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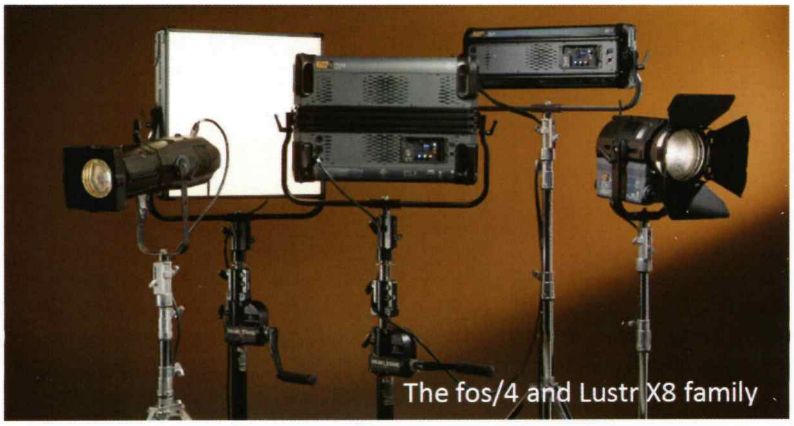
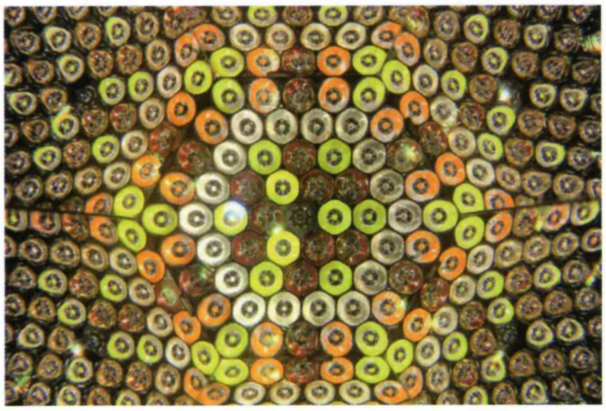
An Array of Choice

Getting the most out of your LED array: Part One of Two; Written by Declan Randall

IMAGINE
Imagine having the power to manipulate colour 'on the fly' – quickly and easily being able to tweak and adjust a colour to make the costumes 'pop', or the scenery really come to life, or adding just a little more life into skin tones.
It is a wonderfully exciting time to be working in lighting. Technology is such that we can do amazing things with light. While not a day goes by where I do not lament the slow demise of tungsten, LEDs have opened a world of possibility and creativity. Tungsten has been a stable and consistent light source for more than 60 years and it is certainly the light that I grew up with and is undoubtedly still the yard stick by which I measure and compare different light sources.
I love the warmth, its three-dimensionality, the way it envelops and sculpts a subject. But more than that, I like knowing exactly what I'll get. Comfortable. Familiar. Dependable. Tungsten is an old friend you've known for years.


The fos/4 and Lustr X8 family



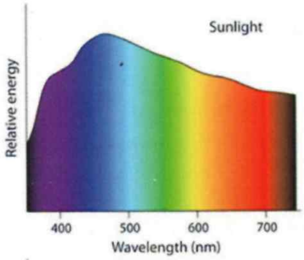
LED
And along comes LED. The new kid on the block. Like any newcomer to the neighbourhood, they are trying to fit in. After some hesitancy and reluctance on our part, the lighting community has welcomed them, and like any young child, it's been fun watching them grow up. I also think that I have tortured that metaphor enough now, so I will move on to the point of this article – taking a closer look at the LED arrays that we have available today and talking about why our choice of LED array is becoming more critical than ever.

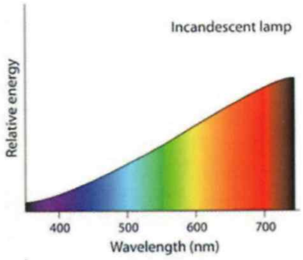
If we cast our minds back to the arrival of the high intensity LED in the marketplace, we started with the simplest array – RGB. The common red, green, blue array seemed to be a good starting point as it made use of the three primary colours of light and introduced additive color mixing into our world, bringing with it the advantages over the more conventional subtractive mixing we were all so familiar with. This system was not without its pitfalls of course, and it wasn't long before the RGB array was being expanded to include white, amber, lime and a host of other emitters too. But, first things first. Let's look at the LEDs that are commonly found in modern luminaires, why they are there, and how each of those different colours contributes to the overall spectrum and colour rendering properties of the light.

RGB
I think it's is important to clarify at this point that the 'B' in RGB is not actually 'blue'. It is in fact, indigo. A much richer and more saturated colour. The industry has widely elected to refer to this as blue, although technically this is incorrect.
The fos/4 and Lustr X8 family

An LED Array
The technical bit: The indigo emitter typically has a frequency of 450 nm and is a very efficient LED. It is this saturated indigo that enables us to mix the wonderfully rich magenta tones that only LED fixtures can

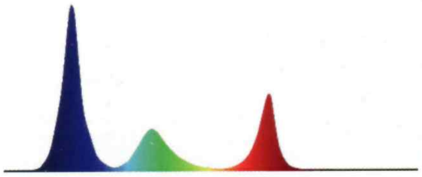
deliver. The major drawback with an RGI(B) array is that all the LEDs are narrow-band emitters. The red (630 - 640 nm), green (530 - 550 nm) and indigo (440 - 450 nm) are designed to emit light in specific frequency bands. So, while in theory it is possible to achieve any colour by mixing these colours additively, the reality is different.





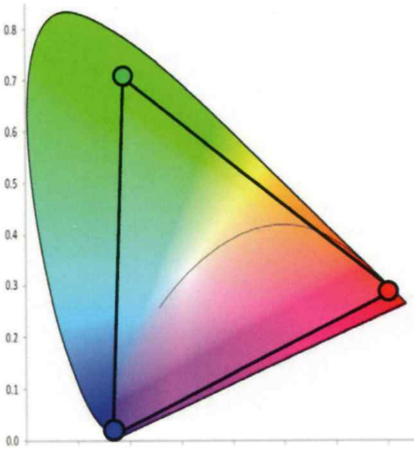
If we consider the Spectral Power Distribution (SPD) graphs for both sunlight and a tungsten lamp, we can see that both sources cover the full visible spectrum albeit with a bias towards the blue and red portions respectively. When comparing this to the SPD for a simple RGI(B) system, the missing portions of the spectrum become apparent.

The arty bit: If we were only projecting light onto a white surface, the RGI mix would suffice as these three colours provide enough spectral information to trick our eyes and brains into filling in the gaps.



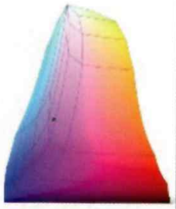
When it comes to lighting a cyclorama, an RGI fixture works, provided you are not too demanding on the precision of your colour. Of course, we tend to light surfaces and objects of complex colour and the RGI(B) LEDs are simply not capable of rendering these colours correctly due to the missing portions of the visible spectrum.

Looking at the chromaticity diagram (CIE 1931), we can plot the points on the scale where the RGI emitters land. By then connecting these points we create the gamut of colour that these emitters can produce. The fixture is only capable of producing colours that fall within this triangle. All other colours are considered 'out of gamut'.



While it appears that we are able to produce almost any colour, it is how this colour will render the lit objects that we should be concerned with – and the missing portions of the spectrum have a huge impact on how the light will be perceived.

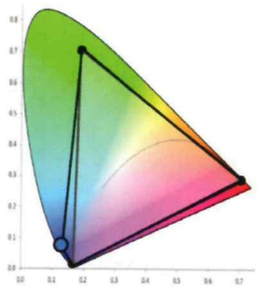
Enter broad-band emitters. LED technology is constantly developing, and phosphor-coated LEDs are common in all applications. It is this technology that allows for certain colours to exist – without phosphors, a white LED would simply not exist. Neither would the amber, lime, mint, cyan or any of the other colours of LED exist either. By including broad-band emitters in the LED array, we can include greater portions of the spectrum to the light source, meaning that it can render larger portions of the spectrum more accurately.



As we take a look at the different emitters used by different fixtures and manufacturers, we will also look at how these can contribute to the overall gamut and spectral power distribution (the technical bits) and also how these can help you to make beautiful lighting (the arty bits). Understanding how the different emitters contribute to the overall light quality will help to inform your choices when selecting luminaires for your next project.

BLUE
The arty bit: If we consider that most luminaires actually use the indigo emitter, then adding in a blue LED means that we are able to soften the colour mix slightly and make magentas and lavenders that do not have that almost ultraviolet zing to them, bringing the colours more in line with the subtle jewel tones that filters were traditionally able to create. If your application is for lighting cycloramas, then you might favour the indigo emitter as you will be able to achieve more saturated 'midnight blues', but some caution should be exercised here – overly saturated blues can be hard on an audience's eyes and will often not respond well on camera.

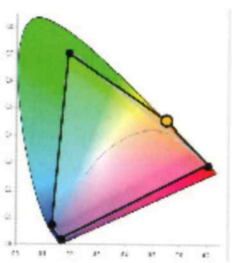
The technical bit: As we plot each new emitter point on the chromaticity diagram, we can see how the colour gamut increases with each new addition. The blue LED (460 - 485 nm) does not immediately appear to make a huge difference, but it is worth remembering that colour acts in a three-dimensional space and not the 2D space that the CIE graph shows. This graph represents the x and y co-ordinates to show a colour point but does not show the z axis, brightness.
The blue emitter also results in us

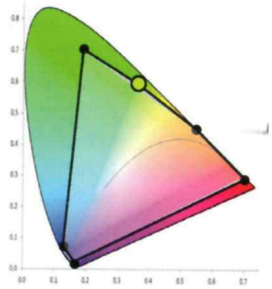


being able to achieve better whites without the strong presence of the over-saturated indigo. This emitter helps to achieve cleaner whites at the higher end of the colour temperature scale.

AMBER
The technical bit: The amber LED (600 - 615 nm) is a broad-band emitter and in addition to adding nuance to the colour mix, it contributes greatly to the adjustment of colour temperature. The grey curved line shown on the CIE graph represents the blackbody locus – the curve that shows colour temperature. The addition of the amber emitter has greatly increased the CT gamut making it easier to mimic the lower, warmer colour temperatures.

As you can see in the SPD, the amber emitter covers a broad portion of the spectrum. It is this wide band that increases the colour gamut and allows a greater range within the blackbody curve.
The arty bit: If you know that you need to recreate the effect of fire- or candlelight, choosing a fixture that has amber as part of the array is essential. While you can arguably mix the same amber tones using just the red and green emitters, this will result in a light that is not very realistic due to the green content in the mix. The amber will also contribute to your being able to create beautiful sunrises and sunsets by giving you the finer control over the colour temperature you need when trying to emulate the light nature provides for us. It also allows for the more subtle mixing of yellows, ambers and yellow-greens.



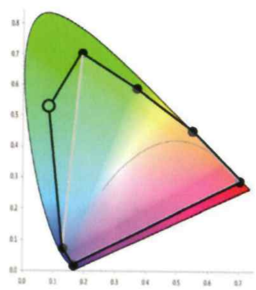


LIME
The technical bit: The lime LED (550 - 560 nm) is extremely efficient and as its frequency aligns with our eye's peak sensitivity, it contributes significantly to the overall output of the luminaire. The lime emitter is a wonderfully broad-band emitter that fills in a large portion of the (previously) missing spectrum.

While on the CIE graph it appears to not make a significant difference, the impact on the z-axis (brightness) is huge. ETC were the first manufacturer to introduce the lime emitter in an entertainment fixture (Source Four LED Series 2 Lustr) in 2014 and its impact on the spectrum and colour rendering properties of the light were phenomenal.

The arty bit: The lime can be a tricky colour to work with, so having a console that understands this emitter and its contribution to the mix is certainly going to be helpful. I find adding the lime to almost any colour that I mix, even at low intensities, adds an extra layer of depth and 'rounds out' the colour as it helps to soften some of the huge spikes that additive mixing with LEDs can cause.

CYAN
The number of fixtures that make use of this emitter are limited to a few manufacturers, but for work on camera or in instances where skin tone rendering is important, having this as a part of the array is definitely beneficial.

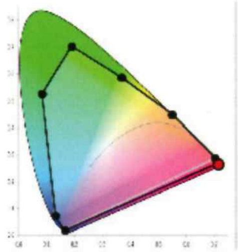


The technical bit: use of the cyan LED (500 - 525 nm) helps to widen the colour gamut even further and of all the emitters, the cyan is probably the one that makes the most significant improvement to the overall colour gamut.

The arty bit: This is a really useful addition to the LED array due not only to its contribution to the rendering of skin tones, but also to the depth it adds to the blues and greens. Your nighttime scenes and moonlight filtering through the leaves or in through the windows will take on a more lifelike quality.

DEEP RED

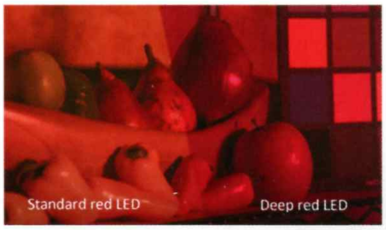
In early 2020, ETC introduced the deep red LED. This emitter fills in a missing portion of the spectrum allowing for richer ambers, oranges and reds, resulting in a wider colour gamut.

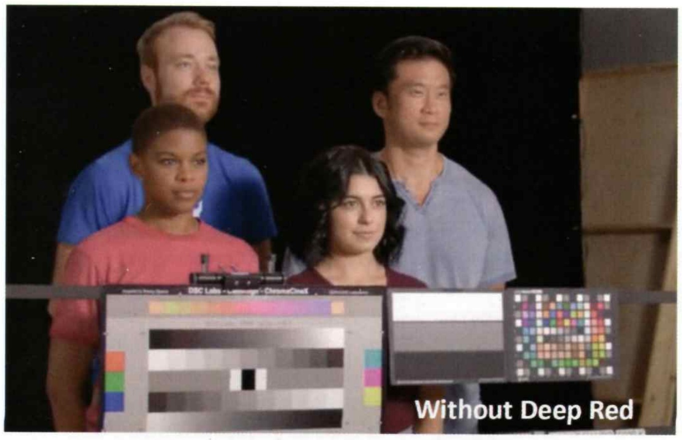


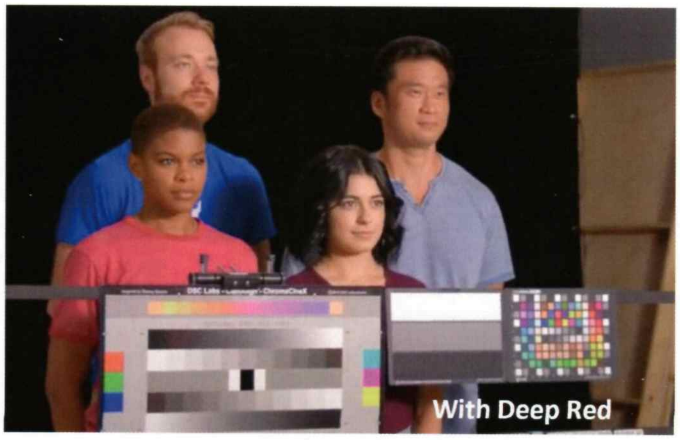
The technical bit: The deep red emitter (660 nm) widens the gamut even further. It is worth noting that although the apparent change to the gamut seems small, the actual contribution to the overall spectrum and rendering capabilities of the luminaire is huge. The deep red contributes significantly to the rendering of skin tones – across all ranges of skin tone, a universal skin-tone tool, if you will. The deep red makes the standard red look quite orange by comparison.

The arty bit: This is the colour you probably did not know you were missing. Recreating the light of the 'golden hour' is easier and made more realistic with the addition of a deep red emitter. Firelight, candlelight and low-level sunlight are all enhanced by this emitter. On its own, it is not terribly bright, but this does mean that you can layer it into most of your colours to get the reds to 'pop' without altering the colour point you have selected. If you are trying to emulate the characteristics of a tungsten source, then the deep red goes a long way to filling in the portions of the spectrum you have been missing to make this possible.

If you are working in film, the presence of the deep red rounds out the colour spectrum and provides a greater amount of digital lighting information at the time of shooting, meaning that you need to spend less time adjusting colours in post-production. The more digital information you have available at



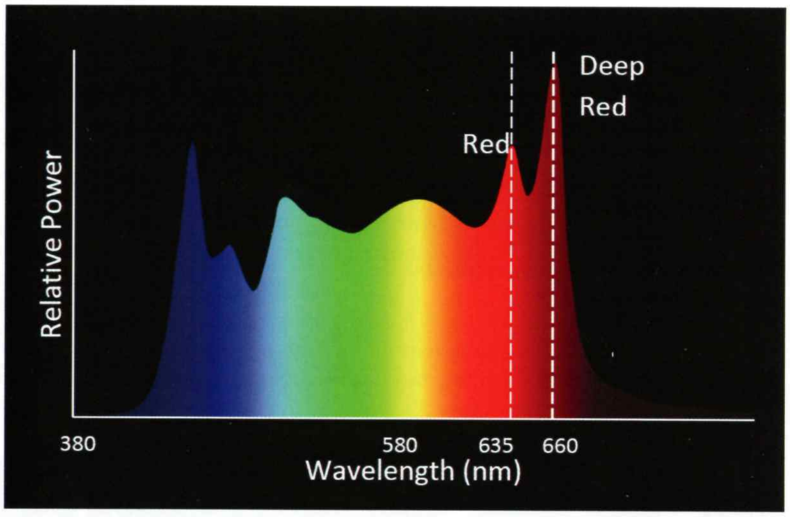


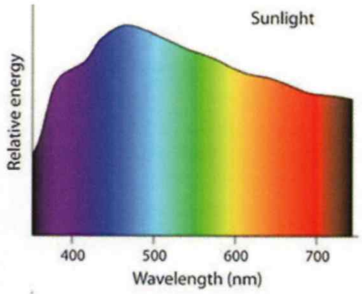


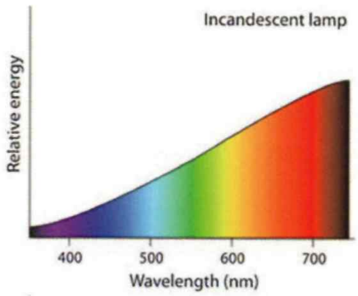
the time of recording means the more power and control you have over the manipulation of the colour and the rendering. Being able to have full colour control at the time of shooting can save you time and money by reducing the amount of post-production time required.

A tungsten lamp warms up as it dims down, resulting in portions of the visible spectrum that we have not been able to recreate accurately using LED until now. Tungsten sources have long been the preferred light when lighting actors as the natural bias towards the red portions of the spectrum are flattering for all skin tones. The inclusion of the deep red emitter brings back the vitality and depth to skin tones that have been missing in LED arrays.

Knowing how each of the different emitters can contribute to the light quality will help you to make an informed choice of fixture when planning your next project. Depending on your requirements, you may choose to favour one array over another. Ensuring that your selected fixture has at least some of the broad-band LEDs in its array will offer peace of mind that you will be able to achieve acceptable colour renders. They say: "less is more", but in the case of an LED array, if less was more, just imagine how much more "more" would be!







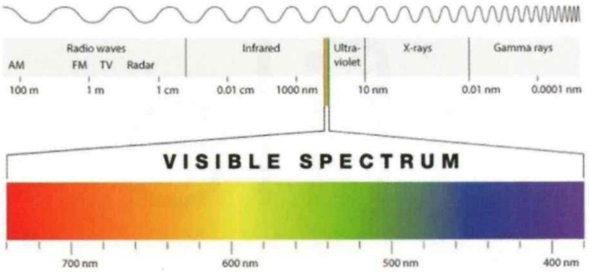
A WORD ON GAMUT

We have spoken about how the number of emitters impacts the gamut of the fixture – the range of colour that the luminaire is capable of reproducing. Another factor to consider is the gamut of the colour space you are working in. The most common colour spaces are the Kodak ProPhoto RGB, Rec.709 and Rec. 2020. The Rec.709 space is designed for use in HDTV and the Rec.2020 for use in UHDTV applications. Selecting fixtures capable of providing spectral content across the colour space you are using ensures you will be able to capture sufficient digital spectrometry to allow the colourists to grade the shoot more easily.

Kodak ProPhoto RGB

Rec. 709

Rec. 2020



A BIT ABOUT CHROMATICITY

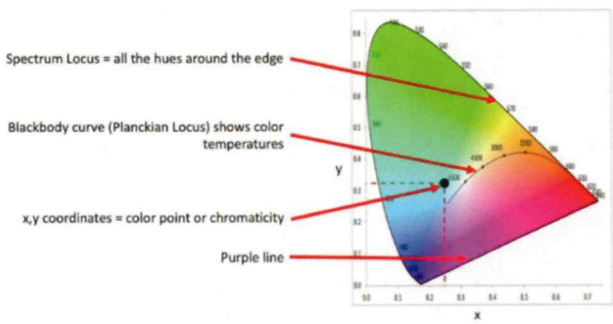
In the examples we have been using above, we have been referencing the CIE 1931 Chromaticity Diagram. What exactly is chromaticity? It's a technical term used to describe the 'colour' of a light source, independent of its intensity. A chromaticity diagram is a scientific map to unequivocally specify exactly which chromaticity, or colour point, is intended.

Let's break down a chromaticity diagram into its components. The CIE 1931 model is perhaps the most well-known as it represents the range of colour that the human eye can perceive, visible light occupying a narrow portion of the electromagnetic spectrum between 400 – 700nm. The horseshoe shaped border is called the Spectrum Locus and is created by plotting the chromaticity of each individual wavelength of the visible spectrum. This is where pure hues at full saturation are found.

The blackbody curve in the centre of the diagram, formally referred to as the Planckian Locus, shows where colour temperatures are plotted. See Colour Temperature in Part Two of this article.

The line on the bottom is called the Purple Line and is there simply to close the diagram. There are no purple wavelengths – this is a colour that is only possible to create through colour mixing.

By selecting colour anywhere in this space, you are effectively plotting an x and y coordinate in colour space. This defined point can then be interpreted by a lighting console or fixture to reproduce that colour in light, but remember that the diagram is for visual orientation purposes only and the background should not be expected to exactly match the appearance of colour emitted by the light source. And, this is only describing the overall colour. It is not describing how this colour is achieved in terms of spectral content or spectral power. We will circle back to these diagrams in part two, in the next issue of Set & Light.



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An Array **of Choice**

Getting the most out of your LED array – other options: Part Two of two.
Written by Declan Randall

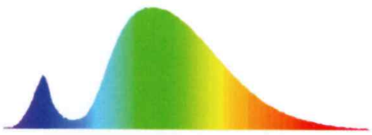
TUNABLE WHITE

"Well, having all these colours available is great," I hear your say, "but I spend most of my time just shifting between colour temperatures."

There are different ways to achieve 'tunable white' fixtures – some make use of an RGBW (RGB, white) LED array, others are simply a combination of warm white (WW) and cool white (CW) emitters, and there are some that include a blue and amber in addition to the white emitters. One of the drawbacks of CW and WW LEDs is that they are phosphor-coated, broad-band emitters and they all use a high intensity blue (indigo) LED as the 'pump'. This leads to a spike in the blue portion of the spectrum that can be hard to control.

The technical bit: Warm white and cool white LEDs use a tri-phosphor chemical composition to generate light, the large blue spike caused by the pump is still apparent – perhaps not the eye, but certainly on camera and to the way objects will render. Adding a filter to a WW or CW source will expose just how different the spectral range is.

> ***"...I spend most of my time just shifting between colour temperatures."***



MINT

There are LED arrays which use mint as one of the emitter options. The mint is also a broadband emitter that contributes to a wide colour temperature range as well as being able to easily pull saturated cooler colours into more pastel tones.

The technical bit: Mint's phosphor-converted broadband spectrum is really well suited to helping 'tune' whites to desired CCTs (Correlated Colour Temperatures) in the range of 1900 – 10000 K. When used in more complex colour arrays like ETC's Daylight HDR is allows for more control over the subtleties of the colour mix verus a simpler array like RGBW or RGBM. A complex array allows for easier adjustment of the green/magenta shift, something which is particularly useful for camera work.

The arty bit: Using RGBW arrays will give you different results as your source is making use of the narrow-band RGB emitters – the only broad-band emitter is white. The cyan, blue and mint emitters are all broad-band phosphor coated so you can be assured of a fuller-spectrum light source at any colour temperature, without any strange spectral shifts as you move through the range. The addition of the deep red means it is possible to more closely emulate the warmth and depth of tungsten that has not previously been possible.

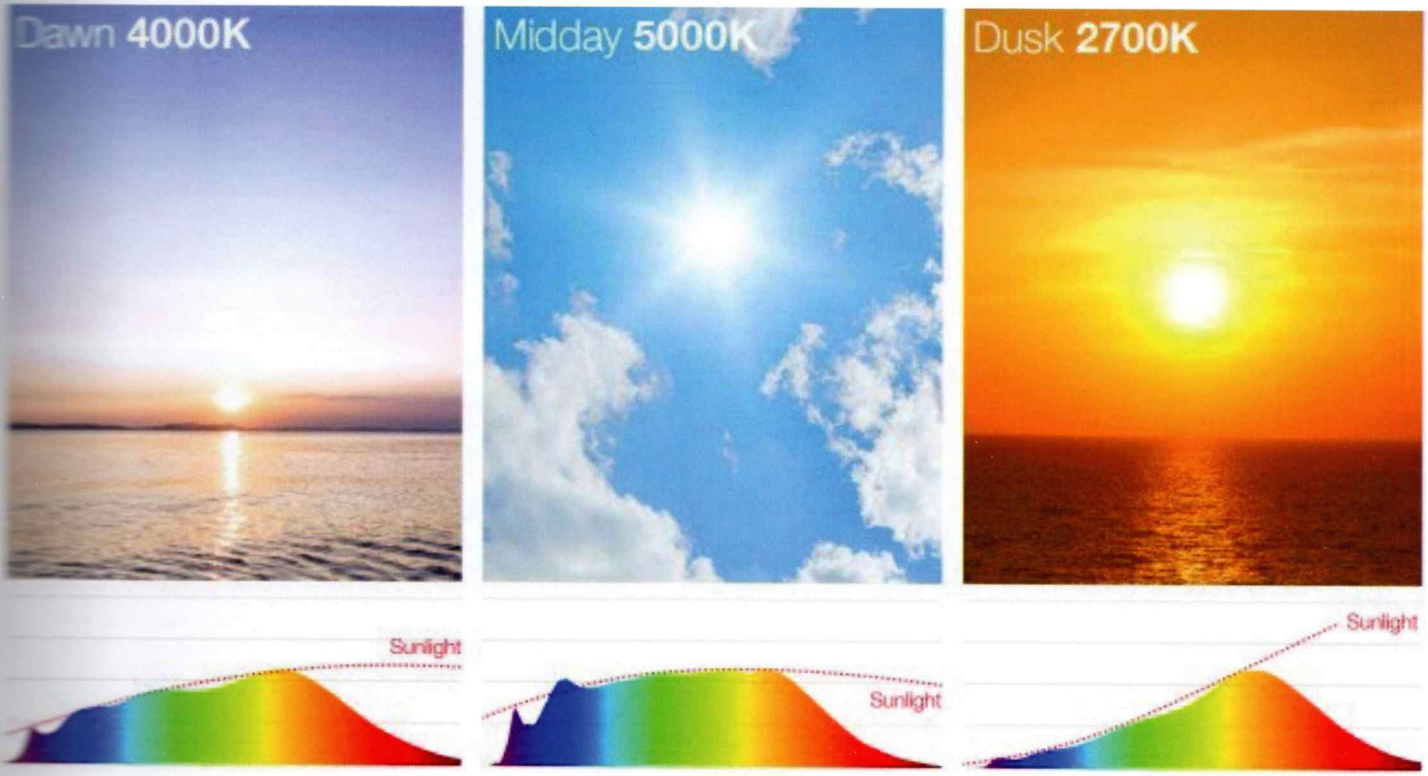
There is nothing wrong with fixtures that use differing combinations of emitters – the key lies in understanding how the resulting output may affect the colour rendering so that you can take the necessary steps to correct and adjust for these changes.

COLOUR TEMPERATURE

Colour temperature is a term that describes the 'colour' of a particular nominally white light source. Rather than using non-specific descriptors like warm, neutral or cool, colour temperature provides specific measurements, expressed in kelvin (K), to keep specifications, well... specific.

If you think of a steel rod in a furnace, as it heats up it starts to change colour, first red, then orange, to yellow, then white and then blue. This same principle is applied to colour temperature, except instead of a steel rod, we use a blackbody radiator. This is a 'theoretical blackbody" – it would not be physically possible to heat an object to infinity, so the theoretical model plus the wonders of maths give us our standardised reference scale. As the blackbody is heating up, the electromagnetic energy it is radiating is directly linked to and changing with its temperature. The corresponding chromaticities are plotted on a graph forming the blackbody locus or Planckian curve. The kelvin scale is used as this is an absolute thermodynamic temperature scale.

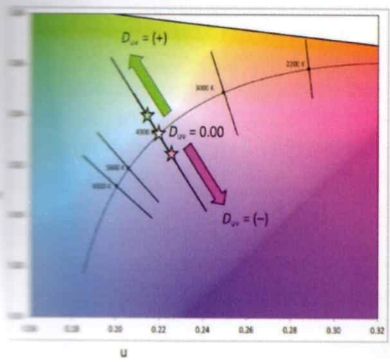
So, why is colour temperature important? We experience changes in colour temperature throughout the day as the sun rises and falls. Similarly, different light sources are thought of to be 'warm' or 'cool'



depending on their spectral content and how orange or blue they are.

No light source is a true colour temperature however. There are inherent deviations in the spectral content of different whites.

Enter CCT – Correlated Colour Temperature.



If a light source does not plot exactly on the blackbody curve, a perpendicular line is drawn from the source's chromaticity coordinates through the blackbody curve. Where they intersect is the correlated colour temperature. In reality, the light emitted by many luminaires doesn't plot directly on the blackbody. It plots a little above or below. Because that difference can be visually apparent, it is important to look at Duv values for any sources not sitting on the blackbody curve. Two sources could be 3500 K, but one might be a slightly pinky warm white while the other might be a yellowy/greenish warm white. If used in isolation these differences may not matter, but this difference will become apparent when viewed together. A positive Duv indicates a shift towards yellow/green and a negative Duv indicates a shift towards magenta.

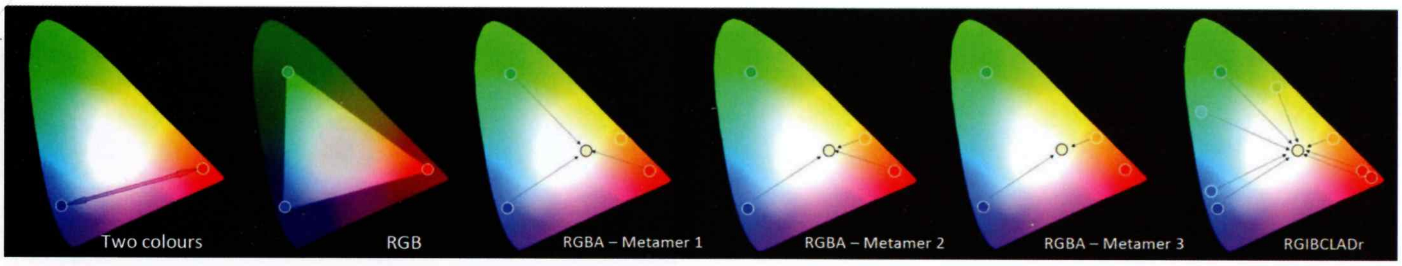
In this example, light from a 4100 K source with a positive Duv (when viewed by itself) will appear as neutral white.

Repeat that with a 4100 K source with a negative Duv and it too will appear neutral white.

When viewed together however, the difference is apparent and may not be desirable.

COLOUR MIXING

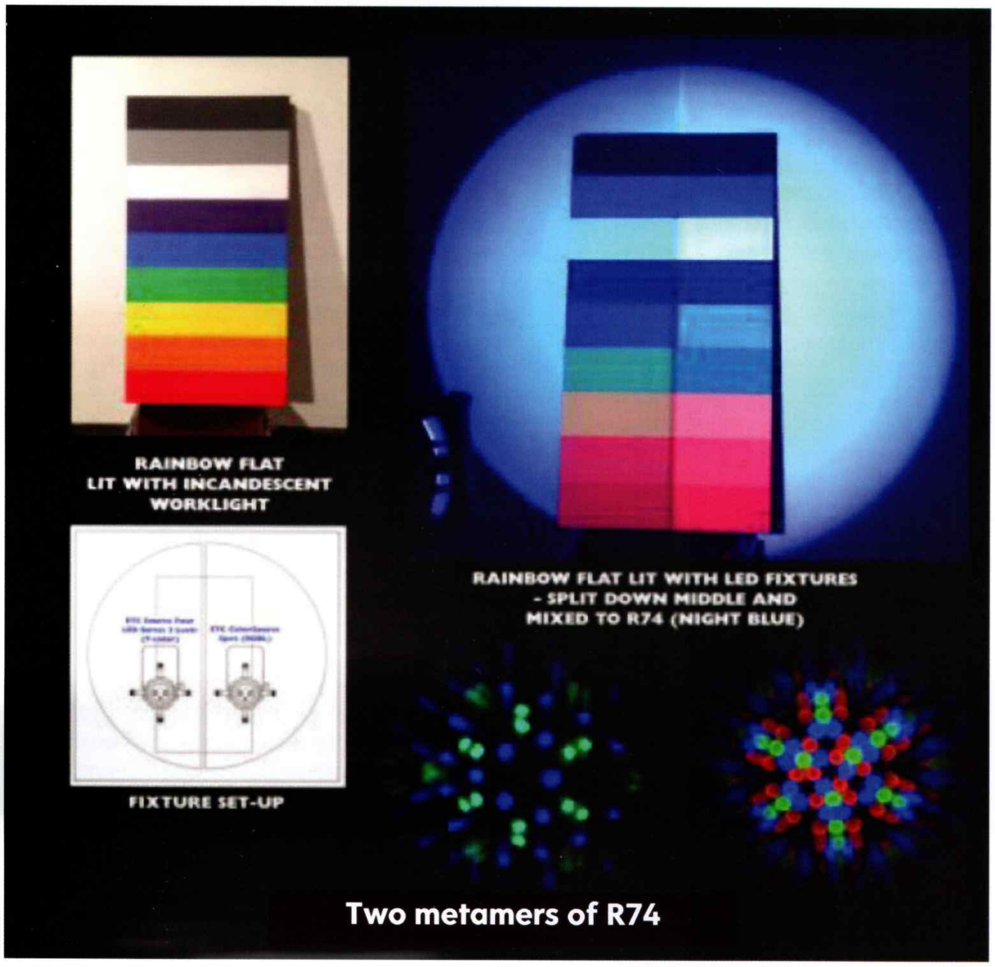
LED technology has changed the way we work and the way we need to think about light. Traditionally, we are used to starting with a full-spectrum light source (be it daylight or tungsten) and then we used filters to remove the portions of the spectrum we did not want. Moving lights made use of a subtractive CMY (cyan, magenta, yellow) colour mixing system. This process of adding filters to a white light source is familiar and comfortable – we've been doing it for years and have a good understanding of how it works. Additive colour mixing as a concept is not new to us either. When lighting cycloramas with flood battens, these were typically gelled in red, green, blue and either amber or white – but we were still essentially starting with a white source, filtering out portions of the spectrum and then using the remaining light in our additive mix.



LEDs are different. With an LED fixture, you are essentially starting with nothing and adding in the portions of the spectrum that you want, to arrive at the colour of your choosing. While this means you could be very precise in your colour mix, it does require that you add as many individual spectral components at your disposal as possible. The more of the spectrum you have available in your array the more spectral content there will be in your mixes and the more accurately the colours of the lit objects will render, both to the eye and to the camera.

COLOUR INTEGRITY

The ability to mix your favourite colour is one thing. Being assured that the colour you have chosen remains consistent and repeatable can be an entirely different matter. As an LED heats up, it becomes less efficient. A red emitter, for example, can lose up to 40% of its output as it heats up. This is a phenomenon known as "droop" (or "thermal droop") and it is something that all LEDs are affected by. To make matters worse, not all LEDs droop to the same extent. This loss of efficiency and output can have a huge impact on your chosen colour, output and spectral composition and has the potential to be disastrous and could lead to your colours not looking as expected. You do not want to have to worry about the potential difference in colour after a full eight hours of shooting versus the colour when the fixture is turned on in your first cue. Selecting fixtures that offer a degree of "droop compensation" may be important to you, depending on your application.



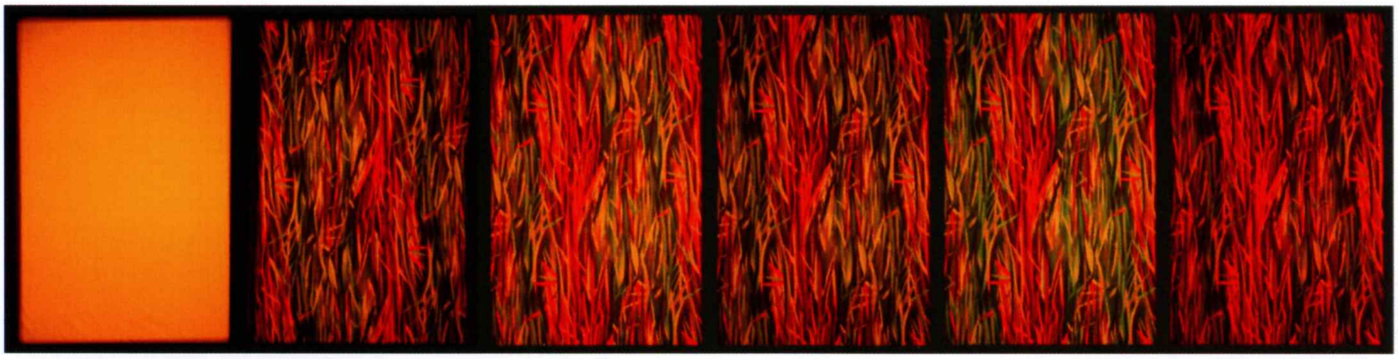
Two metamers of R74

CONTROL

Having luminaires with multiple emitters is hugely beneficial in terms of accurate colour rendering and digital spectrometry but ensuring that you have a means of control that enables all the benefits this system has to offer is equally as important, if not more so. If you only have two colours (plotted as points in an xy colour space), you can mix to any point in the colour space between those two points, but in a straight line only. When working in an RGB colour space, you can mix to any colour point within the triangle created between those three points, but there is only one possible combination of colours, or 'recipe' if you will, that will achieve that colour. The introduction of another emitter changes this. As soon as another colour is introduced, the number of possible 'recipes' increases – the more colours you add, the greater the number of recipes there are. These color recipes are known as "metamers" and each new metamer will have an impact on the way an object is rendered and therefore perceived by both the eye and the camera. The ability to fine-tune your colour at this granular level is a powerful tool and another of the aspects of LED lighting that I find so exciting.

The choice of metamer can radically alter the appearance of an object and a good understanding of metamer control is becoming essential in the world of LED lighting. In the example on the left, we show two metamers of R74. One metamer is offering the brightest version of that colour, the other a more spectrally accurate option. You may find that when you use a console's filter picker the colour does not necessarily render as you were expecting. One of the reasons for this could be the chosen metamer. As the designer, you may choose a version of that colour that is the brightest option, or a metamer that is a closer spectral match to the filter selected. You may opt for a hybrid metamer that lies in between.

Full X8 Array | Red, Indigo, Green | Red, Blue, Green | Indigo, Lime | Red, Blue, Cyan, Green | Blue, Amber, Cyan



Full X8 Array | Red, Green | Red, Amber, Green | Red, Amber, Lime | Amber, Red

In the first examples above, the rendered result of using different metamers becomes apparent. In the first example, there are 6 different "white" metamers – to the eye on a white surface, all the whites look the same even though they were 'constructed' in different ways. On a coloured surface, the differences in metamer become more obvious.

Similarly, we get different results when mixing different metamers for a more saturated colour. In the second example above, we used Lee 021 as the reference point and created different metamers to achieve the same colour, but with different results.

Basically, what I am saying here is that spectral content matters! The laws of reflection apply here too. To see an object as having a specific colour, that colour must be present in the spectrum of the light source hitting it so that it can be reflected towards our eyes. The same is true for camera sensors – the more digital content is present in the spectrum, the more information the camera will be able to capture, the easier it will be for the colourist to balance light and colour in post-production. That said, no two people see colour in the same way. Everyone's perception of colour is slightly different, so there are no hard and fast rules. Similarly, camera sensors are different too – each manufacturer has their own unique 'recipe' they use for their sensors – and you choose cameras based on these differences to get specific results.

Different white light metamers can make the timber surround feel cold and impersonal, or warm and inviting.

So, if spectral content matters and some emitters are only narrow-band, then why not only use broad-band emitters? Firstly, to have the power of metamer control, you need the differences in spectral content. If all emitters were broad-band, then there would be no saturation. It is also worth keeping in mind that the presence of a white emitter in an LED array does not increase the gamut of the fixture as the white point sits within the gamut created by the other emitters. The same can be said for the mint emitter. Their contribution to the array lies in saturation control as well as to the output of the fixture.

CIRCLING BACK TO CHROMATICITY

Throughout this article, we have referenced the CIE 1931 chromaticity diagrams. This was done for ease and because this is the diagram that is most familiar and is also often used when showing LED luminaire gamut. This diagram was updates in 1960 and again in 1976.

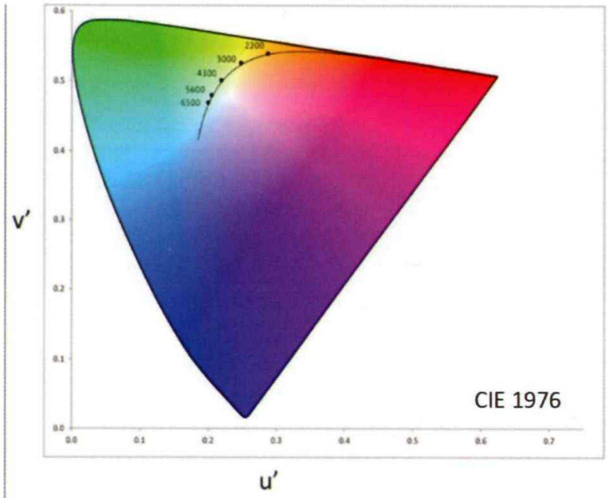
The CIE 1960 Chromaticity Diagram is technically the proper place to chart the blackbody curve.

The CIE 1976 Chromaticity Diagram was created to make a more uniform chart for plotting chromaticity. It uses u', v' coordinates and is scaled so that distances in the diagram more closely align with perceived differences in colour appearance. The 1976 diagram is preferred for showing colour differences because the distance between points correlate more closely to the variations we perceive in colour.

LED LIFE

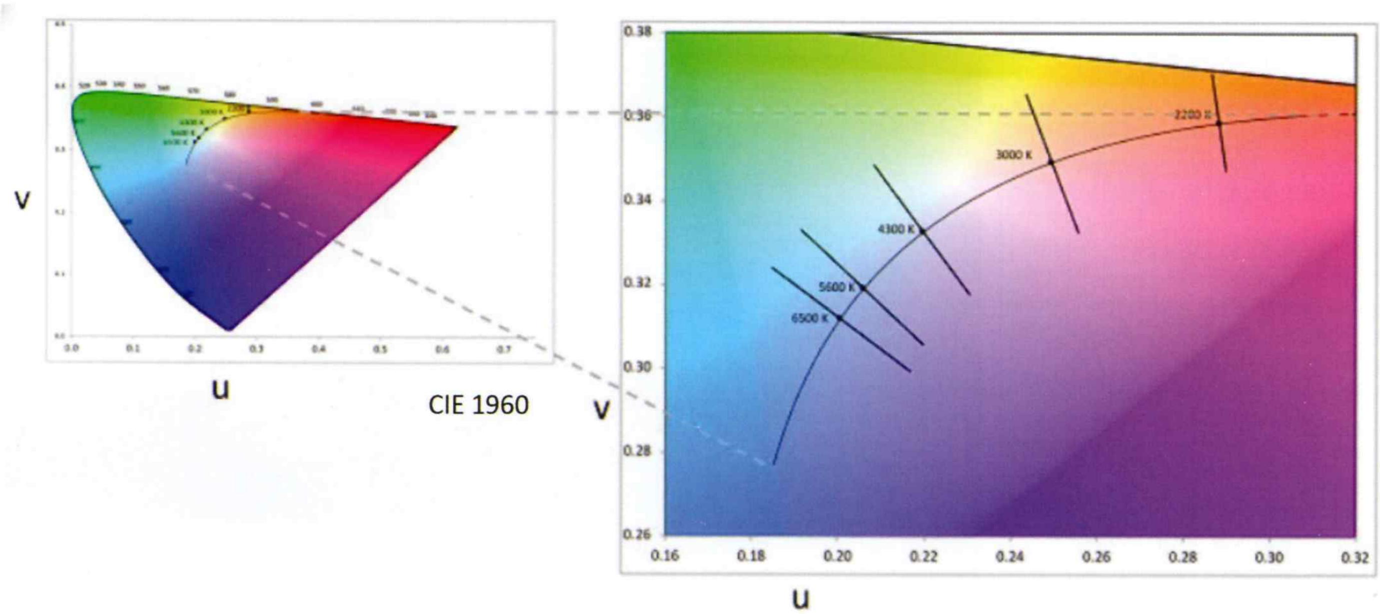
To add yet another degree of complexity into the mix, LEDs do not simply fail when they reach end of life. Unlike a tungsten lamp, where the end of life is very apparent and definitive, LED's simply keep getting dimmer until they reach the point where they no longer emit usable light. As manufacturers, this poses a problem in terms of how to rate the lifespan of a particular luminaire. To this end, there are two standards to measuring the life of an LED light source.

The first is L70. Essentially the standard means that when an LED reaches 70% of its initial light output, it is deemed to have reached 'end of life'. So, if an LED is rated at 54,000 hours, does this mean the manufacturer has run the LED for this entire period? No! This would take too long and prevent fixtures from ever coming to market. To measure L70, an LED is run at its manufacturer-specified optimum ratings and its output is measured every 1,000 hours. This is repeated at least 6 times (6,000 hours is the minimum) and this data is then



extrapolated mathematically to calculate the L70 life span. It is worth noting that this standard tops out at 60,000 hours – so LEDs claiming a longer lifespan than this have not used the L70 standard. This standard is applicable to the LEDs (emitters) only.

The other standard for measuring LED lifespan is LM-84. This is a test that is applied to the complete luminaire – and not just the LEDs. Some manufacturers may overdrive their LEDs to get more output, which shortens their life. Perhaps the cooling system is not as efficient as it should be – this too would shorten their life. These practices would not be reflected in L70 testing, but would be tested under LM-84 as this tests the complete luminaire under normal operating conditions. The testing is



also done in sections of 1,000 hours and is repeated up to 6 times, with the light output being measured at the same 1,000 our intervals.

WHAT'S NEXT?

Given how LED is a relatively new technology, we have managed to come a long way in a relatively short time. Are they perfect? Of course not. Will they keep getting better? Without a doubt. But in the meantime, we all have to carry on with the business of lighting, whether it's for stage, film, architecture of any other discipline. All we can do is be curious – never stop questioning, never stop experimenting and never stop discovering. The world of LED lighting is exciting and I for one, cannot wait to see what new developments lie in store.

At the time of writing, Deep Red LEDs are only available in the fos/4, Desire and Source Four LED Series 3 product ranges from ETC. Advanced metamer and colour controls are available when using these luminaires with any of the Eos family of lighting consoles.

Additional article resources:

fos/4 Panel
https://youtu.be/VTWd9qrpuW8

fos/4 Fresnel
https://youtu.be/Dx8VFHiIYGc

fos/4 UI
https://youtu.be/hs0r60PfrH4

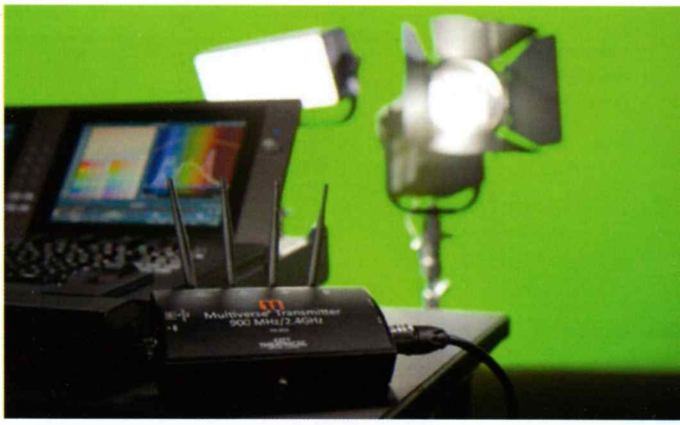
fos/4 Brochure
www.etcconnect.com/WorkArea/DownloadAsset.aspx?id=10737503388

Source Four LED Series 3
https://youtu.be/OjdVerorbMs

Eos color controls
www.youtube.com/watch?v=X_OqzmzSRLo&t=580s

ARG – Advanced Research Group at ETC https://youtu.be/kKx545RPWNA

ARG are a team of specialists at ETC who conduct deep research into LED technology, colour science and lighting. It is through their research that many great ETC products have come to market and



have become industry standards and they are the reason why ETC is the world leader in understanding and implementing colour and colour control in the entertainment industry.

Declan was a freelance lighting, set and projection designer for 23 years before joining ETC as Training Program Coordinator in 2018.
www.declanrandall.com

You can read the full article on our website: https://stld.org.uk/articles/an-array-of-choice