The video industry has an established history of employing ever higher resolutions to achieve improvements in image quality.

With LED screens this means squeezing more and more LEDs into a given space, and ever-finer pixel pitches have been seen as the primary route to improving the image. That is - make the pixels small enough that they cannot be seen; make the technology disappear, leaving only an image in its wake.

Unfortunately, for any given viewing distance there is a point beyond which there is no visual improvement to be gained from increasing pixel pitch, and a number of disadvantages start to tip the balance.

First, higher pixel pitch usually means significantly higher cost: We need more LEDs and we need more electronics to run them. Second, smaller LEDs of reasonable cost are typically less capable when it comes to brightness and colour saturation, and analogue electrical issues with scan-multiplexing of more and more pixels potentially leading to lower PWM bit depth and visible artefacts.

Last, finer pixel pitches can result in more fragile LED panels that are more difficult and costly to repair, which again increases the associated costs of purchase and maintenance.

Choosing an LED panel is always about finding a balance. We need a fine-enough pitch that the pixels cannot be independently resolved, and with enough detail in the image. But it should not be so fine as to cause an unacceptable increase in cost or open us up to the other issues highlighted above.

What we need is better image quality without requiring more pixels to achieve it.
The Future’s Bright

Fortunately, recent video technology developments mean this isn’t just a pipe dream.

Rather than simply another increase in resolution, High Dynamic Range (HDR) video brings a trio of image quality improvements that are particularly well-placed to be the next big thing for LED screens.

For every pixel, HDR describes a larger brightness range, a wider colour gamut, and a higher bit depth.

The brightness range offered by conventional Standard Dynamic Range (SDR) video’s ‘gamma curve’ - the transfer function that encodes luminance or brightness into a video signal - doesn’t get close to exploiting the 10,000:1 brightness range perceptible by the human visual system.

To improve this, we have to expand the brightness range by breaking away from that basic gamma curve.

As a result, HDR video uses different curves with extended ranges to represent the much darker and much brighter levels required.

One of two new ‘Electro Optical Transfer Functions’ (EOTFs) is typically employed: The Perceptual Quantisation (PQ) transfer function (developed by Dolby and standardised by SMPTE as ST.2084), or the Hybrid Log Gamma (HLG) transfer function.

The latter is a hybrid of a standard gamma curve for low brightness and a logarithmic curve for high brightness, jointly developed by the BBC in the UK and NHK in Japan.

Both PQ and HLG EOTFs are described by ITU Rec.2100 standard, which defines various aspects of HDR, though naturally they’re incompatible with each other so HDR equipment needs to support both standards.

The benefits of the wider brightness range include greater detail within the shadows and highlights, increased contrast, and more headroom for exceptionally bright content that might otherwise be ‘clipped’.

All of this is perceived by the human brain as a sharper, more detailed image with greater ‘depth’ than SDR video (see Figure 1) - even when the pixel count remains the same.

Figure 1: Images of identical resolution with increasing contrast (from left to right), resulting in increased detail and ‘depth’ in the higher contrast images.
The Full Gamut

A ‘colour gamut’ describes the range of available colours that can be displayed. SDR video uses the ITU Rec.709 high definition TV standard colour space, while HDR benefits from the Wide Colour Gamut (WCG) of Rec.2020 colour space.

The Rec.2020 colour space is 72 percent larger than Rec.709 - a massive improvement in available colour saturation that is easy to visualise (see Figure 2) when both gamuts are mapped out on the CIE 1931 colour space (a standardised definition of the extent of human colour perception).

The wider colour gamut of HDR video means that the brain perceives a much more vivid image, with lifelike colours that map accurately to the real world. Again, this is a big improvement in quality, without increasing resolution.

Figure 2: An illustration of how the colours in a source image (inset) are distributed in the CIE 1931 xy colour space.

Most of the colours are outside of the smaller Rec.709 gamut triangle, and so could not be displayed accurately in SDR, requiring clipping and a general desaturation of the image, resulting in a ‘flatter’, more drab appearance.

The additional space of the larger HDR Rec.2020 wide colour gamut triangle is required to ensure these colours can be displayed in all their glory.

Deep Joy

Bit depth determines the range of numbers available to represent values digitally, with each additional ‘bit’ doubling the range.

With 8-bit values, the available range of zero (black) to 255 (white) is usually acceptable for SDR content, but it’s too coarse for HDR, resulting in banding where there should be smooth gradients (see Figure 3).

A minimum of 10 bits (a range of zero to 1023) is therefore necessary to provide suitable precision for HDR.

Coupled with HDR’s extended brightness range and wider colour gamut, the higher bit depth used for HDR delivers significantly fewer visual artefacts than SDR.

Figure 3: Banding, the result of insufficient bit depth. The worst affected areas of the image are those that should have gradual, smooth gradients (such as the sky).
Putting all this together, HDR is potentially fantastic news for LED screens.

First, LEDs can offer the brightness range necessary to display HDR content, which is typically thousands of Nits (cd/m²), and modern high-quality RGB LEDs are capable of a colour gamut approaching that of Rec.2020, ensuring saturated colours can be faithfully reproduced.

Independent control over every LED means we can reproduce the full brightness range without losing detail, and with perfect blacks and no backlight bleed, LED screens generate far fewer undesirable artefacts than many other technologies (see Figures 4a and 4b).

Equally importantly, HDR is resolution-agnostic. It can improve image quality no matter what the resolution or the size of the screen.

As always, there are caveats to this. Lower quality LED panels will likely not see any benefit. HDR isn’t a magic fix for poor quality panels; it asks even more from the panel and will more quickly show up any weaknesses in the panel’s design.

The entire system also needs to properly support PQ and HLG HDR formats as well as wide colour gamuts and high bit depth.

Just supporting these features on an LED processor’s video inputs will offer no benefit; the support needs to follow all the way through every aspect of the system, including the electronics and signal processing within each panel.

Conventional (SDR-style) processing will only offer SDR-level performance, even for HDR video inputs.

We also need to rethink calibration. To achieve uniformity, conventional LED screen calibration compromises both brightness and colour saturation - the very things that have to be maximised for HDR to deliver.

Fortunately, new calibration techniques have been developed that can be used to offer the required performance increase for HDR without sacrificing uniformity.

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In Conclusion

The race for resolution is not the most important race any more. Beyond a certain point, fine pixel pitches in LED panels can do more harm than good, to both budget and performance.

High Dynamic Range video offers a new approach, and when done properly it’s a sure-fire route to sharper, more vivid, and more lifelike images.

Recent technology demos have shown that with the right LED panels, the right processing system, and the right calibration techniques, HDR can offer a huge step up in image quality on LED screens. Check it out.