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THE PROMISE OF 4K

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THE PROMISE OF 4K

In terms of industry buzz, there is little doubt that 4K has arrived. 4K cameras and recorders are proliferating. Throughout 2012, it was a central topic of discussion at numerous industry forums. At CES2013, it was a highly visible reality in terms of many large screen 4K consumer displays by multiple manufacturers. 4K Production Standards are firmly in place. 4K represents a four-fold increase over the approximate 2K of the 1920 x 1080 high definition digital image format. The implications of this are significant – to both cinema and home viewing experiences. That, in turn, has implications for lenses and cameras. 4K post-production also becomes a major topic. But, perhaps the implications of 4K distribution services to the home are the most challenging topic of all. While these are still early days, it can be said that much is happening with 4K.

The 4K Viewing Experience

Implications of 4K for the Cinema Viewing Experience

The cinema entails far greater image magnification and potential wider viewing angles than television home viewing, and it is here that 4K has much to offer. A contemporary 4K digital projector offers significantly more resolution than a 35mm motion picture film print presented on a similar screen size. Perceived picture sharpness is much improved and reproduction of textural detail is superior. There is, of course, a wide range of viewing distances in a cinema. Clearly, only a finite range of seating will ensure the full 4K resolution perception. Nevertheless, most will experience an enhanced psychophysical "sense of presence." For preferred seats in the theater that can deliver that heightened viewing experience, it has been reported that the viewing angle ranges between 33 and 53 degrees [1].

Implications of 4K for the Television Home Viewing Experience

Our Human Visual System (HVS) is quite implacable in what it can perceive at a certain distance from a television screen. It was recently reported that the most popular HD screen size sold in the U.S in 2012 was 40-49 inches. If the consumer's favorite viewing seat remains in the vicinity of the reported [2] average distance of nine feet from that size HDTV screen, then the HVS system fails to see the six-fold increase in resolution. Thus, few consumers today are even close to enjoying the full visual promise of HDTV.

Various papers have emphasized that a greater sense of presence in displayed imagery can only be achieved with screen sizes that occupy a far wider angle of view. NHK's UHDTV research reports that the "sensation of presence" (or sensation of "being there") is related to the field of view and the "sensation of realness" is related to angular resolution [3] [4].

One hears a great deal today about the "immersive" nature of 4K images on large screens. Indeed, some argue that this represents a more comfortable and satisfying viewing experience than 3D. It is noteworthy that many of the consumer 4K displays on view at CES2013 were at least 84 inch diagonally. This is a significant recognition by the display manufacturers that screen size is hugely important for 4K. However, the full promise of 4K can only be realized *if content creators fully exploit that larger screen size*. Let us explore this.

Producing In 4K

Implications of 4K on Content Creation

While the four times additional pixels of 4K over HD packs far more resolution into a screen the same size as an HD screen, the perceived resolution by the viewer will be attenuated by the viewing distance. However, if the viewing distance remains unchanged while the screen size is made four times larger in area than the HD screen, then the most important step will have been taken. The effective use of that larger screen from the viewpoint of the viewer would be to exploit those extra pixels to create a radically *different picture content*. Opening the field of view of the 4K camera lens will do that. It is this deployment of the additional resolution to create *different content* that offers the full promise of 4K – as indeed was the intended promise of HDTV over SDTV. We will simulate this key point with the two figures below comparing a 42-inch HDTV display with an 84-inch 4K display.

Figure 1 Simulating a 42-inch HDTV screen with a medium wide shot containing a lot of detail

Figure 2 Simulating the four times larger 84-inch 4K screen with a wider field of view capture.

It is important to note that the angular resolution has not changed between the two screens, but the deployment of the four-fold increase in pixels to *add picture content* brings in a huge amount of environmental detail as well as foreground figures not present in the HDTV image. *This is a radically different image to the HDTV image*. 4K can deliver imagery closer to the way we see the real world.

For sports, the goal of achieving a stadium experience in the living room could come closer to being realized. Wide angle viewing of sports in 4K would dramatically add to the communal viewing experience. For concerts, television drama and special events such exploitation of the wider angle of view, accompanied perhaps by a slower pace of cutting between cameras, could introduce an entirely new viewing experience and possibly a new choreography in television coverage.

With 42-inch HDTV screen being today's most popular size, it is perhaps no surprise that the CES industry have unveiled 84-inch 4K displays from the outset. Clearly, the full exploitation of 4K imagery will require new thinking on the part of content creators. Close-up shots will remain important to all genres of programming but a more imaginative use of wider angle fields of view will produce the compelling imagery warranted by the 4K system. It is this different content portrayed on significantly larger screens – not resolution per se—that will be the "wow" factor in 4K. Capitalizing upon this fact requires a much needed industry discussion that is important to all constituencies interested in successful 4K businesses. Certainly, for 4K considerations in sports coverage – the Sports Video Group would be the ideal forum for such discourse – and indeed for possibly organizing major experiments to explore the new imagery.

Implications of 4K for Television Production

Only a year or two back, few broadcasters wanted to even discuss 4K for television. This is understandable, given that many remain challenged by the ongoing transition to full HDTV services. However, at recent technical and creative forums, an increasing number of broadcast network and cable operation senior management are opining about the potential value of 4K production to extend the shelf life of their more important archives. During the past year, a modest number of television shows have been originated and mastered in 4K – specifically to build an archive that can service some future 4K distribution service to the home [5]. In addition, downconverting these super sampled masters for today's HD distribution produces a higher resolution HD – an important consideration.

Separately, 4K has been increasingly deployed over the past year by some broadcast networks for their coverage of major sporting events. The age-old challenge of capturing contested plays with adequate resolution (to unambiguously resolve the issue) is being addressed by use of some 4K cameras whose outputs are digitally zoomed to create a satisfactory HD portrayal of the specific action of interest. This is, of course, a niche application of 4K acquisition. The larger question is whether there might be interest in exploring complete 4K coverage of a sporting event in the foreseeable future. Arguably, sports could be the primary driver for such coverage by offering a dramatic new stadium experience on large 4K screens in public venues or, ultimately, in the home. If the potentials of 4K sports coverage do stimulate interest, then there are some important considerations – starting with the 4K lens and camera.

4K Image Acquisition – Implications for the Lens

There are both technical and operational implications for the 4K lens. On the technical front, it must start with the established standards for digital 4K (see Figure 3). From these standards, it can be established that for popular Super 35mm image format found in most contemporary digital cine cameras, the requisite optical resolution requirements are based upon the need to deliver 2160/2 line pairs (LP) in an image height of approximately 13.8mm. This represents the Nyquist frequency of the associated digital 4K camera. To do justice to that 4K camera, the lens must deliver 80 LP/mm with as high a contrast as possible.

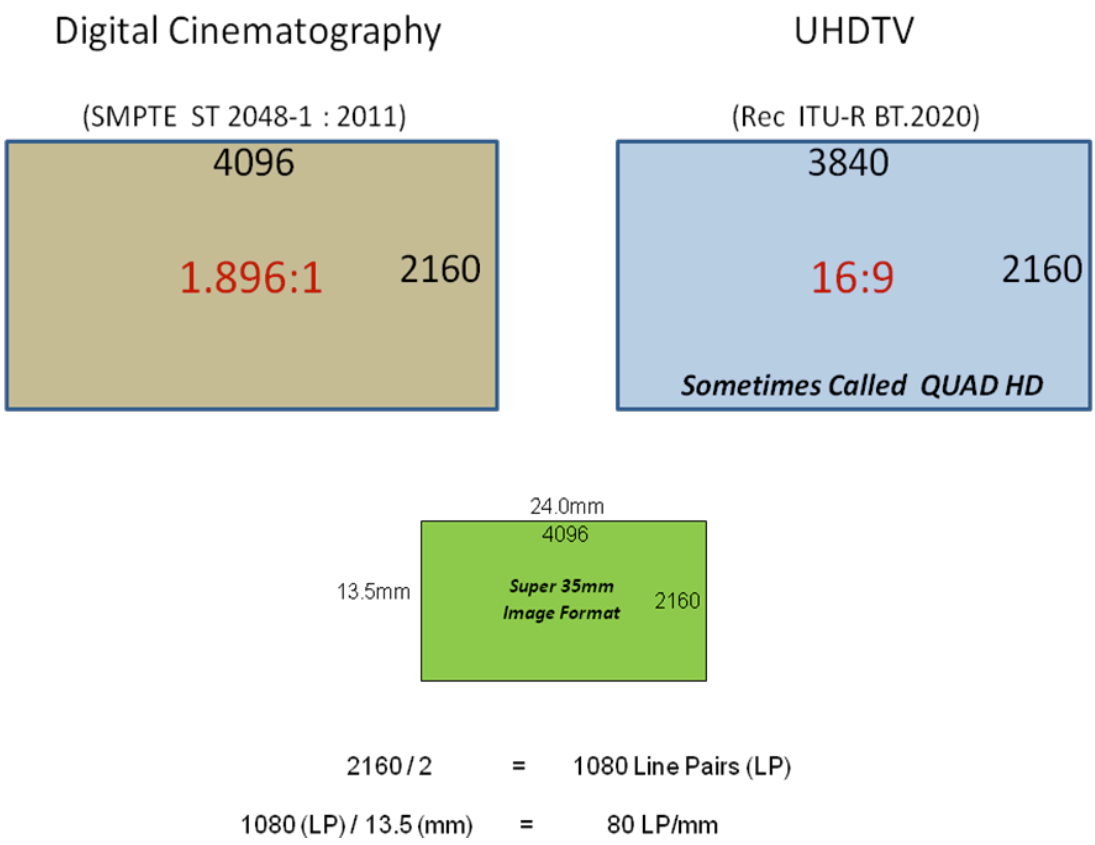

Figure 3 *Showing the two published standards for 4K Production and the implication for a Super 35mm image format lens*

Bearing in mind the large screen portrayal in the cinema, it is important that the lens be capable of sustaining that level of resolution out to the extremities of the 1.896:1 aspect ratio image without losing too much of the central contrast specification. What is even more important is the transfer of a high level of contrast through the 4K lens at spatial frequencies in the vicinity of 40 - 50 LP/mm – for it is in this frequency range that textural and facial details are represented that can add so much to the realness of an image. This is where the impact of 4K optical performance really scores.

On the operational front, it has to be recognized that the 4K Super 35mm zoom lenses available today have largely been developed for cinematography applications. Accordingly, they top out at around 400mm in focal range. To match the focal range capabilities of long zoom 2/3 inch lenses presently in use for sports coverage, they would need to reach 2200mm.

The larger format also reduces the depth of field, which is not consistent with current imaging practices in sports coverage. This does beg the question of what level of 4K optical performance might be achieved with some future small format lens – perhaps 1 inch or 2/3 inch image format. But, that begs the far larger question of whether an associated small-format 4K camera could ever meet the sensitivity requirements for sports coverage. That returns the discussion to future possible developments in large format lenses. However, if the primary attribute of 4K wide-angle imaging is adopted, then current 4K lenses can play an immediate role. The full implications of what 4K can offer over HDTV needs to be examined with real world testing. Collaborative 4K test shoots – between sports leagues, broadcasters and cable operators, and mobile production facilities – would be invaluable in assessing the capabilities of contemporary large format 4K cine lenses and guiding future developments. An industry dialog is clearly needed to help shape 4K lens developments for future television production and, again, SVG could play a role here.

4K Image Acquisition – Implications for the Digital Camera

The single-sensor large-format digital cine cameras of today invariably utilize the Bayer Color Filter Array [6] to encode the color information. The encoded output of the image sensor is termed "RAW signal output" and it takes many forms, depending upon the particular cine camera. The subsequent decoding of the RAW signal – termed "debayering" – also entails a wide range of implementations. There is considerable industry debate as to the ultimate image quality that is recorded from these disparate cameras. Some insist that the inevitable disparity in resolution between the 4K RGB components created by the debayering process produces imagery inferior to that of motion picture film that is followed by a DI process. In fact, this is too simplistic. It ignores the fact that the motion picture film negative itself has always entailed a large disparity between the resolving powers of the three emulsions, which produces its own significant disparity between the RGB video components created in the DI process. Some recent major movies originated on single-sensor 2K/HD Super 35mm digital cameras that were portrayed via a 2K digital projector produced overall imagery superior to that of 35mm film origination. 4K digital origination displayed via a 4K projection has now moved that performance bar very much higher.

4K cameras are now available at many price levels and that, in combination with the disparity in their respective Bayer encoding and debayering processes, does suggest an inevitable range in overall image performance (the traditional price-performance hierarchy). Given the enormous image magnification associated with an ultimate cinema portrayal of these 4K images, it is important to carefully pre-check the 4K camera, recorder, and associated workflow chosen for deployment in a major movie production.

For television production – and most especially for television sports production – the 4K camera must offer the same essential systemization as contemporary HD field cameras. At a minimum, there must be a link between the camera head and the CCU in the mobile production truck that can transmit the singular 4K RAW signal originated by the single image sensor. There must be means of remote control of the lens iris, means of real-time debayering of the camera head's 4K RAW signal to RGB components, and means of monitoring and "shading" the 4K cameras so they can be matched.

4K Content Creation – Implications for Postproduction

The replacement of motion picture film origination, followed by DI processes with contemporary all-digital production and post-production, is seeing the emergence of a proliferation of overall workflows. Lines are blurring between production and post-production and on-set processes are increasingly sophisticated. The diversity of management of subsequent dailies, editorial, and finishing processes are limited only by the imagination of the creative teams involved. Four times as many pixels as HDTV for 4K means four times more detail information within the image. That is four times as much data to store and move through the post-production process. That adds extra time and cost to the 4K production project. Where post-production entails collaboration between geographically separated suites, the requisite data networking poses additional data management challenge and is even more so when new "cloud" services are deployed for special effects rendering.

For television production, there are other critical workflow implications. Having the ability to pass the 4K video through routing switchers, production switchers, and digital image manipulation tools (like replay systems for sports) are essential to live television coverage. Issues of editing, graphics, and asset management all become important considerations. Fortunately, today there is a rapidly growing range of 4K grading and finishing tools available from multiple international manufacturers.

Delivery of 4K

Delivering 4K to the Living Room

Delivery of 4K is being discussed a great deal today. Just as in the pioneering days of HDTV, there was wide skepticism with respect to the practicality of over-the-air transmission of HD within a 6 MHz channel – the same doubts persist today on 4K. Yet advances in digital compression technology never cease. At IBC 2012, live demonstrations of 4K via satellite, with an average transmission bit rate of 50Mbps, using the presently established H.264 compression astonished many with its superb subjective picture quality on an 84-inch screen. In October 2012, a live broadcast of a 4K@60P soccer match took place in Japan [7]. HVEC looms as the next generation compression and is anticipated to achieve a similar image performance at perhaps 30 Mbps.

While the "chicken and egg" was much discussed at CES2013 – in terms of the looming availability of 4K displays from multiple manufacturers with little 4K content being available – there was also revelation of an interesting visual phenomenon. Many were showing high quality upconversion of good HD material on those 4K displays and in some cases, this was surprisingly good and a definite subjective improvement over a native display of that same HD material. This is a testament to the advances that have been made to upscaling technologies. For both sports and movies, this could constitute a significant driver of 4K displays in the early days. The emergence of 1080@60P HD cameras and associated system components, allied with the proliferating 3G SDI links to transport these high data rate signals, holds promise of considerable image quality enhancement to upconversion to 4K. Augmented by future 4K packaged media supply of movies (for example, the much discussed 4K "blu ray" successor) those could start the necessary movement to drive 4K large screen displays into many homes. While over the air broadcasting of 4K would require new transmission standards, there are no such impediments to the launch of a 4K cable or satellite service to the home.

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