

## Root6 Tech Breakfast – July 2015

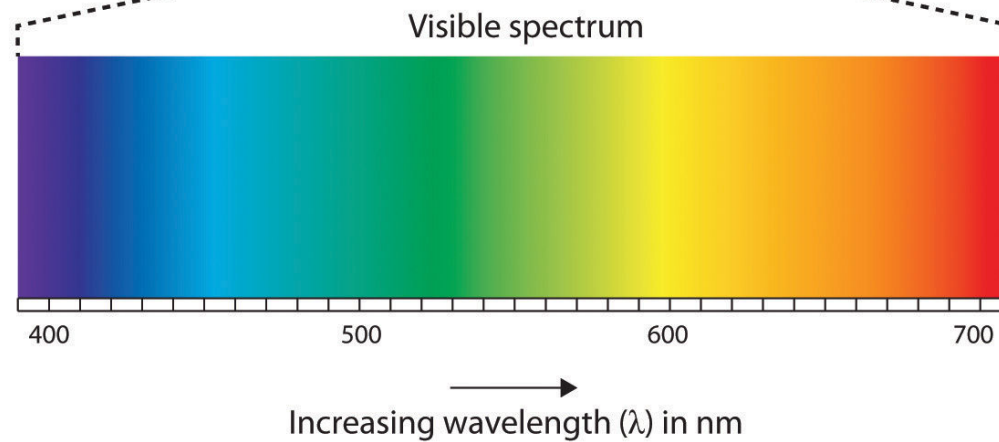
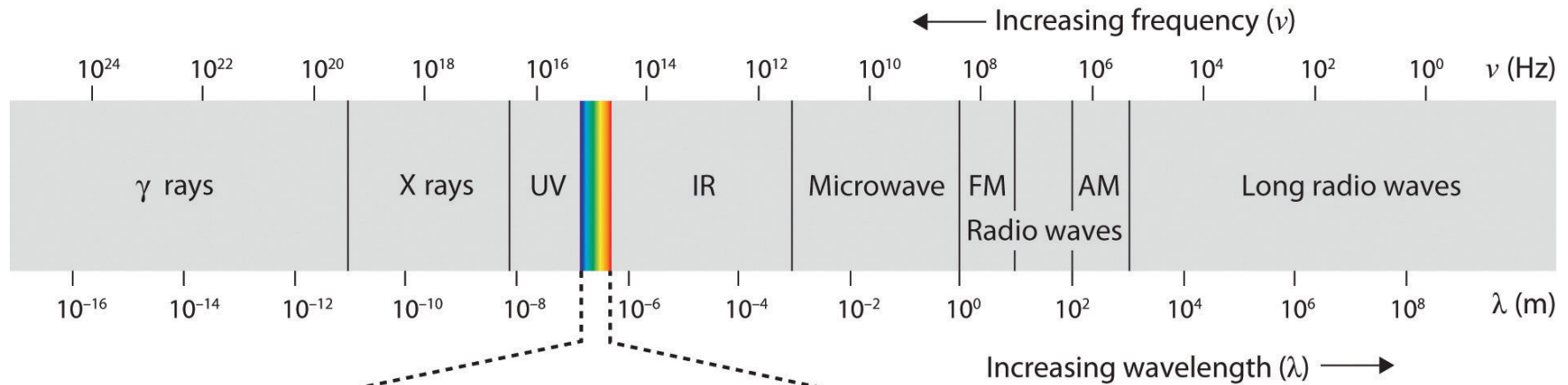
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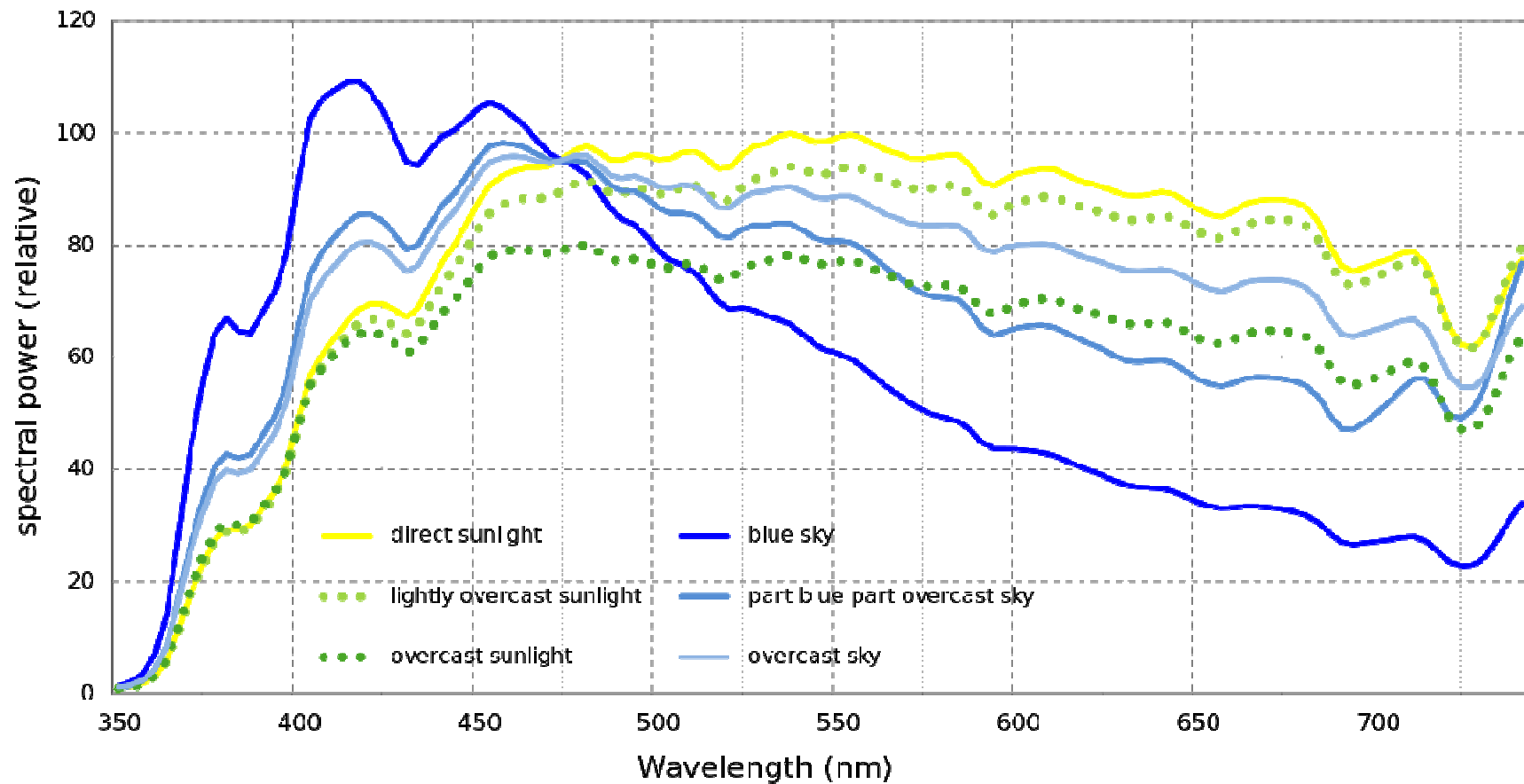
### Colourimetry, Calibration and Monitoring

- Colour – models of human vision
- How they translate to Film and TV
- How we calibrate and why it's important
- How metamerism affects choice of probes
- Current state of broadcast monitors
- Boland and their offerings

## The Nature of light



## Spectrum of sunlight at sea level

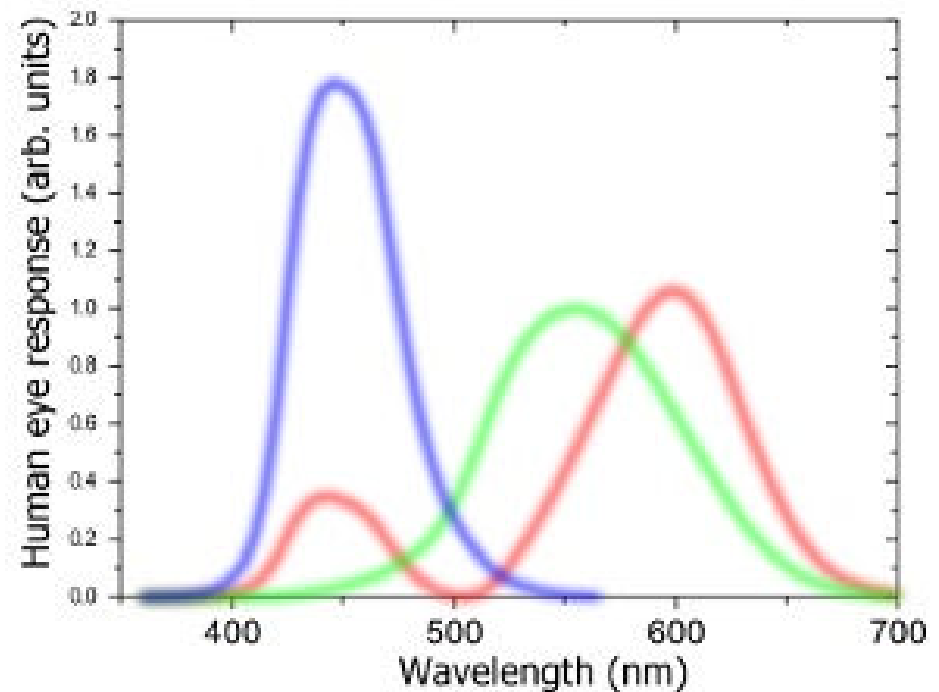


## Perception

- Human vision is a 'tri-stimulus' system
- We perceive overall light level via our eye's 'rods'
- We perceive red, green and blue colour via our eye's 'cones'

Diagram shows the relative response of the cones and reveals that all the intermediate colours have to be "filled in" by your brain.

Looking at the diagram and thinking about combinations of Red, Green & Blue you can see that some colours could "fall between the cracks" – this is called **Observer Metameristic Failure** or more likely **Metamerism**.



## Metamerism and colour

The upshot of all of this is that we have different metameristic failures between different display technologies; CRTs (which with the benefit of history have had the chemistry of their phosphors refined to match human vision quite well), LCDs, plasma and projectors (of various flavours) all have different tri-stimulus RGB curves (all differing by different degrees to your eye and hence 'scaled' to try and best fit). It's amazing they can be made to produce any kind of colour fidelity!

## Colour Constancy

Edwin Land showed that colour is almost entirely relative. The paint on the back wall of the edit suite is as important as the colour on the monitor.

*In this image 2<sup>nd</sup> card from the left (pink) is **exactly the same colour** in both images.*



## Colour Systems

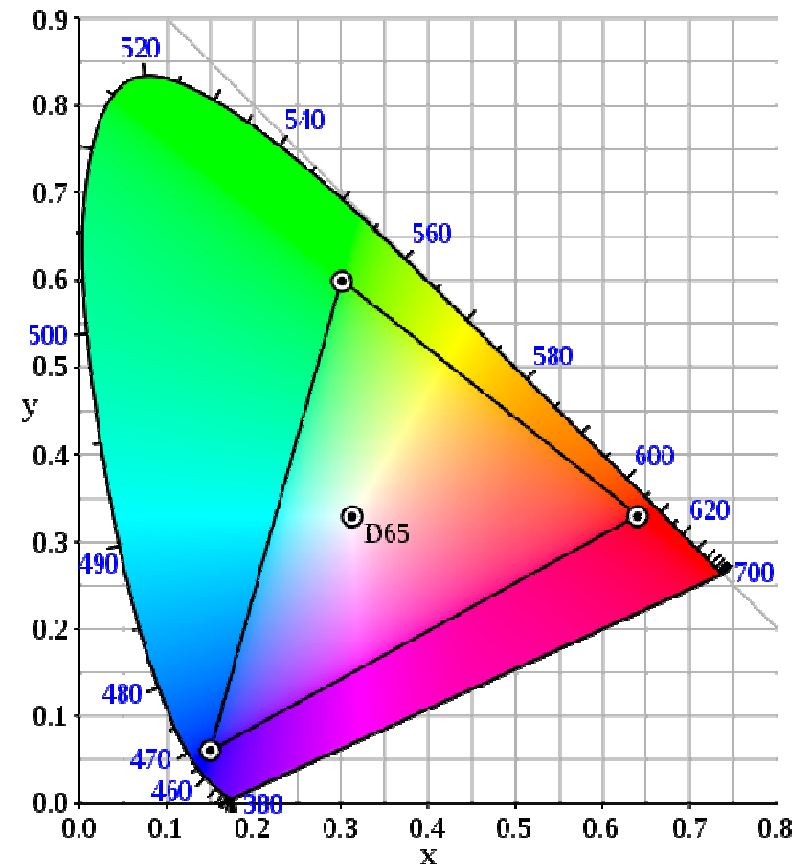
The range of visible wavelengths (380 – 700nm) runs from ultra-violet through to infra-red. The much-smaller range of colours that a TV camera can capture are shown.

The range of display'able colours is referred to as the 'gamut' of the system.

D65 is the 'colour of white' that we use for TV.

*Russian speakers & tetrachomats*

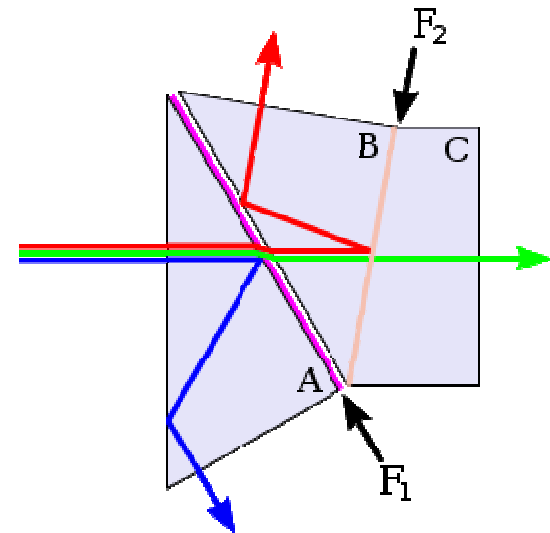
LightSpaceCMS is the standard software people use for managing colour in TV facilities.



## Colour Systems

### Image acquisition

- All devices that make pictures (TV camera, Telecine machine, computer graphics workstation etc) make pictures as three monochrome images; Red, Green, and Blue.
- This mimics the way the eye works, 'tristimulus'
- In the case of a TV camera this is achieved with a specially designed glass component referred to as a 'dichroic block'



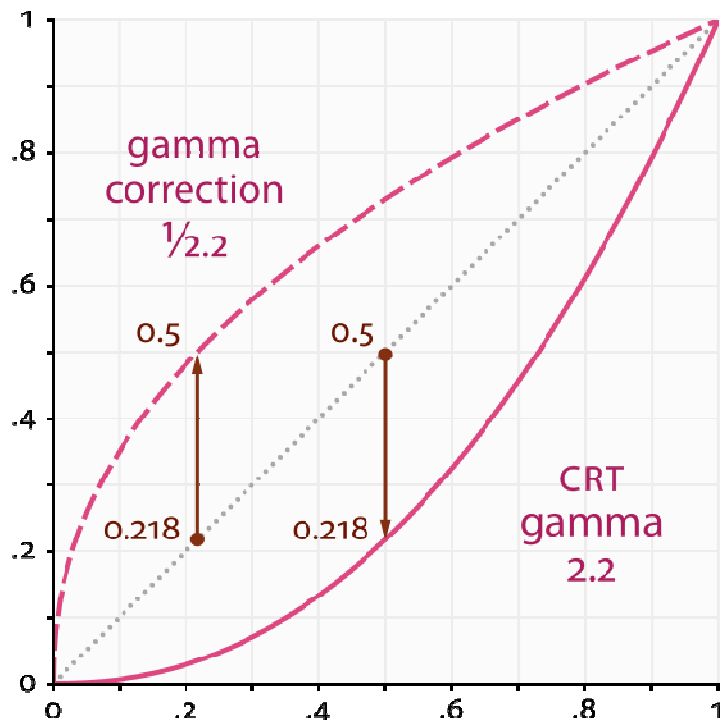
Original Image.



Image when separated into RGB components.

## Gamma

The relationship between the amount of light entering the camera and the R, G, & B signals is not a linear relationship.



- This was a function of how old tube-based TVs worked
- Some disagreement over constant luminance
- Some benefit from "concentrating" digital ranges in the blacks
- Still used everywhere in TV.
- Rec.601 (standard def) defines a gamma of 2.2,
- Rec.709 (high def rasters) only defines the camera's gamma – NOT display; 2.2 to 2.4 used,
- **2.35** most often used in general HD TV work.

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Linear encoding $V_S =$	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
Linear intensity $I =$	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0



## Gamma for TV cont.

The new BT.1886 specification (from 2011) is complex and its precise recommendations vary depending upon the white level, and especially the black level, of the display.

$$V = \begin{cases} 4.500L & L < 0.018 \\ 1.099L^{0.45} - 0.099 & L \geq 0.018 \end{cases}$$

However, if you don't want to bother with a precise BT.1886 calculation a 'best approximation' of this would be a gamma of 2.2 in the low end of the curve rising to a gamma of 2.4 at the high end. In fact it's worse than that - it's linear for the first 10% of the range.

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*The intended appearance for an HD master is obtained through a 2.4-power function, to a display having reference white at 100 Cd/m<sup>2</sup> – but that appearance will not be faithfully presented in different conditions!*

- Charles Poynton

## Calibrating Monitors for TV use

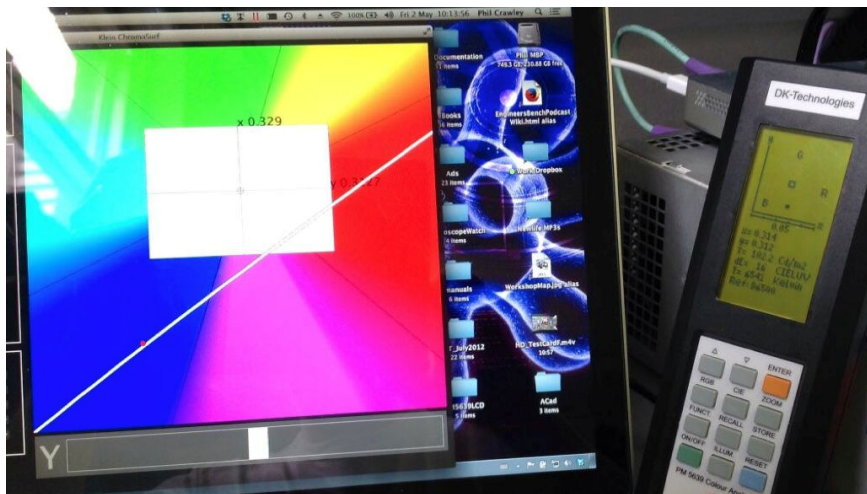
1. Set the overall black level using PLUGE so that dark areas of the picture are faithfully reproduced.
2. Set the peak-white of the monitor to around **80Cd/m<sup>2</sup>**
3. Check the colour of the white point so that it sits as near to **6504 kelvins** as possible
4. Check the 10% grey point for the same colour; track up to peak white and ensure the colour temperature remains constant
5. Check the saturation by putting the monitor into blue-check mode and match the blue coming through the luminance path to the blue coming via the C<sub>b</sub> channel.
6. Go back and do it all again as the controls interact somewhat.



## Calibrating Monitors for TV use; probes

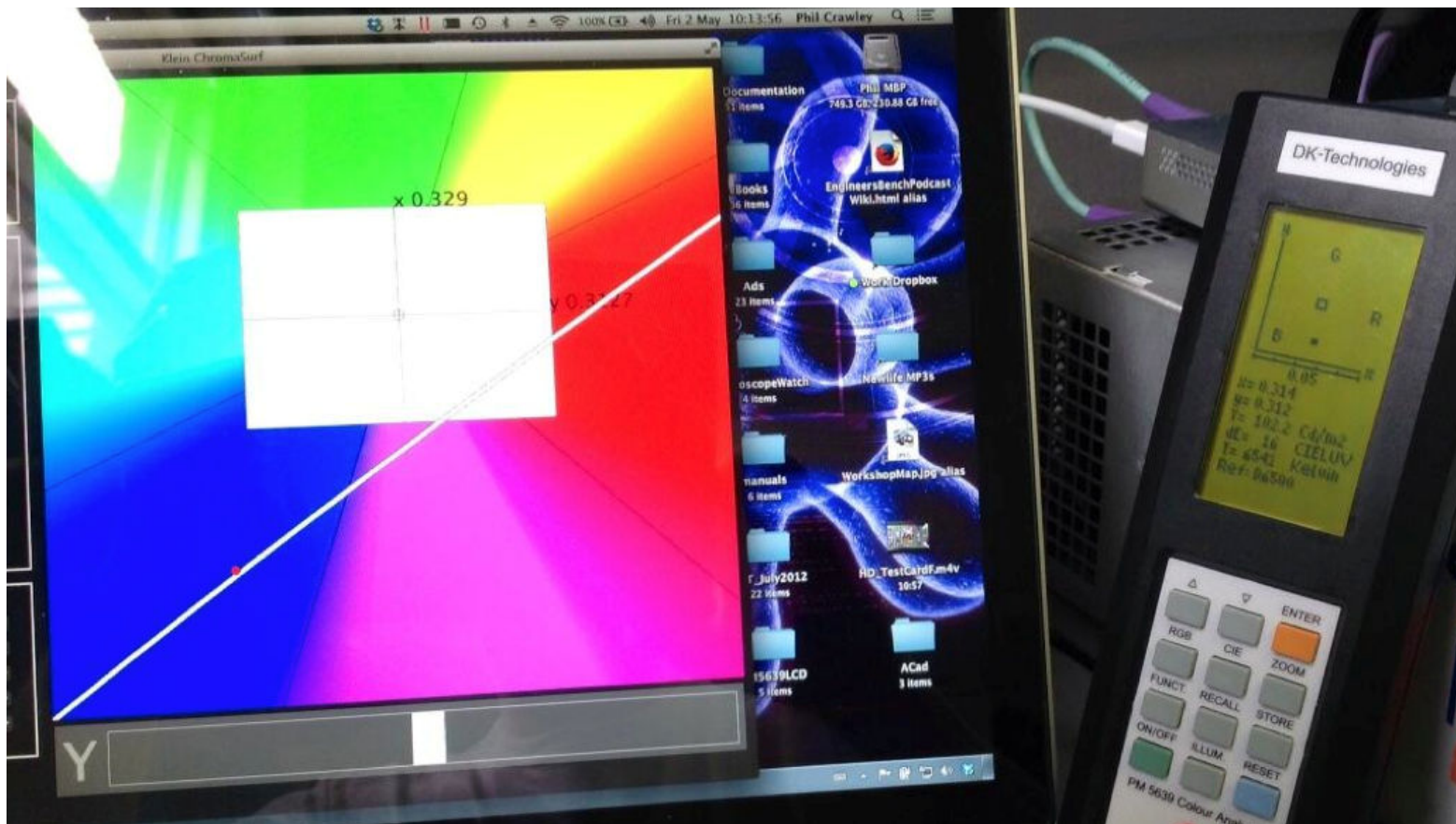
Despite what people think very few people have perfect colour memory and so to be able to calibrate a display you need a probe.

- Photometers – Tristimulus devices (like your eyes), sub £10k
- Spectralradiometers – wide-band devices > £20k for a good one!



**DK** - x:0.314, y:0.312, Y:102.2 Cd/m<sup>2</sup>

**Klein** - x:0.329, y:0.313, Y: 98.9 Cd/m<sup>2</sup>



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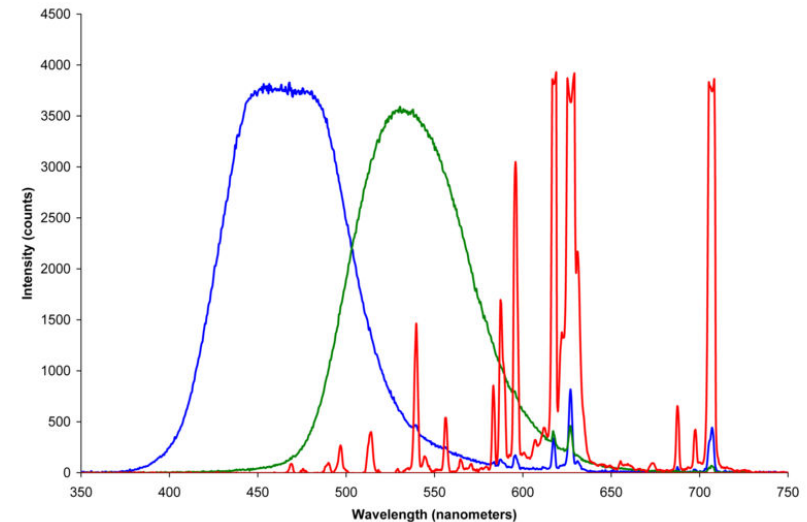
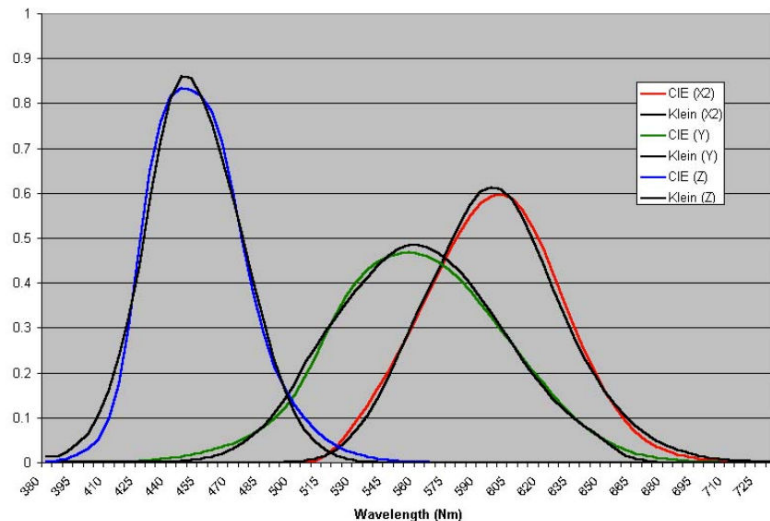
## Calibrating Monitors for TV use; probes

The traditional problem with Photometers is that they are matched to the spectrum of the display technology they are sold for.

*Response of the phosphors used in CRTs*

The eye's sensitivity curves for its three sensors X, Y and Z:

Klein Filters v.s. CIE



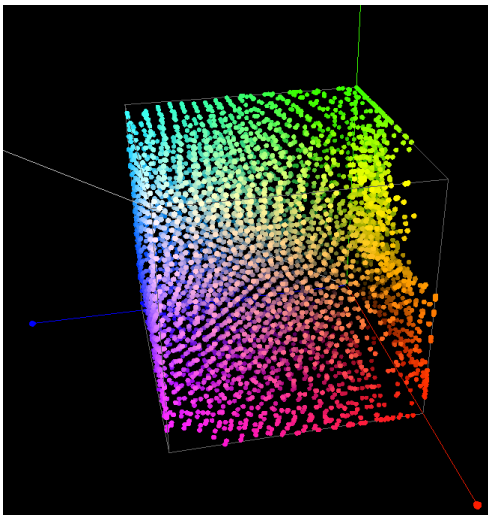
*Response of human vision overlaid with the response of a contemporary photometer (Klein KT10-A)*



## Using LUTs to tame domestic displays

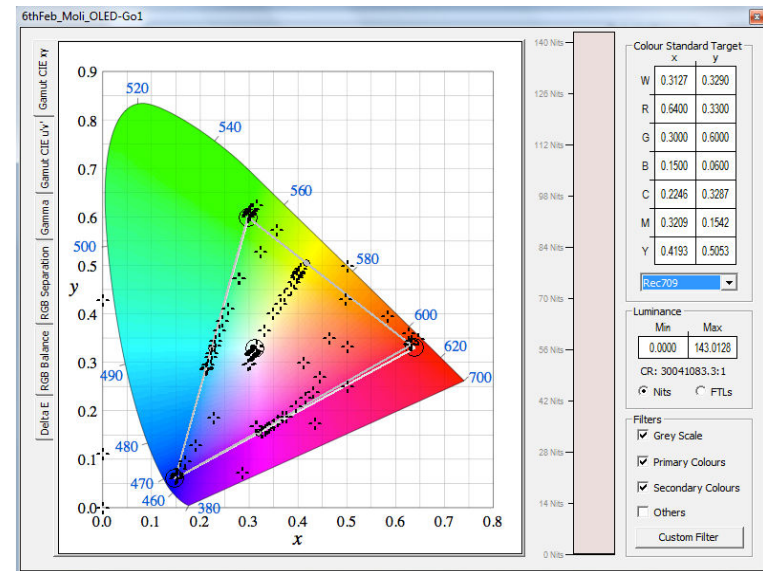
- LUTs have been used for a long time to make electronic displays emulate film stock
- A 1D LUT merely allows a set of transforms for the Red, Green and Blue values
- A 3D LUT allows the monitor to take account of the cross-talk between R, G, & B

The first step is to “profile” the monitor using a probe and a patch generator. This is the profile of an LG OLED.



*Profile transformed in a LUT*

- This is a 17-point LUT
- It reveals the inadequacy of the domestic TV
- Once loaded into the LUT box the display is a lot closer to Rec.709



## Colour channel linearity

Rec 709 states;

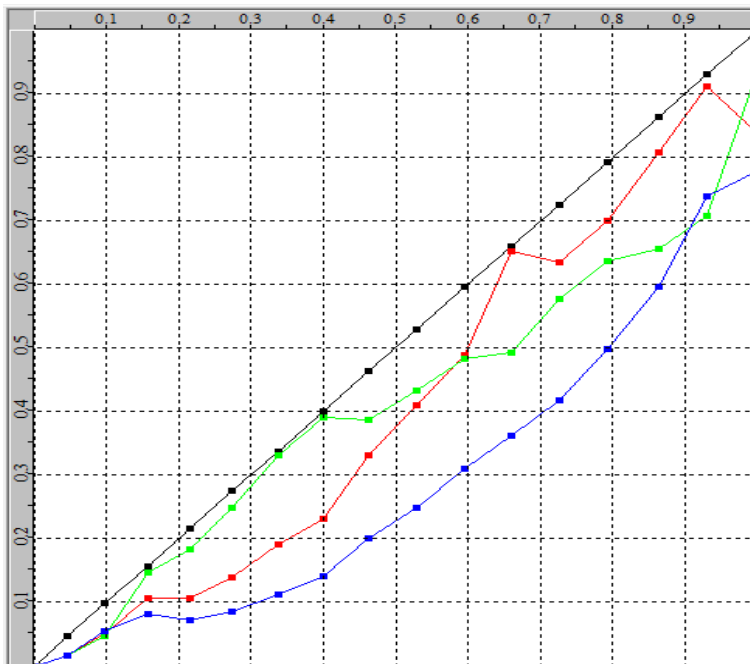
$$Y = 0.213R + 0.715G + 0.072B$$

$$C_b = 0.539(B-Y) + 350\text{mV}$$

$$C_r = 0.635(R-Y) + 350\text{mV}$$

So our greyscale fidelity is dependent on linearity in the luminance channel.

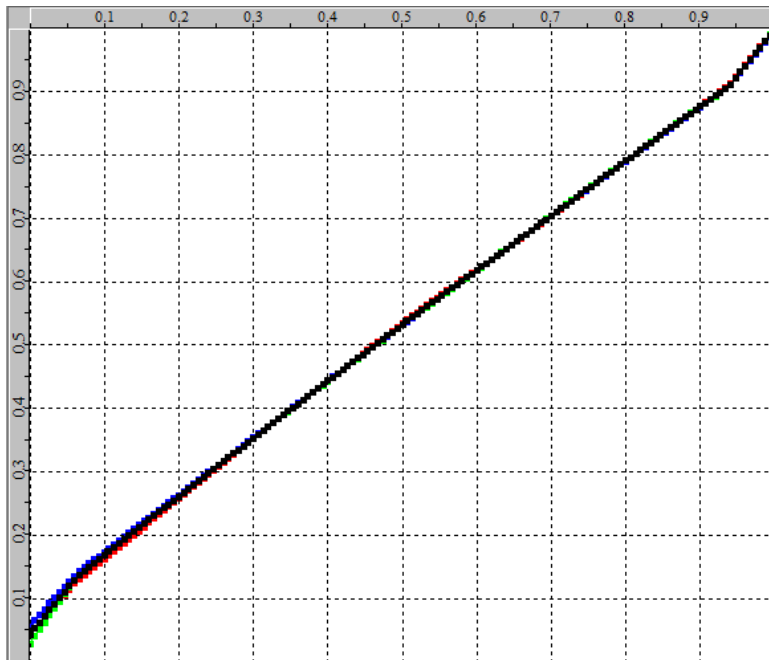
## Colour channel linearity



- Well known “broadcast” display(!)
- Blacks and whites converge but greyscale is poorly represented
- Greys are where colourists and clients look...



## Colour channel linearity



### **Boland BVB25**

- Full TV raster Grade-1 monitor
- >100% Rec709 colour space
- Excellent value next to Sony and Flanders OLEDs

## Boland

- California-based manufacturer of LED and OLED broadcast monitors
- Many years in the market supplying to US broadcast and industrial users
- Root6 appointed as the UK reseller.

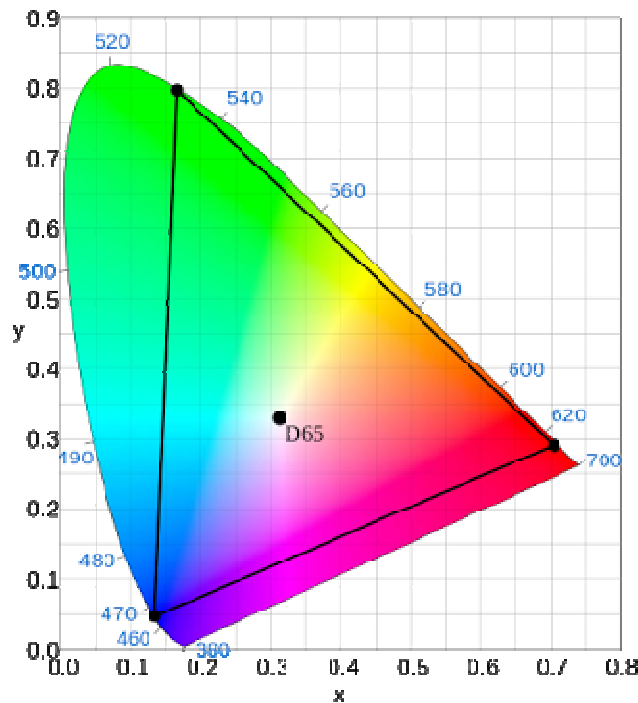
Products from on-set 7" LCDs to 84" 4k-native panels.

The model we have today is the edit-suite 25" OLED.



## The future!

ITU Rec.2020 is the document that covers 4k & 8K (AKA "UHD TV).



**The colour space is monstrous!** The 2020 triangle is even bigger than the P3 colour space (as defined by the DCI) - It'll be a while before ANY display device can faithfully reproduce that gamut.

red: 0.708, 0.292

green: 0.170, 0.797

blue: 0.131, 0.046

white: 0.3127, 0.3290

### The new luma transfer function

$$Y' = 0.2627 R + 0.6780 G + 0.0593 B$$

For the first time ever in television an allowance for *constant luminance* is included.

## Constant Luminance

Charles Poynton (who has forgotten more about colour than I know!) maintains that *even if gamma was needed* it should be applied to the luminance after matrixing the RGB values.

...in nonconstant luminance system some brightness information necessarily "leaks" into the colour difference components because of gamma, and the colour difference components reduce the bandwidth of the colour information. When this is done, the discarding of high spatial frequencies also discards high-frequency luminance "leakage" components in 4:2:2"

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However – imagine if we had another set of conversion consideration along with;

- R,G,B  $\leftrightarrow$  Y,  $C_r$ ,  $C_b$  – different matrices for 601 and 709
- Graphics full-levels & studio swing levels
- Different gammas (S-log, C-log etc) from CMOS-sensor cameras

So perhaps Poynton would be making an additional rod for our backs?!