

LENS STRATEGIES FOR THE ERA OF 4K UHD DIGITAL MOTION IMAGING



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CINEMA EOS



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Abstract

4K digital origination is today firmly entrenched in the world of theatrical motion picture production. The Super 35mm image format size had reigned for the many decades of motion picture film production and it became the pivotal format during the transition from film to digital – although it is not the only image format size in use in the new digital motion imaging era.

Separately, digital 4K has been internationally standardized for television production under the banner of UHD or 4K UHD – a consequence of the slightly different digital sampling format to that of cine 4K – and it is already being used for some high end television production. Meanwhile, the Super 35mm image format has become quite popular for many program genres in broadcast HDTV production that favor the accompanying cinematic look.

It was probably inevitable that broadcasters would begin to explore the possibilities of 4K UHD for the globally popular world of outside broadcast sports coverage; and indeed, recent years have seen a great deal of related experimental projects. The 4K UHD lens issue soon surfaced as the limitations of presently available Super 35mm zoom lenses quickly became apparent.

A year ago the first 2/3-inch digital camera appeared – retaining the long-established B4 lens-camera mount and delivering a digital 4K UHD output. By NAB 2015 no less than four major camera manufacturers were showing 4K UHD camera systems based upon the 2/3-inch image format. This paper will review Canon's involvement in both digital cinema lenses and in this relatively recent 2/3-inch 4K UHD movement.

CHANGING LANDSCAPE IN DIGITAL MOTION IMAGING

The New World of Digital Cinema

Separate to the television world, large-format single-sensor digital motion imaging – generally centered on the Super 35mm image format size – started within the Digital Cinema world and offered a digital alternative to motion picture film origination. The original concept was to use the existing extensive inventory of Super 35mm lenses on the newly emerging large-format single-sensor digital cameras. Most of these early cameras had digital sampling structures of 2K (2048 x 1080) or HD (1920 x 1080). This movement has since seen an unprecedented expansion in associated digital cameras, camcorders, and lenses. In recent years increasingly higher digital sampling structures have become more attractive to those producing theatrical motion pictures – with 4K currently very popular – and this has spurred a broad and rapid development in 4K lenses and cameras for cinematography.

The New Multi-format Television Environment

Over the past decade the broadcast television world has been slowly migrating to a true multi-format production environment. On the imaging level this encompasses program origination using different image format sizes for camera image sensors; on the digital level it entails different digital sampling formats. Multiple image format sizes in lens-camera systems offer a broad diversity in television camera sizes, configurations, and shooting expedencies as well as important choices in the creative look of a broad range of television program genres. And separately, while HDTV delivery services are largely based upon two separate standardized digital sampling structures – 1920 x 1080@59.94i and 1280 x 720@59.94P – the origination of these are now sometimes at higher level digital sampling structures.

Broadcast Television – a World of Multiple Image Format Sizes

On the imaging front for HDTV television production – the longstanding 2/3-inch image format size remains the bedrock for both television studio and for outside broadcast (OB) live event production (that cover most sporting and major events). However, in the arena of broadcast news, smaller image formats – such as 1/2-inch, 1/3-inch and variants on the latter – have become ubiquitous. Further variants on the latter – in the form of both tri-sensor and single sensor camcorders – have significantly broadened digital HDTV image acquisition choices in terms of costs and mobility.

More recently, large-format single-sensor digital HD / 2K motion imaging cameras – largely of the Super 35mm image format size – are being enthusiastically adopted for a variety of television program genres because of the different cinematic look they impart. Indeed, even the full frame image sensor DSLRs have incorporated digital HD video capabilities and are being mobilized for certain television programs inserts because of *their* particularly unique look.

Broadcast Television – a World of Multiple Digital Sampling Formats

On the television digital image format sampling front – there is also a migration underway. Many contemporary high-end 2/3-inch studio cameras can originate in 1080/59.94P and be subsequently converted to either of the 1080/59.94i or 720/59.94P HDTV formats for distribution to the home. By having the masters in 1080/59.94P their archival value is increased. Similarly, many of the contemporary Super 35mm digital camcorders record only in progressive formats – such as 23.98P / 29.97P / 59.94P – and are also later (and easily) converted to these same two digital HDTV distribution formats.

In addition, on the temporal front, HDTV originations at increasingly higher frame rates in outside broadcast camera systems have also grown in popularity by their support of an expanding use of *Super Slo-Mo* in sports replays.

Broadcast Television – Enter 4K UHD

In 2012 the ITU international standardization organization published a global recommendation for the long term advance of television production [1] — having both 3840 (H) × 2160 (V) and 7680 (H) × 4320 (V) sampling formats at a variety of progressive frame rates up to 120P. The 3840 x 2160 format is sometime labeled 4K UHD TV. There are now many Super 35mm cameras and lenses available to support this particular format. This 4K UHD TV format is gaining the attention of some of the world's broadcasters and producers of television programming. Super 35mm single sensor cameras are already being used on many outside broadcast live events to support digital zooming in replays of fast action situations on the field.

Broadcast Television – the New Era of 4K 2/3-inch Lens-Camera Systems

As broadcasters experimented with the new 4K UHD television production format it quickly became apparent that existing “long” zoom lenses for the Super 35mm image format size fell far short of the focal ranges to which they are accustomed in the world of HDTV program origination. This is true in the studio, in portable EFP origination, and most especially in coverage of sporting and other major live outside broadcast events. And indeed, the industry has been quick to respond to this void.

Over the past year and a half no fewer than five of the world's major broadcast camera manufacturers have introduced 2/3-inch tri-imager (four imagers in the case of one company) cameras – that maintain the globally established B4 lens-camera mount – that can deliver 4K UHD TV digital outputs. From the outset, some of these cameras systems are upgradable – both spatially (HD to UHD) and temporally (various multiples of the standard 60i frame rate) for slow motion capture. This is in recognition of the industry uncertainty as to the pace of penetration of 4K UHD TV to the homes of consumers.

LENSES FOR 4K / UHD / 2K / HD

First Phase – a Coordinated Super 35mm 4K Cine Lens Strategy

While all of these advances have been unfolding, Canon has been very actively working with the industry to develop lenses to meet all of the manifestations of 4K origination. Our initial thrust was to produce a solid core of both zoom and prime large image format lenses – all having 4K optical performance – to support the Digital Cinema agendas.

S35mm Lenses for Digital Cinema

Four Super 35mm zoom lenses were developed. Two of them were designed to have the highest possible overall optical performance – anticipating high-end theatrical motion picture production. They are available in PL mount in recognition of this defacto standard in professional cinematography lenses; however, they are also offered in the alternative Canon EF mount in support of a separate large global constituency already using EF lenses and hybrid DSLR cameras for video production. Two smaller and lighter zoom lenses (termed Compact Zooms) were developed to support portable and Steadicam τ m shooting. A core family of six prime lenses was also developed – using the EF mount and having a full frame (36 x 24mm) image circle.

S35mm Lenses for Television Production

With the more recent rising interest of broadcasters in large-format imaging Canon produced two additional zoom lenses – termed CINE SERVO Super 35mm 4K lenses – that were specifically designed for the needs of television production. They anticipate a future era of 4K UHD production among the world’s television broadcasters. The second of these two lenses – the new CN20x50 – pushed the envelope in Super 35mm zoom lens design (at the exhortation of some prominent broadcasters) with its 20x zoom range and a built-in 1.5x range extender [2]. Given that 2K / HD large-format cameras are still widely used at this time these 4K lenses offer the advantage of enhancing the overall HD lens-camera picture sharpness.

Super 35mm Image Format Size			
Digital Cinema Origination 4K (4096 x 2160) and 2K (2048 x 1080)		Television Production 4K UHD (3840 x 2160) and HD (1920 x 1080)	
		<ul style="list-style-type: none"> • Episodic • Drama • OTT Original Content 	<ul style="list-style-type: none"> • Documentary • News Magazine • Sports • Live events
			
Primes		Compact Zoom	Top end Zoom
		Cine Servo Zoom	

Figure 1 Summarizes Canon’s dual development strategy of 4K Super 35mm lenses intended to support both digital cinema and television production (including both HD and UHD)

Hybrid Combinations of Large-Format Lenses

The strategy just outlined assumed a separation in shooting priorities between television and digital cinema production. Historically this tended to be the case. However, the unprecedented diversity of the new large image format digital motion imaging acquisition systems has tended to blend creative practices that were once quite separate. Today we see producers, directors, and cinematographers harnessing disparate lenses, cameras, recorders, and associated digital production workflows according to creative aspirations and production budgets. Nowhere is this more visible today than in the mix of large-format lenses mobilized for shooting all forms of movie and television productions.

The Role of the Full Frame EF Lens

The huge worldwide inventory of Canon photographic EF zoom and prime lenses that have supported more than thirty years of SLR film and digital DSLR photography are today in wide use on digital motion imaging cameras and camcorders. While these lenses do not entail the stringent design imperatives of the professional S35mm cinematography lenses – their design criteria rather center on excellence in all aspects of still photography – they do offer wide choices in unique imaging attributes that can support specific needs in shooting certain scenes. These might include the need for long focal range image stabilized lenses, macro lenses, tilt-shift lenses, fisheye lenses, and soft focus lenses. Today, it is not uncommon to see Super 35mm cine lenses combined with various EF zoom and prime lenses on a given production. An important additional consideration is the cost-effectiveness of the EF lenses when compared to professional cinematography lenses for lower budget productions.

Mixing S35mm Cine Lenses and EF Full Frame Lenses

Figure 2 suggests the new-found creative flexibility offered by mixing Super 35mm cine lenses and full frame EF photography lenses – a flexibility increasingly embraced by both the digital cinema and television production communities. For example, while the breakthrough CN20x50 ultra telephoto S35mm lens was very specifically developed to support the television documentary world it is to be anticipated that enterprising directors and cinematographers will surely find unique and creative uses for the same in moviemaking.

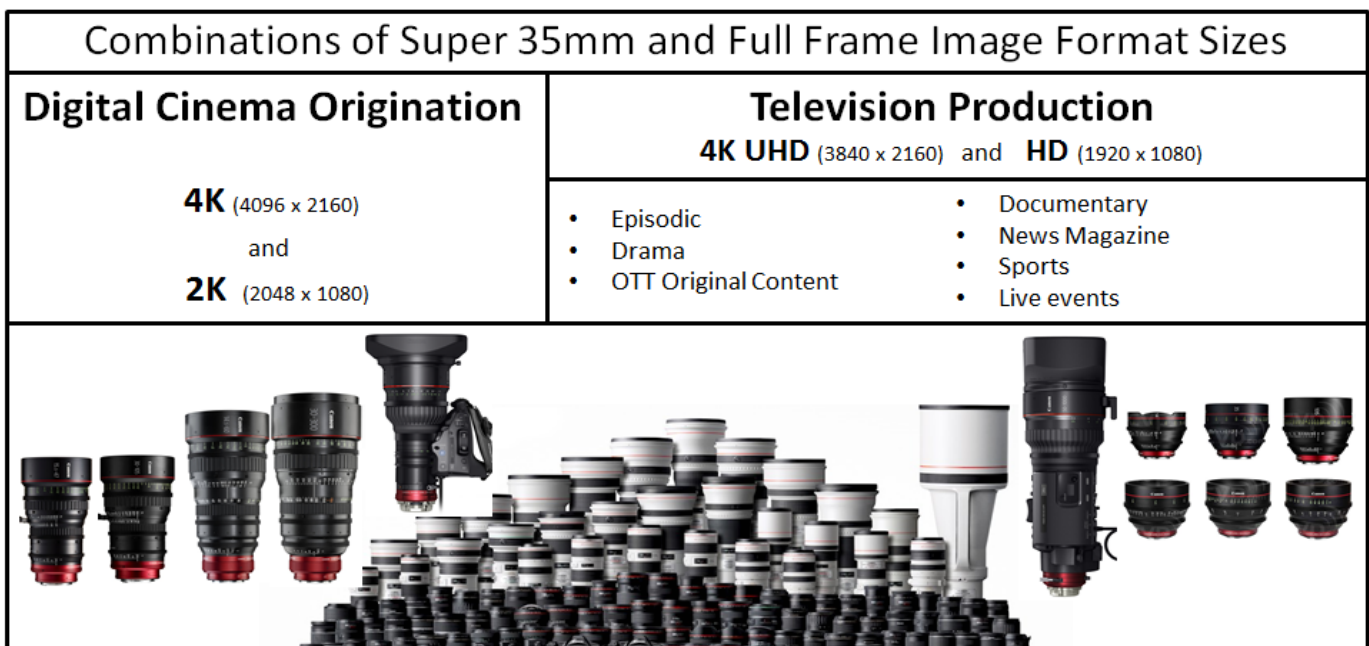


Figure 2 *Suggest the present day blurring between digital cinema and television production*

Phase Two – a Carefully Paced 2/3-inch 4K UHD Lens Strategy

Within the recent new movement in 2/3-inch 4K UHD cameras, Canon closely collaborated with the respective camera manufacturers to define the technical parameters of lenses required to meet the elevated imaging performance and operational requirements for television program production in that much higher resolution format. While it is anticipated that broadcast television production will continue to be largely in HDTV for many years to come, it is now clear that 4K UHDTV will also steadily grow in parallel. Investment in new 4K 2/3-inch lenses that anticipate this future trend will have the additional advantage of enhancing the image performance of existing HDTV cameras.

Sports Coverage is the Primary Driver of 2/3-inch 4K UHD Television Productions

At this juncture it is apparent that outside broadcast television production is the spearhead of the still slow adoption of 4K UHD. Just looking across the first half of 2015 conveys a sense of the growing interest: major US sporting events included 4K coverage; a 4K UHD Mobile Facility made its debut at NAB; both Australia and New Zealand covered major cricket matches. In many of these events 2/3-inch UHD lens-cameras were being tested for the first time.

First Priorities in 2/3-inch 4K UHD Lens Development

In light of this global activity in UHD, Canon has given a first priority to developing the long zoom field box lenses and portable lenses that are central to such television productions. In August 2015 we announced the world's first 4K wide angle portable lens – the CJ12ex4.3B. In September 2015 we announced two new 4K UHD Long zoom field lenses – the UJ86x9.3 Premier UHD lens and the UJ90x9B UHD lens and a longer zoom portable lens CJ20ex7.8B. The UJ90x9B and CJ12ex4.3B are now shipping to customers.





2/3-inch Image Format Size		
Television Production		
4K UHD (3840 x 2160) and HD (1920 x 1080)		
Television Outside Broadcast and Electronic Field Production	Television Studio	
<ul style="list-style-type: none"> • Sports • Live Events • House of Worship 	<ul style="list-style-type: none"> • Sports • Documentary • News Magazine • Live events 	<ul style="list-style-type: none"> • Episodic • Drama • Game Show • Performance Reality
 <p>UJ86x9.3B</p>  <p>UJ90x9B</p>	 <p>CJ12ex4.3B</p>  <p>CJ20ex7.8B</p>	<p><i>Future Development When Market situation is more clear</i></p>
Long Zoom Field Lens	Wide angle Portable	Studio

Figure 3 Showing the two long zoom field box lenses and the two wide angle portable lens that are the initial priorities of Canon in developing a complete family of 2/3-inch 4K UHD lenses

The 4K UHD Television Studio Situation

Few television studios in the U.S. have yet committed to fully outfitting a 4K UHD studio. Those that are originating some 4K UHD programs are typically operating hybrid studios – that continue to use 2/3-inch HDTV lens-camera systems for ongoing HDTV program origination and alternating with Super 35mm 4K cameras for those few shows that seek to originate in the UHD format. Some broadcast studios have, however, found that while certain television program genres capitalize on the cinematic look of the Super 35mm systems other shows are better served with the same depth of field to which they are accustomed when originating in HDTV. As a consequence of this some major broadcasters are presently conducting serious testing of 2/3-inch 4K UHD lenses and cameras. Canon is participating in many of these tests. While serious discussions are underway on the anticipated needs of UHD television studios – no studio to date has made any decisions to begin originating with 2/3-inch 4K lens-camera systems. That can, of course, change at any moment.

In the meantime, Canon's initial 2/3-inch 4K UHD lens development priorities are centered on the long-zoom field lens and the EFP portable lens needs. From a technical stance this is a fortuitous progression as the optical, optomechanical, and electronic requirements of very long zoom 4K field box lenses are significantly more challenging than those of the more modest zoom box studio lens. Mobilizing the best in contemporary computer simulation, new design tools, new optical glass materials and associated optical coatings to help optimize the overall performance of the 4K UHD field lens will help pave the way to a more expeditious design project for the future 4K UHD studio lenses.

Summary

The past decade has witnessed quite astonishing advances in motion imaging. Both theatrical motion picture and television production have been profoundly affected by the global developments in cameras, camcorders, and their associated lenses. Canon is today immersed in innovative developments on all of these fronts. HDTV and 2K continue to play large roles in theatrical motion picture and television production and will continue to do so. 4K and UHD are garnering increasing worldwide attention. The blurring between moviemaking and television production is exemplified by the emergence of the latest generation of cameras and camcorders that can switch between 4K / UHD / 2K / HD. The Canon EOS C500 and the EOS C300 Mark II cinema cameras typify such creative flexibilities.

It was this fluid global production scenario that guided the unusually expansive lens development programs within Canon. Our Cinema EOS professional cinematography lenses have all been designed to full 4K optical performance – anticipating the era of 4K / UHD while also offering enhanced performance to the all-important 2K / HD lens-camera systems. The relatively sudden emergence of 4K UHD 2/3-inch camera systems sees Canon now energetically engaged in broadening our lens portfolio to encompass this important new movement. Today the formidable optical design team of the tradition broadcast lens division and their renowned peers within the EF Lens division are collaborating on the extensive development agenda to expand choices in lenses for all of the existing digital motion imaging systems as well as anticipating those developments yet to appear.

The UJ90x9B UHD field lens began delivering in December 2015, and the CJ12ex4.3B wide angle portable UHD lens began delivering in January 2016. The UJ86x9.3B Premier UHD lens and CJ20ex7.8B is expected to be delivered in June 2016.

REFERENCES

- [1] ITU-R BT.2020 Parameter Values for UHDTV Production and International Program Exchange
- [2] SPIE2015 Baltimore Technical paper: *“New Long Zoom Lens for 4K S35mm Digital Cameras”*