from NetFlix, Hulu, Amazon, YouTube, BellMedia, and Rogers, among many others.

4K provides production opportunities which are useful even in HDTV production. Shoot a larger frame for Pan and Scan effects, or shoot broader dynamic range (more highlight and shadow detail) than would ever be possible with HDTV cameras.

4K cameras and television sets can now be found which are comparably priced to HD sets. Manufacturers are reducing the number of HD sets they make, preferring to concentrate on fewer, newer models. The end of manufacturing for HDTV display units is imminent.

This is not to say that most broadcasters will be delivering 4K in the next year, but what it does mean is at the very least, you're going to have to deal with this format internally. Media from independent productions, as well as user generated content originating from cell phones and personal cameras is increasingly going to be in the 4K format.

It's almost guaranteed that no matter what type of production you are currently doing, your next camera will be 4K capable. You will want to understand the format in order to take advantage of its capabilities, even if you still plan to downconvert to HD for distribution.

WHAT IS 4K?

HDTV contains a lot of legacy links to television as it was designed over 50 years ago. At that time we were using a cathode ray tube – CRT - and its limitations defined much of television for the next half century. These included:

- Colour Gamut limited to what a phosphor on a CRT would display
- Brightness limited by CRT, which was about 100 'nits'
- Small Screen sizes (poor spatial resolution)
- Lower frame rates (poor temporal resolution)
- Pixels were 'dumber', only able to encode a few colours and a low contrast (limited Dynamic Range and narrow colour gamut)

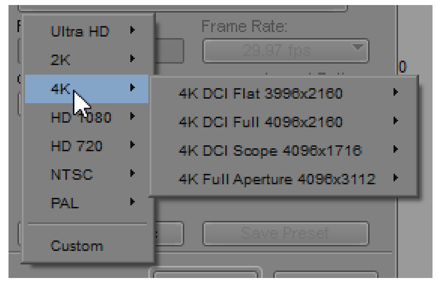
For many people 4K simply means more pixels on the screen. 4K does indeed offer a larger picture, but goes far beyond that. It overcomes many of the limitations of traditional television systems:

- Larger frame size – increased spatial resolution
- Higher frame rates – increased temporal resolution
- Better dynamic range - HDR
- Better colour - WCG
- Enhanced production techniques

Higher Spatial Resolution

CINEMA 4K

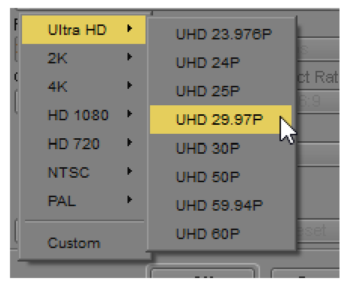
4K itself comes in many different frame sizes. True 4K was developed primarily for cinema. Most of the cinema 4K sizes have a width of 4096 pixels. They do however have different picture heights to accommodate the various aspect ratios required for cinematic production. This is why a true 4K format is not described by its width, such as '4096'. This would not allow you to differentiate between the multiple versions of 4K. Instead, it is described by its height, '2160p' or '3112p' .



A current Avid editing system supports the cinematic resolutions for 4K shown at the right (Media Composer 8.6.3).

BROADCAST 4K: UHD

The 4K that is viewed in your home is not one of the frame sizes we just discussed. For compatibility, it was decided that home 4K would be twice the width and height of High Definition. This maintains the 16 x 9 aspect ratio, and makes the frame size compatible with legacy content displays and other devices.



Broadcast 4K actually has a frame size of 3840 x 2160 pixels. To try and help avoid confusion it's referred to specifically as UHD, which stands for Ultra High Definition. Occasionally, particularly at Sony, it is called QFHD, for Quad Full HD.

Notice when selecting a project on the Avid editing system no frame sizes are shown, because UHD is always the same frame size. The choice you have is between varying frame rates only.

BROADCAST 8K: UHD-2

The term UHD is also used to describe an image with a frame size which is 8192 pixels in width, and 4320 pixels in height, at up to 120 frames per second. This format is currently in development, and has been successfully demonstrated at recent tradeshows for both recording and broadcast. NHK of Japan shot 8K at the Rio Olympics to demonstrate its viability.

While 8K sets are not currently available for home use, in the future they may very well be. To avoid confusion, this format is referred to as UHD – 2.

WHAT DOES THE LARGER FRAME SIZE MEAN?

The larger frame size of course means new cameras, new codecs, new displays, new workflows and much more. For entertainment programming it also means a new experience for the viewer at home.

The larger screen the size changes a few things for the home viewer. They can sit closer to their TV now without being able to see the individual pixels. If they do this, the screen will fill the wider angle of their field of view. More information, more detail, and more realistic images will be presented to their retina.

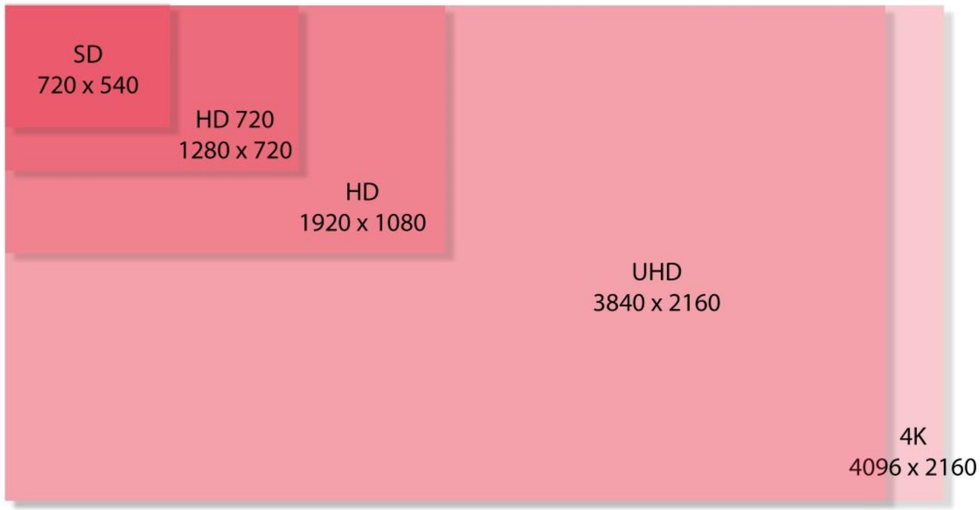
Assuming the viewer takes advantage of the closer seating (or buys a larger display to achieve the same effect), the screen is going to fill a much larger proportion of their field of view. An HDTV fills 1/3 of the users field of view. A UHD TV set will fill 2/3 of their field of view. This changes the experience dramatically, as the peripheral vision now comes into play. Viewers will also now have to turn their head to see different parts of the image on the screen.

There are many other differences in perception as well. An object on a screen this size will move further per frame than on the smaller screen. This means that smooth motion will require higher frame rates.

	SD	**HD**	**UHD**
Viewing distance, in picture heights	6 x	3 x	1.5 x
Field of View degrees at this distance	15	30	60
Portion of visual field covered	1/6	1/3	2/3
Pixels per degree on retina of viewer	30	60	120

The point of this discussion is that we are not just looking at a larger frame size. For entertainment programming when the viewer is sitting at the recommended viewing distance, the experience and realism of the picture can be significantly greater than with any other home imaging technology that was previously available.

If they don’t sit closer to a UHD set, the viewer will not be able to appreciate the benefits of the increased resolution.



	TYPE	COMMON USAGE	FRAME SIZE	ASPECT RATIO (approx., HD as reference)
HD	Home Distribution	TV Broadcast	1920 x 1080	16 : 9
4K	DCI Flat (Digital Cinema Initiatives)	Production and Digital Cinema format	3996 x 2160	1.85 : 1
	DCI Full (Digital Cinema Initiatives)		4096 x 2160	16 : 9
	DCI Scope (Digital Cinema Initiatives)		4096 x 1716	2.39 : 1
	DCI Full Aperture (Digital Cinema Initiatives)	Digital Intermediates Master	4096 x 3112	1.32 : 1
UHD - 1 Ultra High Definition	Home Distribution	TV Broadcast	3840 x 2160	16 : 9

A CAUTIONARY TALE

Possibly the most important thing to take from this discussion is that 4K is not the format for broadcast television. Broadcast television is ***UHD*** format. A lot of footage is being shot at 4K when it's intended for a UHD Broadcast production. This means the footage must be distorted slightly, or resampled to fill the UHD frame. This is of course tremendously inefficient.

For UHD broadcast programs, we should be very clear about this in the entire production chain. For example to avoid confusion we should ask the camera operators to set their cameras up for UHD, not for 4K. While the terms are often used interchangeably, they are not the same.

Higher frame rates HFR

Higher temporal resolution

All 4K video is progressive. There is no interlace, and there are no fields.

Our nominal 30 frame HDTV actually updated the picture 60 times a second as there were two fields per frame. Since this does not occur in 4K, a frame rate of 60 progressive frames per second are required to deliver the same degree of motion updating. It surprises some people to learn that this is happening already with home delivery. BellMedia Fibe delivers 60 frames per second with their 4K service.

Currently, a lot of 4K production is still being shot at 23.98 or 29.97 frames per second. This produces media which is compatible with our current North American HDTV distribution. It also requires only a fraction of the media storage, bandwidth and computational power that would be required to produce broadcast content at the higher frame rates.

Some broadcasters have multiple tiers of 4K production. The lowest tier will accept these conventional (lower) frame rates, while the higher profile and higher quality productions will require 50 or 60 progressive frames per second.

It’s worth keeping in mind that if the viewer is watching the 4K presentation at the recommended viewing distance moving objects are traveling a greater distance than they would be if the same image were being watched on an HDTV screen. Smooth motion in 4K will require higher frame rates to overcome this issue.

Preserving more shadow and highlight detail

The difference between the brightest to the darkest tone which can be recorded is often referred to as the dynamic range of the image.

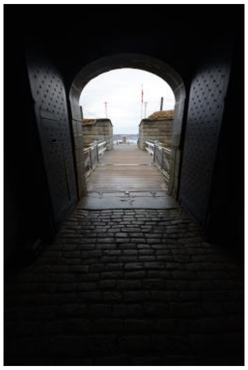
There are many ways to measure the dynamic range of the system. One of them is to state its capacity in terms of photographic f-stops. UHD systems, being the newest on the market, are capable of recording a higher dynamic range than previous TV systems.

	PLATFORM	f-stops of Dynamic Range
SDR	*Conventional* 8 bit TV	6
Print	High Quality printed material	7
SDR	*Professional* 10 bit TV	10
HDR	UHD Camera recording capability	Black Magic Elmira 12 stops Arri Alexa, Sony FS7 – 14 stops Arri Amira 15 Sony F65 16
HUMAN	Human eye looking at a scene	14

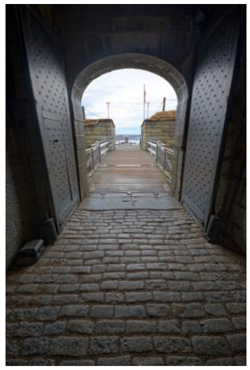
NOT NECESSARILY A BRIGHTER PICTURE

At this point it is worth clarifying that the previous table shows the dynamic range which can be captured by the imaging device. While a UHD camera may see 14 stops worth of dynamic range, this is certainly beyond the capability of most display devices, and indeed beyond the range of most recording systems to record and reproduce.

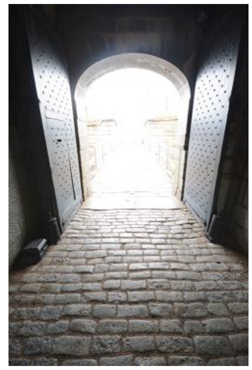
HDR means the image presented can combine and display a broader range of tones than an alternative system of lower capability can. The extended dynamic range from the capture device is mapped to a display device which doesn't have the same dynamic range as was contained in the original scene. HDR means a larger range of tones from the real world have been scaled down to a range which can be displayed on a typical UHD set.



BRIGHT part of scene recorded on an SD system



Bright and Dark scaled to fit in one image on an HDR system



DARK part of scene recorded on an SD system

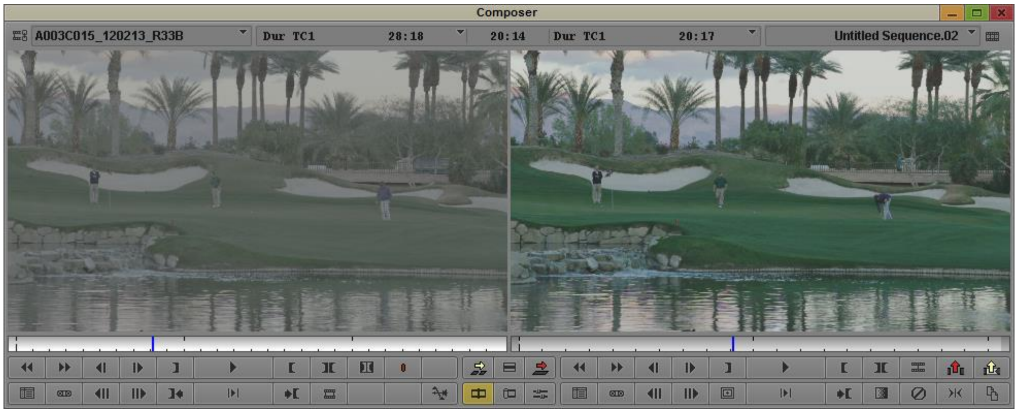
HDR is often confused with brightness and contrast. HDR on its own does not mean a new display device for the viewer which has brighter whites and darker blacks. Instead, the HDR involves scaling a broad brightness range into a smaller range which can be displayed on a device with less dynamic range than the original scene contains.

GAMMA CURVES TO CAPTURE THE INCREASED DYNAMIC RANGE

How are these 14 stops worth of detail shrunk so they can be displayed on a system with less than 14 stops worth of dynamic range, like a UHD monitor?

The recording is made non-linearly onto the record medium. This has always happened in television. A gamma curve is applied at the camera to allow it to record more of the pictures dynamic range without clipping. Simply stated, you might think of it as the signal being scaled down to fit the record media.

If you look at an HDR recorded image, it typically looks flat and lacking in contrast. The image is not supposed to be viewed in this state, it is supposed to be restored to something closer to the original scene through the application of a correcting adjustment on playback. A correcting curve, sometimes referred to as a colour transformation, is applied. In Media Composer, this addition may be done using SOURCE SETTINGS dialogue.



Original Recording (left) **and after correct Colour Transform applied (Right)**

The curves we are talking about are selectable at the time of recording. Different manufacturers offer different curves, or may offer several to give you different looks or to favour the preferential recording of certain tonal ranges in the image. Some common curves include:

- Common TV Gamma, which has always been used
- HYPER GAMMA which 'compresses' more of the highlights
- Sony S-Gamut3.Cine / S-Log3
- Canon C-Log
- Arri Alexa LogC

GETTING THE BENEFIT OF HIGHER DYNAMIC RANGE

If you want an image which is more filmic, more realistic, containing detail in a larger range of tones, then you need to record using one of the logarithmic curves to preserve the detail which the CCD camera is capable of detecting.

Recording with a log curve is not without its issues. These include the fact that the camera output, even a viewfinder, must have a colour transform applied to it for the image to approach looking normal. You must also change your exposure methodology. A typical camera 'zebra pattern' exposure guide will need to be set at different levels depending on the log curve you are using. A search of the literature and reading the manual is certainly in order.

I LIED: IT *IS* ABOUT A BRIGHTER PICTURE and BLACKER BLACKS

While HDR itself is not really all about giving the viewer a brighter picture on the monitor, this is in fact one of the benefits of UHD TV. Brightness is measured in the unit called ‘nits’, and even without defining it we can use it as a relative unit of measure.

A classic film projector image has a brightness of 48 nits. A legacy CRT television can have a brightness of 120 nits. The brightest conventional UHD sets are approaching 1,000 nits. By comparison the brightness of daylight is 10,000 nits.

A brighter image has more implications than you might initially imagine. For example, it affects our perception of flicker rate (flicker fusion), motion smoothness, picture depth and sharpness as well.

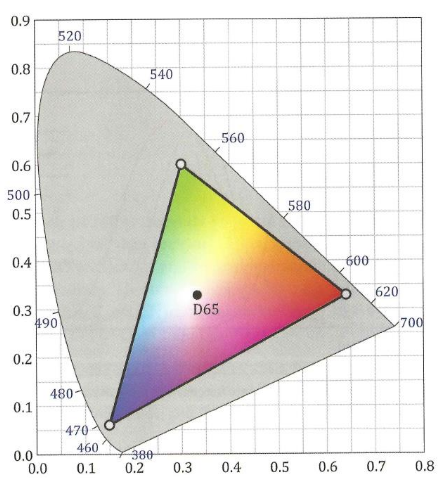
Wide Colour Gamut

Most of our current recording systems are nowhere near being able to reproduce all the colours which can be seen by the human eye. In the charts below the gray blob represents the colours which can be observed by a typical person.

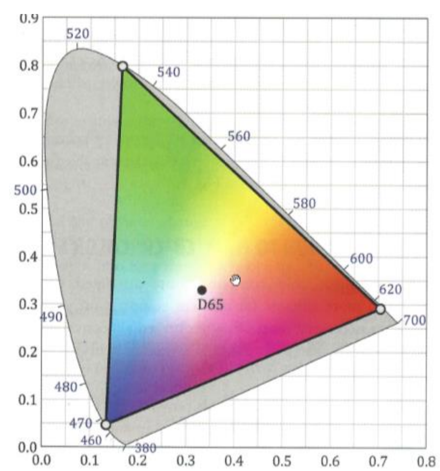
On the left we see the subset of colours which can be recorded and reproduced by a conventional television system. These represent only about one third of the colours which we can perceive.

On the right we see the subset of colours which are recorded using a new wide colour gamut standard. This represents closer to two thirds of the colours which we can perceive

It's clear to see that the new UHD wide colour gamut standard is going to increase substantially the number of colours available for the program creator as well as the audience.



Conventional TV
BT.709



UHD
BT.2020

COLOUR MANAGEMENT

It surprised me that the most challenging aspect of UHD was not the frame size or frame rate, but colour management. There are so many aspects that must be managed it's easy to become confused and make a mistake.

Colour may be considered and managed by breaking down production into three separate phases:

- Capture
- Editing
- Delivery

At each phase, decisions are going to be made that affect the dynamic range and the colours in the final product. In all cases, a much better result will be achieved if you record in a 10 bit or higher codec, rather than a traditional 8 bit codec.

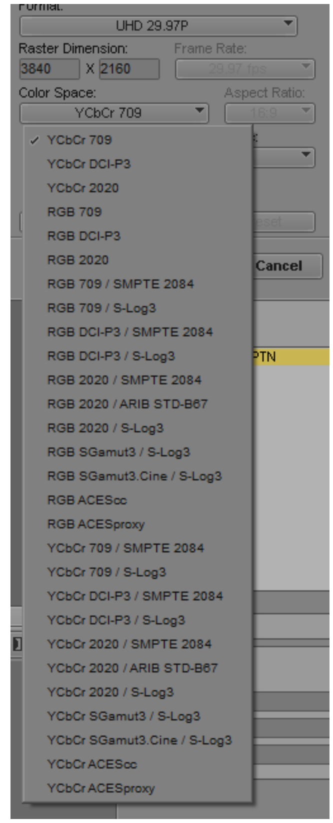
CAPTURE

To provide what is arguably a better picture for the audience, at the time of shooting you might choose to use one of the log curves available on your camera. Only by using one of these curves can you indeed preserve the higher dynamic range of the scene you are shooting.

Using one of these curves results in the recording of an image which appears gray, and significantly lacking in contrast. This presents challenges for production on set, as the camera output and viewfinder must be properly set up to show what the final image might look like after it's corrected in post. Adjustments must be made in the exposure of the scene.

I have found the biggest challenge to be however that if the camera (log) curve is used on the set this information is not always correctly communicated to the post department. I've seen numerous instances of editors trying to correct log footage while having to guess at how it was initially recorded. For fast turnaround, editors will want to apply a colour transformation to the footage as a starting point, but won't know with certainty which one to apply.

EDITING



There are two new steps which must be undertaken in the editing of a UHD production. First the nature of the footage itself must be correctly identified, and the correct look applied as a starting point.

Before this can happen, the editor must make a project which has the appropriate colour space for the project they are creating.

The colour space you choose will be used for all the video recording, calculations and display.

For broadcast television currently, one of the '709' choices is traditionally the best one. While it offers maximum compatibility with the current system, it incorporates all the limitations of the legacy television system.

If you were trying to produce an HDR project, a program which did indeed have an extended dynamic range for the audience and a wider colour gamut, you might choose one of the '2020' options which offer the expanded range which we just talked about.

DELIVERY

The delivery format you choose may require a different choice to be made.

For example you may export UHD master using the YCbCr 2020 colour space, and perform a second export to a codec which uses the YCbCr 709 colour space for HDTV delivery. (Note some productions would manually recolour for each colour space – called a "trim" pass)

It would not be unusual to create your production using one of the newer wider colour spaces, to gain accuracy and better control during the post production process. You might then convert and adjust the delivery masters using colour spaces of 'lesser quality' which would still have benefited from your high quality post production process.

TERMS

AVC H.264	**A**dvanced **V**ideo **C**oding
HDR	High Dynamic Range
HEVC H.265	**H**igh **E**fficiency **V**ideo **C**oding is used for transmission of 4K
HFR	High Frame Rate
UHD	Ultra High Definition
WCG	Wide Colour Gamut