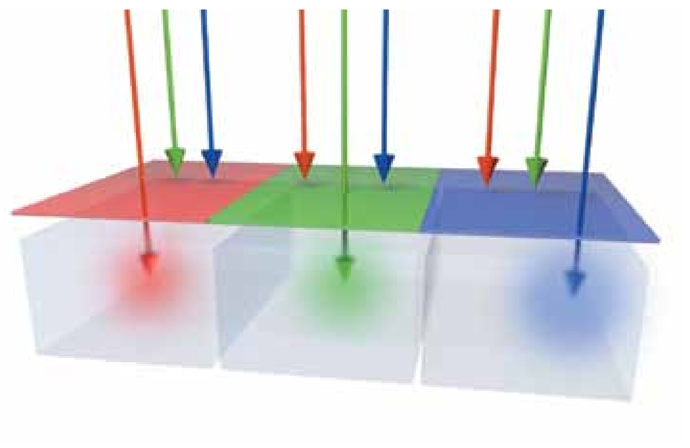
4K

separating the truth from the hype



Already arrived at a cinema near you, 4K may also be coming at some point to a TV screen near you. But what do these numbers actually mean? Zerb editor Mark Langton has been looking into the reality of the numbers behind 2K, 4K and wondering whether bigger is always better.

4K seems to be the buzzword doing the rounds at the moment. Many camera manufacturers are announcing products capable of recording video images in 4K and higher that are not just intended for high-end digital cinema shooting: they are hinting at the next logical progression in the acquisition of television programme content. Personally, I still don't accept 3D television as anything other than a fad, but that sort of complacency could be seriously damaging to my potential work opportunities! I run the risk of falling behind the times with a format that looks frighteningly likely to stay for some time.

4K television, or the failure to acknowledge its looming presence could be even more damaging. If you are a lighting camera person or a DoP working in television or digital films, you are expected to know your formats, codecs and resolutions, to understand them and then to be able to translate that technical knowledge into layman's terms for the producer, director etc. As well as all the current skills you possess, you now also need to be an IT expert too!

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Pixels

Before we go any further, a brief explanation of a pixel is required since it gets mentioned quite a lot in the rest of this article. Pixel is an abbreviation of 'picture element' (sometimes also called a Pel) and, when talking about camera imaging sensors in particular, it refers to the smallest controllable photosensitive component. It may also be referred to as a photosite or photosensor. The pixel responds to light intensity and turns it into an electrical signal. In its basic form an array of pixels would produce a black and white image.

The red, green and blue (RGB) colours we are familiar with are created by overlaying a transparent colour filter. It is common for three pixels to be grouped together to form one RGB pixel and the pixels within that group are then usually referred to as *sub-pixels*. Of course, life isn't always that straightforward and there are deviations from this simple model, as we shall discover.

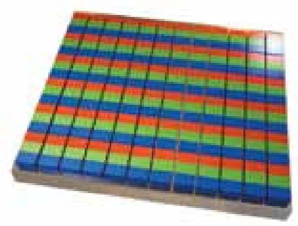
The truth behind the numbers

Coming from a television background, I am comfortable with my broadcast high definition knowledge; 720 refers to an image size of 1280 x 720 pixels. Conveniently, that equates directly to 720 horizontal TV lines. 1080 refers to either 1440 x 1080 or 1920 x 1080 pixels, depending on which camera you are using, but both have 1080 horizontal TV lines.

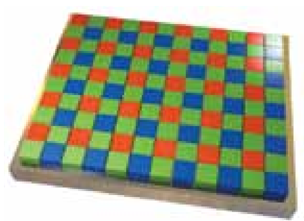
That's all very logical and straightforward, but until recently I hadn't given any serious thought to 2K, 4K etc. From talking to fellow cameramen I realised I wasn't alone in assuming that a 2K or 4K camera sensor would give you a horizontal resolution of 2000 or 4000 lines respectively. It took a fair amount of research to discover the revealing truth behind those impressive sounding numbers. Here then are the basics of 4K and all the other resolutions that reside beyond 1080 HDTV.

The jump from 1080 to 2K and beyond is a leap from the safe, organised 'bedroom' of television standards, through the wardrobe and into the multi-resolution, multi-aspect-ratio Narnia that is cinema, and things add up quite differently there.

2K, 2.5K, 3K, 4K, 5K and all the other permutations of high resolution sensor are products of feature film technology. Traditionally, 2K and 4K imaging chips were used in big, heavy line array scanners for transferring film to high resolution digital video.



▲ An RGB line array sensor contains an equal number of red, green and blue photo sensors, arranged in a linear fashion



▲ A Bayer filter mosaic contains twice as many green photo sensors as it does red or blue. Some arrays have a different configuration to this example but the end result is always the same

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As soon as technology was able to shrink the once-cumbersome computer components into a box the approximate size and shape of a film camera, the all-digital-workflow cinema revolution was under way. Predictably, that also fuelled the inevitable format interbreeding that is starting to happen with broadcast cameras; 35mm digital cinema cameras are getting the green light for use in everyday television programme-making. As television camera folk, we need to know about these high resolution sensor-equipped cameras because they are appearing alongside regular broadcast cameras and are quickly becoming the preferred choice for DoPs shooting drama, reconstructions, documentaries and anything generally 'arty'. On the whole that's a good thing because, in the right hands, they produce amazing images and provide not only the shallow depth of field but also the subtle light characteristic that many of us have been looking for in order to tell our stories with more cinematic quality.

We are not currently at the stage of making 4K broadcast television, but high resolution video, especially uncompressed RAW video, is currently very useful for high-end digital effects due to the sheer amount of data available. And it's always good to start with more resolution and then 'down-res'. But, exactly how much resolution you have at your disposal is a subject of much debate.

In its simplest form, 4K doesn't refer to 4000 TV lines; it actually refers to 4000 pixels per colour: 4000 red, 4000 green and 4000 blue. In other words, 4000 RGB pixels (in reality it's often 4096 per colour, but for the sake of simplicity we'll stick with saying 4000).

Alhough the dimensions of the sensor can vary from manufacturer to manufacturer, many digital cinema cameras will contain a single imaging chip with a 4:3 aspect ratio in keeping with film. So a 4K sensor will typically be 4000 x 3000 pixels, thus containing a total of 12,000 sub-pixels, but some manufacturers still like to refer to this as 12,000 pixels. Technically, they are not wrong but the distinction between a single pixel and an RGB pixel has already begun to get blurred. Interestingly, if you applied the broadcast HDTV method of identification, it would make this a 3K camera – 3000 horizontal TV lines. But, of course, that doesn't sound nearly as impressive does it? Calling it 4K is going to sell far more cameras than calling it 3K!

And that's assuming the entire 4:3 area of the chip will be used with an anamorphic lens. In feature film production maybe, but in most other genres that's very unlikely. It's much more likely that you will shoot with standard lenses in one of several widescreen aspect ratios. This means you won't even be using the full 3000 horizontal lines. For example, If you were to shoot with a 16:9 aspect ratio that would result in 4000 x 2250 (or 2250 horizontal lines). If you employ a cinema aspect ratio, like 1.85:1 or 2.35:1, you will get even less horizontal resolution.

Real-world examples of different sensor resolutions are:

- RED One 4K camera with a 16:9 aspect sensor recording 4900 x 2580 pixels,
- Dalsa Origin II, 4K camera with a 4:3 aspect sensor recording 4046 x 2048 pixels,
- ARRI Alexa 2K camera (standard version), 4:3 aspect sensor recording 2880 x 2160 pixels.

Similarly, if you turn this film-world methodology back on to measuring our trusty 1920 x 1080 3 CDD broadcast HDTV chip, you suddenly have a 2.07K camera (2,073.600 pixels per colour channel). But, of course, we don't because we're too honest. We classify it by the number of horizontal TV lines it outputs – which is 1080. But you can see how things can get misleading.

Bayer filter array

But wait! Even if you could use every pixel on the chip, most 4K cameras don't even resolve the full 12,000 pixels/sub-pixels because we have neglected to consider the colour layout of most modern sensors. Enter the Bayer filter mosaic.

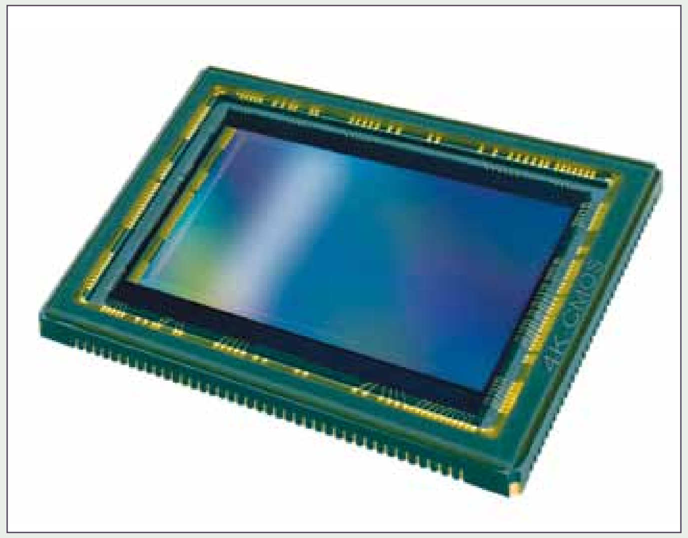
When charged coupled device (CCD) and complementary-symmetry metal–oxide–semiconductor (CMOS) sensors were born in the 1960s they were rather large in comparison to today's offerings and getting thousands of pixels onto a chip small enough to be used in a portable camera was a challenge.

In the mid 1970s a Kodak employee by the name of Bryce E. Bayer devised a way of reorganising the coloured filters that covered the pixels on a single-sensor camera chip by theoretically throwing away half the photosites dedicated to red and blue but retaining the full number of green ones. This system still managed to produce ample detail and colour because Bayer exploited the human eye's increased sensitivity to green light and used the green channel to store all the vital luminance information. The red and blue channels recorded the majority of the colour information. In other words, a Bayer sensor contains 50% green, 25% red and 25% blue. This process allowed for smaller, cheaper, more power-efficient sensors to be manufactured.

▲ *The awesome ARRI Alexa digital cinema camera now comes in five flavours: the standard model, the Alexa Plus – with extra features including wireless control, lens data system and facility for 3D synchronisation; the Alexa M – a modular version with separate imaging and processing unit for situations where size or weight are a concern; and the Alexa Studio – with optical viewfinder, mechanical shutter and a 4:3 sensor for use with anamorphic lenses. There is also an Alexa Plus 4:3 version (see pages 48–51)*

▲ *The Evolution is the latest 4K offering from Teledyne-Dalsa. It's a more compact cinema camera with the same 16-bit RAW data functionality of its predecessor the Origin 2. Many complex effects scenes in the 007 epic Quantum of Solace were shot on the Origin 2*

▶ *Capable of 4K video and 5K stills the recently released RED Scarlet looks set to replace the now iconic RED One cinema camera and is creating quite a stir among indie film-makers and cinematographers working with smaller budgets. It contains the same Mysterium-X sensor as its bigger brother the Epic, but is limited to 30fps*



▲ *4K camera sensors are a marvel of modern optical electronics and come in many different shapes and sizes. Some are 4:3 for use with anamorphic lenses, but most have a widescreen aspect ratio like this one*

> The single biggest component that ultimately dictates the absolute detail reproduction of the final image is the optics… if the optics can't resolve the image accurately, the sensor will just not achieve its maximum potential, no matter what

Did you know?

It's not all about size!

It's worth noting that, with the continuous advances in nano-engineering, large amounts of pixels don't necessarily mean a large sensor any more. A 4K chip can be 7.6mm diameter like the one recently announced by Omnivision and destined for a mobile phone or similar consumer device, or it can be 25.4mm like the one found in the RED One cinema camera.

Bayer-derived sensors currently exist in almost all CMOS single-chip sensors and some high-end single-chip CCD sensors like that found in the Dalsa Evolution 4K camera.

Now, the problem here is that the final RGB output signal from any camera needs an equal amount of red, green and blue information, so somewhere along the line either half the green data needs to be discarded, thus losing luminance detail, or extra red and blue data needs to be artificially created from the existing information, otherwise known as aliasing or interpolating. This does nothing for the image itself as no new information is added, it's just being copied from what's already there.

The process of rebuilding the colour into equal amounts of RGB data is called 'de-Bayering' and is never 100% efficient. Whichever way you do it, it means you can only ever achieve between 50–75% of the sensor's native resolution, depending on the quality of the hardware/software doing the calculations. It's also worth knowing that when you hear people talk about chroma aliasing, de-Bayering is usually the culprit.

Not wanting to deter customers, many manufacturers have started to 'fudge' the numbers a bit. Predictably, most have gone for the interpolation option of adding additional red and blue information rather than discarding half the green information but they still count all the green pixels, all the blue pixels and all the red pixels rather than rating the camera by the true output resolution. Some critics have referred to these confusing figures as 'marketing pixels'– they sound impressive but do little or nothing to improve the actual resolution of the image.

Resolution

Resolution is defined as the level to which an imaging device can accurately resolve detail in an image. It seems many people are obsessed with resolution, but it's important to make the distinction between the number of pixels on a sensor and the effective resolution of the camera. As we have seen with the Bayer filter mosaic, the number of pixels alone does not necessarily translate to an equally high output resolution.

Even if it were possible to output every pixel from the sensor chip, the single biggest component that ultimately dictates the absolute detail reproduction of the final image is the lens. If the optics can't resolve the image accurately and with the appropriate circle of confusion, the sensor will just not achieve its maximum potential no matter what.

Frame rate

The other main factor that influences resolution is frame rate: a greater number of frames per second leads to a direct increase in the perceived increase in detail. This doesn't of course add any more pixels; it is more to do with clarity and reduced motion blur, but the result is sharper, brighter looking images with greater contrast.

But is this a good thing? When it comes to shooting special-effect scenes, the answer is almost definitely a yes. If the intention is to carry that high frame rate over to the final cinema presentation, it's a different matter though. A prime example is Peter Jackson's film *The Hobbit*, due for release November 2012 and shot in 3D with two 5K RED Epic cameras at 48 frames per second (fps), double the fps of conventional cinema films. On paper this looks like a great idea: with all that extra detail and smooth, jitter-free motion it promises be a whole new viewing experience. However, at a special press preview in April 2012, it received a less than enthusiastic welcome. Despite being technically superior, the viewing experience was compared to 'watching a soap opera'. The high frame rate gave the film a live, video-like quality and, even more concerning, the increased perceived depth of field made the backgrounds look unnaturally sharp. The increased clarity also appeared to draw attention to the wigs and make-up, and to imperfections in the set. As one critic put it: *"It takes away the warmth of cinema."* James Cameron is equally obsessed with high frame rates, so expect to see a 48fps or even 60fps *Avatar* sequel arrive at a cinema near you soon.

You could argue that technology has taken preference over content. We as humans are analogue. We've warmed to the romanticism and escapism of film for over 100 years. Camera manufacturers have gone to great lengths to make digital cinema cameras emulate 35mm film so that we wouldn't notice the transition. Furthermore, a great many digital cinema films have artificial, post-production 'film grain' added to soften the image for the benefit of the viewer.

Maybe many of us just resist change? Maybe we are reluctant to accept new processes because it seems like 'change for change's sake'? I go to the cinema to be drawn into a story, into another world for a short while, away from the real world. I don't look forward to the prospect of watching something that is so close to, or even more lifelike than, the real world. For me, that isn't what cinema is about.

Don't get me wrong, I love technology and I love digital cinema cameras as they bring true film-making tools into my reach. But I am also acutely aware of the cold, clinical, dehumanising effect digital video can have on storytelling without a cinematographer's intervention. If technical perfection is allowed to overpower aesthetics and visual creativity, cinema will indeed lose its warmth. Motion blur, grain and smooth contrast work because, in my opinion, they enhance the viewer experience. If I want reality, I'll watch the news or a current affairs programme. If I want to give the right hemisphere of my brain a treat, I will watch a cinematic movie.

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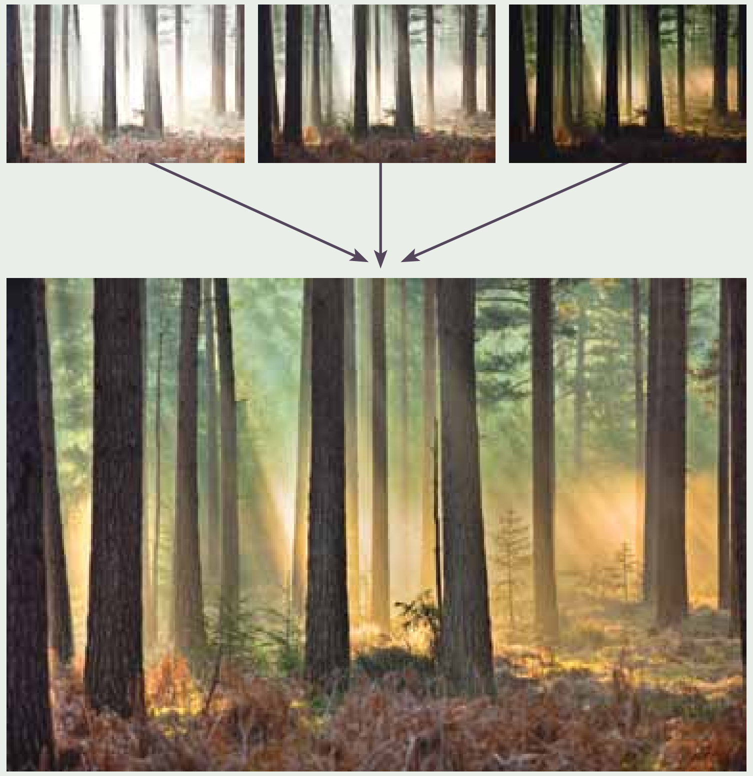
www.gtc.org.uk 4K – what is it?



▲ *A high dynamic range image (HDRI) is currently created by combining several images with different exposure values to create a final image with a broad tonal range. If this process could be implemented into video cameras in real time it would expand the realms of creativity. For example, this picture of a forest has multiple layers of exposure. Optical filters like low contrast or graduated NDs would not be able to achieve the same results as HDR processing.*

Coming soon

Dynamic future

My personal prediction for the next big thing in broadcast camera technology is HDR video. HDR stands for high dynamic range and refers to images with an expanded tonal range, achieved by taking several photographs of the same scene and combining them to extract the optimum detail. In other words, more visible detail in the highlights and shadows than is currently possible with a single image.

Many stills photographers are familiar with HDR images as the process has been around for years, but it's only recently that stills and video technologies have begun to merge. It seems a logical progression therefore that HDR video isn't far away.

For the video cameraman, this would essentially mean no more neutral density (ND) graduated filters when shooting landscapes and no more subjects standing against a window with a burnt-out vista behind. Bright information that would otherwise be either 'blown out' or shadow detail that is so dark it is rendered as solid black, would be brought back into viewable range, all in real time.

Done correctly, an HDR image could mimic the human eye's ability to see everyday detail more accurately.

The idea isn't a new one by any means. Panavision has been working on their Dynamax chip for while. It contains six photosensors per RGB pixel that record different exposure values simultaneously and are then combined. This sensor will probably end up in a digital cinema camera, so it looks like it's up to the usual suspects to develop similar technology for the broadcast arena. I wonder who will be the first to bring it to market?